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FEATURE ARTICLES

TECHNICAL ARTICLES

Vol. 12, No. 4. POWER TRANSMISSION ENGINEERING (ISSN 2331-2483) is published monthly except in January, May, July and November by Randall Publications LLC, 1840 Jarvis Ave., Elk Grove Village, IL 60007, (847) 437-6604. Cover price $7.00. U.S. Periodicals Postage Paid at Elk Grove Village IL and at additional mailing offices. Send address changes to POWER TRANSMISSION ENGINEERING, 1840 Jarvis Ave., Elk Grove Village, IL 60007.

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VOL. 12, NO. 4

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Power Transmission Engineering

Randall Publications LLC
1840 Jarvis Avenue
Elk Grove Village, IL 60007
Phone: (847) 437-6604
Fax: (847) 437-6618

EDITORIAL

Publisher & Editor-in-Chief
Michael Goldstein
publisher@powertransmission.com

Managing Editor & Associate Publisher
Randy Stott
wrs@powertransmission.com

Senior Editor
Jack McGuinn
jmcguinn@powertransmission.com

Senior Editor
Matthew Jaster
mjaster@powertransmission.com

Associate Editor
Alex Cannella
alex@geartechnology.com

Editorial Consultant
Paul R. Goldstein

ART

Art Director
David Ropinski
dropinski@powertransmission.com

ADVERTISING

Advertising Sales Manager & Associate Publisher
Dave Friedman
dave@powertransmission.com

eMarketing Specialist
Matthew Stott
matthewstott@powertransmission.com

China Sales Agent
Eric Wu
Eastco Industry Co., Ltd.
Tel: (86)(21) 52305107
Fax: (86)(21) 52305106
Cell: (86) 13817160576
eric.wu@eastcotec.com

Materials Coordinator
Dorothy Fiandaca
dee@randallpublications.com

CIRCULATION

Circulation Manager
Carol Tratar
subscribe@powertransmission.com

Circulation Coordinator
Barbara Novak
bnovak@powertransmission.com

RANDALL PUBLICATIONS STAFF

President
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Randy Stott, Managing Editor

Choose the Form!

In the 1984 film *Ghostbusters*, Bill Murray and company were asked by Gozer the Gozerian to "choose the form" of their destructor. It was a no-win scenario for the heroes, because no matter what they chose, they were still going to face death.

I, too, am asking you to "choose the form." But unlike Gozer, I have no villainous intentions, because the form I want you to choose is *not* the form of your destructor, but rather the form attached to the front of this magazine. I want you to fill it out. By doing so, you can choose whether you want to continue receiving *Power Transmission Engineering*, and you can also choose the form that works best for you (print or digital).

If, by some chance, there's no form attached to your magazine, you still have to choose. There's another form on page 63. Or just go to *www.powertransmission.com/subscribe.htm* if you're reading this online.

In all seriousness, we NEED your response. It doesn't matter if you've been receiving the magazine non-stop for more than a decade (Thanks, by the way, if that's the case) or if you've just signed up. If you want to keep receiving *Power Transmission Engineering*, you MUST fill this out.

You see, we're completely overhauling the way we handle your information. That includes your name, job title, company affiliation, mailing address, e-mail address and so on. We're doing everything we can to protect that information and to use it responsibly.

Many of you are aware that the European Union's General Data Protection Regulation (GDPR) went into effect last month. No doubt you've recently received a flurry of e-mails asking you to re-opt-in to various lists, because publishers like us want to be able to continue serving you.

But in many ways, what we're doing goes way beyond the GDPR. Yes, we want to protect your privacy. Yes, we want to use your e-mail address and personal information responsibly. But more importantly, we want to provide you with information that's of value to you, and we want to provide it in the way that makes most sense to you, not us. So we're asking you to confirm that you want the information, and we're asking you to specify how you want to receive it.

More importantly, we're asking you to tell us a little bit about yourself. It's not because we're nosy. It's because the information you provide helps us do our job better. Knowing who you are, where you work and how you're involved with power transmision products helps us craft our magazine, newsletters and websites in a way that appeals to the broadest spectrum of readers.

If, for some reason, you don't find our information useful, please fill out the form anyway. It really helps us a lot.

For all of you who follow my advice and choose the form, I offer in advance my heartfelt thanks and appreciation. Your input and feedback allow us to continually improve.

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George Holling

It is hard these days to find any device that is not IoT-compatible or WiFi-connected. I recently had a new well pump installed that requires an iPhone for setup, which makes it hard for me to check or change the setup since I do not own an iPhone. In Olden Times, you had potentiometers or RS-232 connections — and that was fine.

When I came out of engineering school, the microprocessor had started to take over. With a microprocessor we could do everything, and when I graduated I was eager to prove it. But I quickly learned that my senior co-workers were focusing on many other features and design aspects. While performance and flexibility were important, the focus on safety was even more important.

So a few valuable lessons were quickly instilled in me:

- There always is a safety shutoff (red mushroom button) that kills the power
- Never, ever rely on the computer to shut the drive off
- Always have safety features; e.g. — a watch dog timer (WDT) to check the computer along with a hardware path (external hardware WDT) that will cut the power when things go wrong
- If anything does not check, turn it off

And while I initially may have considered this a waste, it turns out that these features saved myself trouble quite a few times. All it takes is one incorrectly entered number and things quickly fall apart — in some cases quicker than you can imagine. That is where the red button comes in handy.

I will readily admit that, in a lab environment, we do not always follow these requirements as religiously as we do in an actual industrial application. And there are times when you quickly reach for the OFF button on a power supply when things do not go as planned. But these are typically small motors with little chance to do any damage in the event of failure.

As the motors become larger, or the potential speed become higher, our lab tests are fully set up with multiple E-stop buttons and multiple personnel — especially in situations where the loss of control or a run-away condition poses a physical threat to the people or the facilities.

One such experience was when we installed a starter/generator on a newly developed turbine engine that was started for the first time with about 20 personnel present in the "bunker." A chain of command was established that could initiate an E-stop and determine which conditions warranted an emergency shutdown. The actual test was much less impressive. Everything ran fine and no intervention was needed, except for a normal shutdown command.

Today everybody has a fascination with connectivity, which is not inherently a bad thing, but it can quickly turn bad if safety is ignored. For instance: Who/what controls the drive and what safety features are present? A bad command, just like a bad number entry in my younger days, can have disastrous consequences without the proper safety mechanisms. Do you solely rely on sensorless feedback or do you have a secondary hardware loop for added safety?

Even if things go well on the drive level and the drive is network-connected, the question remains: "Are we properly protected against network failures?" How do you detect a network failure and how do you respond? A processor can easily lock up while the LAN connection may still appear to be functional.

Now we make the problem worse by adding WiFi into the equation.

A few years ago we completely rewired our wireless office with all name brand commercial equipment and switched back from WiFi to a hardwired LANs. Since then our productivity has soared, data losses were almost completely eliminated, our central servers are now instantly updated and our network could no longer be easily monitored or manipulated from the outside. Even though we would like to think our standard network encryption is well protected, that is not the case; WiFi encryption keys are easily discovered and bypassed. Wireless networks are simply not as reliable as hardwired networks — and they may never be. They are susceptible to interference from other HF sources, electrical noise, etc. I remember the times when my PC network locked up when all I did was use my cell phone. And yet I do believe the newer frequencies have fixed that issue.

Now we add the smartphone into the mix, where the apps may simply

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not have the required safety features to deal with the loss of connectivity, as they were written by young college grads who may know about networking but who have little understanding of the physical dangers of operating industrial drives and plants, where even small errors can quickly have devastating consequences.

True, some of these thing can also happen in stand-alone equipment or when using a hardwired LAN — but they are less likely to happen.

I hear the firestorm already; but I stand by my opinion for the reasons outlined above.

I am all for automation and I believe that automation and AI will continue to proliferate, which is good and beneficial. But that does not mean every piece of equipment has to be controlled via smartphone. My answer is, and will be, NO for the foreseeable future. There still is — and will be — a need for dedicated controllers or PCs and safe, hardwired networks that do not allow for any inadvertent access.

Yes, our lives evolve around our smartphones. But do we want to stake our business on it? How do we insure that the system works reliably? How can I be sure that hackers do not gain unauthorized access? And how do we make sure that someone is not simply goofing off or trying out something that can inadvertently result in major damage?

We are currently trying to set up a new building with smart light bulbs. All of the manufacturers push their mobile control apps, and we had to exclude several products that do not offer PC applications. Why? Because building codes have special requirements and the building must continue to run and lights must turn on and off — even when a specific smartphone is somewhere else. So while it may work for one-room recreational use, it doesn't work for any large-scale practical use.

Do we really need smartphone apps to control industrial networks or is it just a lazy "shortcut" that adds risk without significant benefits? After all, whose smartphone will be in charge of the plant and its equipment? If you simply wanted to know how the plant is running, you could use your smartphone to look up the current production reports and status information online without having access to individual machinery instead. That is why we intentionally create boundaries that keep key systems safe and then use information tools to share this information with those that need to know.

With our lives playing out on Facebook, and living in a household managed by Amazon's Alexa, we are way too focused on the cool gadgets and gimmicks. Gizmos control our lives, but when we apply these designs for gizmos to industrial automation, then the gizmos may truly control our lives and wellbeing.

Technology offers great opportunities, but it also demands respect. Just because we can do something does not mean we should. On the way to an airport, I was listening to an interview where a truck driver was testing autonomous vehicles for his employer — a company that develops self-driving technology. This company wants to run autonomous trucks from town to town, and when they arrive in a town a remote-controlled driver takes over. I do not know about their networks, but the ones I know suffer from regular and occasional hiccups. What do you do if the connection to the remote driver disconnects — hit the brakes and stop without warning and have everybody slam into the truck?

Why am I nervous about this concept? Because I have my concerns about self-driving cars; yes, statistically they may be safer, as opposed to a distracted human, especially when we have the dangers of texting and driving. But a hybrid system that relies on wireless technology makes me feel uncomfortable. Nothing will go wrong — right?

George Holling holds significant influence in two companies — as technical director of Electric Drivetrain Technologies (2011–present) Moab, UT and as CTO of Rocky Mountain Technologies (2001–present), Basin, MT; *George.Holling@RockyMountainTechnologies.com*

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Mesys

EXAMINES INFLUENCE OF ELASTIC HOUSING DEFORMATIONS ON THE LOAD DISTRIBUTION WITHIN ROLLER BEARINGS

Elastic housing deformation can have an impact on the load distribution within rolling element bearings. For many applications this is neglectable, but for large bearings or soft housings, it can be of interest to consider this effect.

The MESYS shaft system calculation could take into account housing stiffness based on a global matrix or an import of a STEP-file or a FEA-mesh for several versions. The housing stiffness was considered as one node at the center of each bearing ring. The ring itself was still cylindrical or has user defined deformations.

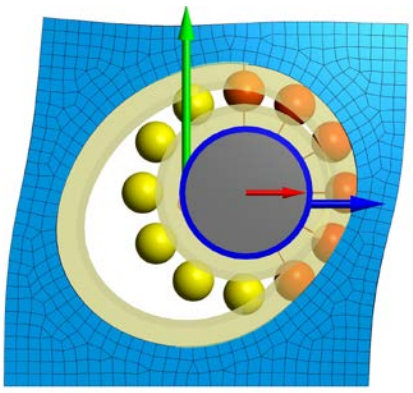
At Hannover 2018, MESYS AG presented a preview of the MESYS shaft system calculation, which considers a coupling between housing deformations and deformations of bearing rings. The housings can be imported as STEP-model or they can be defined parametrically for simple rotation symmetric cases. The STEP-model is then meshed and statically reduced. Optionally a modal reduction is possible too.

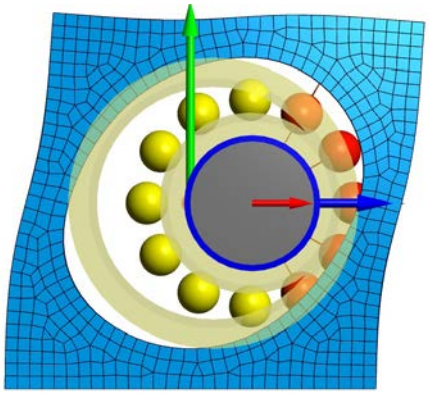
This simple example shows first a deep groove ball bearing in a rectangular block, which is fixed at the bottom side. The bearing is loaded horizontally.

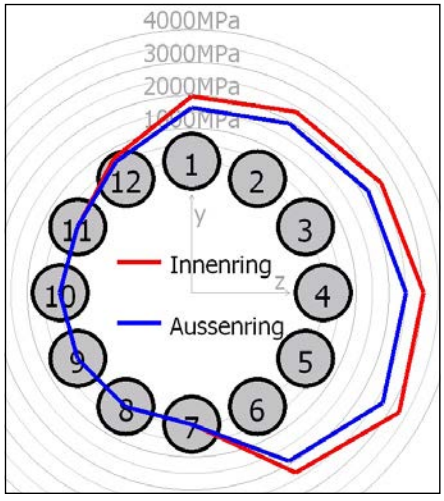
On the left the deformations and the load distribution with consideration of elastic deformations of the bearing ring, on the right one the averaged deformation of the housing is considered with a circular bearing ring:

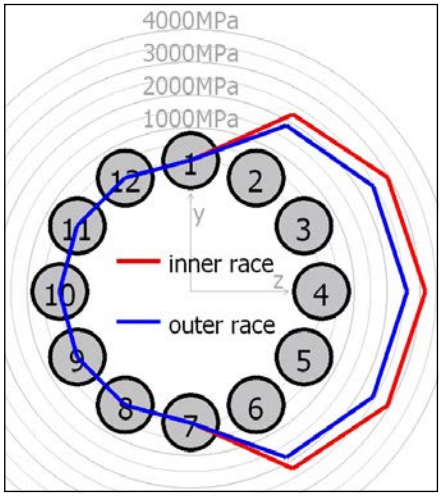
The maximum contact stress is 3285 MPa with elastic ring and 3175 MPa with rigid ring. The horizontal displacement is 0.052 mm with elastic ring and 0.051 mm with rigid ring. The vertical displacement is 0.01 mm with elastic ring and zero with rigid ring. The vertical uplift is only visible using the elastic model. As comparison the horizontal displacement without housing stiffness, which would be 0.032 mm.

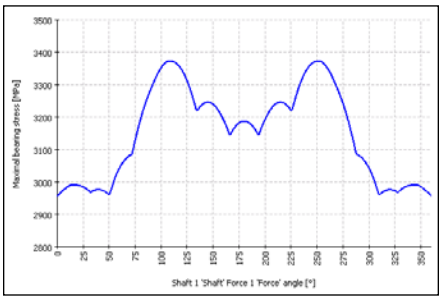
While the contact stress is independent on the load direction using the rigid ring, there is a dependency of contact stress from load direction using the elastic ring:









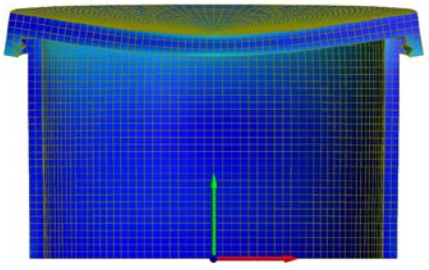


With a force angle of 0° (force to the top) the lowest contact stress results, while the maximum stress results at about 110° load direction. The overlaid variations in the curve have their reason the fixed positions of the rolling elements in the calculation.

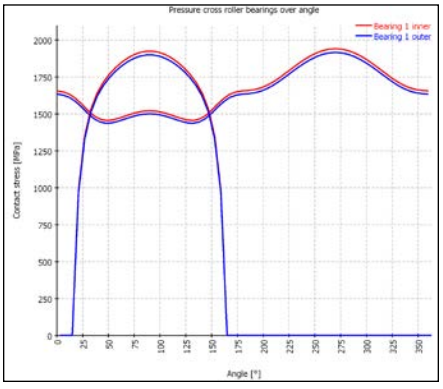
For this example, a bearing clearance of zero was considered. Using a larger clearance would lead to higher contact stress for the cylindrical ring.

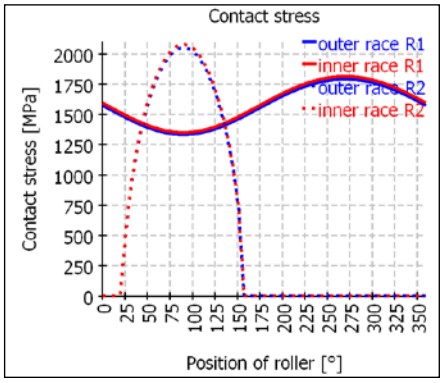
Cross roller bearing example

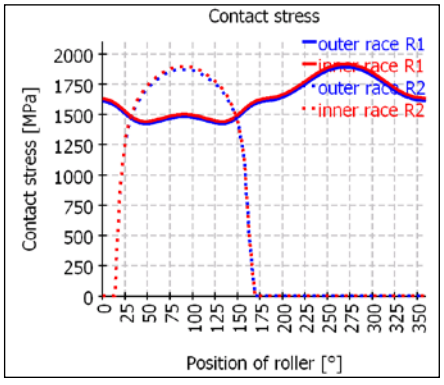
As second example a cross roller bearing under axial, radial and moment load is considered. The loading acts on the upper surface and the lower cylinder is fixed at the bottom face.



The contact stress is shown for three cases. First a full calculation with 3D solid elements without reduction, then for a bearing with rigid rings and a calculation with reduced FEA-model in the shaft system calculation.







The maximum contact stress is 1941 MPa for the full 3D-model, 2078 MPa for the bearing with rigid rings and 1917 MPa for the reduced model. A larger difference is seen at the rolling element forces which are 3734 N, 4540 N and 3719 N.

The curves for the contact stress for the two elastic cases in above diagrams show the same shape with maxima of both races at the same level. In case of the rigid rings one race sees a higher contact stress. A comparison of the axial deformation is difficult because of the large deformation of the top. For the radial displacements there is a result of 0.03 mm for the rigid case and an average radial displacement of 0.2 mm (0.19 mm) in the elastic cases (the average value is determined differently in both cases).

In many cases the deformations of the bearing rings lead to a larger load zone and therefore to a smaller contact stress.

The full 3D-model is a little software than the reduced model as the reduced model uses the same tilting angle for both races in a ring. The reduced model does currently only consider global ring deformations, but no deformation within the ring. This is a special case for a cross roller bearings as it contains two rows.

A calculation using the full 3D model takes a little more than 3 minutes, while a calculation for one load case of the reduced model only takes less than a second. The full 3D-model would allow to consider nonlinearities like contact, while the reduced model is a linear stiffness matrix only.

A preview version was available at the Hannover Fair, the final version with coupling of housing stiffness and elastic ring deformations will be available with version *08/2018* this fall.

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Diabetes is among the most common diseases in today's societies. If the disease is not treated in time or treated incorrectly, important organs, such as heart, eyes and kidneys could suffer serious damage. Chronically ill patients can optimally control their treatment with an insulin pump – supported by micromotors from Faulhaber.

There is, in fact, a relatively recent technological development that should considerably simply life for diabetes patients: the insulin pump. The patient wears it directly on the body. It constantly delivers a small quantity of insulin to the blood; the additional insulin required at mealtimes can be controlled by pressing a button. It does not eliminate the need for patients to estimate their carbohydrate intake, but it is a huge relief for most users in daily life. It is even already in use by small children and can be remotely controlled by parents.

Though available from various manufacturers, the design of insulin pumps is always similar: an ampoule contains the insulin, which enters the body as needed by means of the battery-operated pump via a catheter and a cannula. A small motor pushes the plug of the insulin ampoule forward via the threaded rod, causing insulin to be released. Extremely high demands are made of the motor: In order to keep down the weight of the wearable device the motor must be compact, and as a rule the diameter must be no more than about 10 millimetres. The motor must be reliable and precise, since too little or too much insulin is harmful to the patient. A human life may even depend on the reliability of the motor that is used. Since the insulin has to be injected into the body every few minutes, the motor must start and stop at regular intervals. In addition, the motor must operate in a very efficient manner due to its battery operation.

In order to fulfil all of these high demands, insulin pump manufacturers rely on the micromotors from Schönaich. Various motors produced by Faulhaber are used here: Motors with precious-metal brushes, brushless motors with 2-pole technology and stepper motors. The 0816…SR series is an example of micromotors with precious metal commutation. The brushless DC-servomotors of series 0620…B and 0824…B have an extremely long service life. Precision dosing control is possible here using the analogue Hall sensor. Some manufacturers rely on the stepper motors of series AM 0820 or AM 1020.

The insulin pump is primarily used by diabetes patients as a wearable medical pump, but other application areas are emerging—patients with other chronic illnesses such as Parkinson's disease or immunodeficiency are also reliant on regular injections. Faulhaber stepper motors of the AM 0820 series are already in use here.

For more information:
Micromo (Distributor of Faulhaber)
Phone: (727) 572-0131
www.micromo.com

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Maxon

OFFERS EXOSKELETON JOINT ACTUATOR

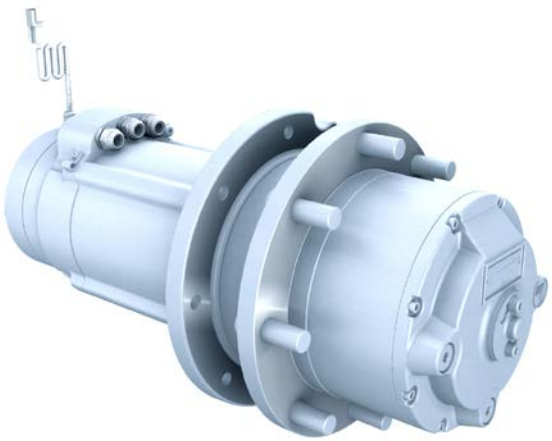
Maxon Motor has developed an exoskeleton drive for use in robotic limbs. This complete joint actuation unit consists of a pancake brushless DC motor with inertia optimized rotor. Also included is an internal high resolution encoder, planetary gearhead with absolute encoder and a position controller with CAN and RS232 interface. Fitting absolute encoder directly at the joint rotation provides designers increased positioning accuracy. The unit delivers 54 Nm of continuous torque and 120 Nm on a 20 percent duty cycle and may be operated on supplies between 10 and 50V DC and the actuation speed is up to 22 rpm. Other key features include: compact housing, integrated controller and reduced weight and cost.

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

Bonfiglioli

OFFERS ROBUST AND COMPACT WHEEL DRIVE FOR HYBRID AERIAL PLATFORMS

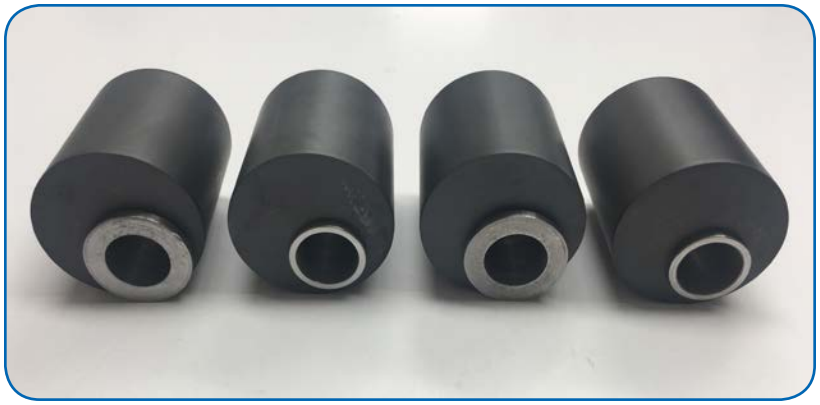
The 605WE wheel drive, designed and developed by Bonfiglioli, has been created in cooperation with one of their customers for a new innovative hybrid aerial platform. Bonfiglioli 605WE, which provides an output torque of up to 10.000 Nm, is a 3-stage gearbox with a fully-integrated 8 kW electric motor and parking brake that guarantees maximum efficiency and compact size. The integration of all the components in an optimized space gives the machine builder the opportunity to benefit from a cost-effective solution easy to maintain. Thanks to the direct-mounting flange, it is also easy to install. The 605WE series perfectly adapt to both hybrid and electric applications. The special degree of protection (IP67) and the special painting coupled with high torsional resistance wiring makes it suitable for four-steering wheel vehicles, even in harsh environmental conditions faced in any construction site.



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

Drake Motorsports Development

OFFERS HIGH PERFORMANCE POLYMER PARTS



Drake Motorsports Development, LLC was recently formed to accelerate the availability of track proven race parts and to continually develop new racing products from a racing industry insider perspective. The first part developed is an offset control arm bushing machined from Torlon 4435. The bushing delivers an increased static negative camber range of adjustment for the front wheels, which is used as a suspension tuning method to optimize tire contact under high lateral loads. Tyler Quance, owner of Drake Motorsports Development, and the engineering manager for Drake Plastics, has been racing a Spec Miata with a set of these bushings since mid-2017. During this time, the bushings have shown no measured wear. The bushing material is self-lubricated and requires no grease, making a totally maintenance-free, non-consumable part which is intended to last as long as the racecar.

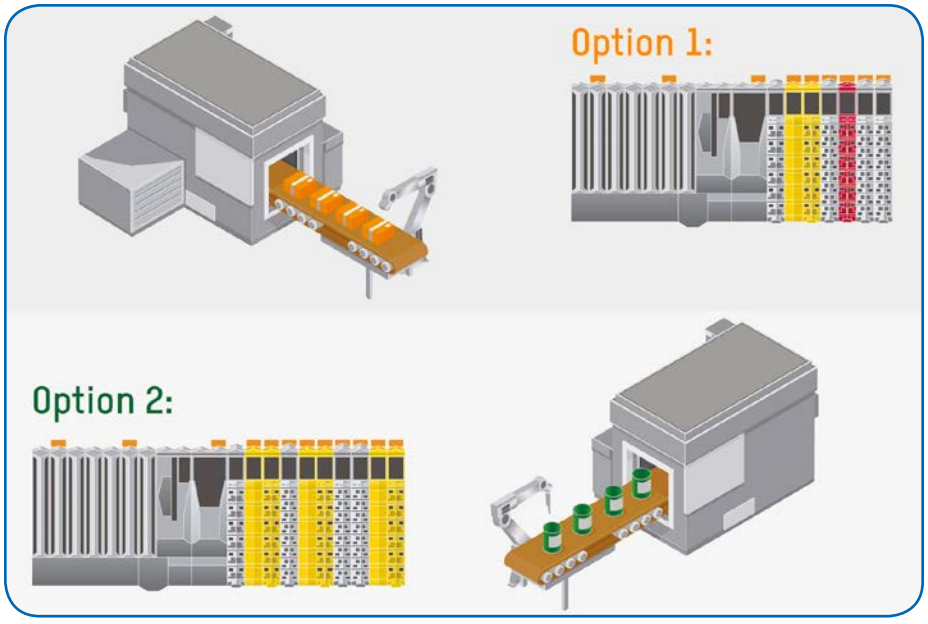
The bushing was designed in collaboration with Chris Haldeman and X-Factor Racing of Princeton, Texas. This collaboration resulted in a decision to supply the bushings already installed in control arms with a steel anti-rotation dowel pin to ensure each bushing stays in place under demanding race conditions, and to finish ream the offset hole after installation for a precision fit with the steel inner sleeve. This process saves the customer a great deal of time and hassle during installation and ensures the bushing set is aligned to deliver maximum available front wheel camber in a ready-to-bolt-on assembly.

The extreme wear resistance and excellent lubricity of Torlon 4435 provides the combination of improved performance and improved part life. This grade and suspension bushing application supplied previously by Drake Plastics, has a pedigree with the Risi Competizione Ferrari race

team. Now that Drake Motorsports Development is assembled to expand the accessibility of Torlon 4435 bushings as performance aftermarket parts, Torlon is poised to obsolete traditional bushing materials in higher-end performance and racing applications. According to Quance, "once drivers and race prep shops try Drake Motorsports Development's Torlon 4435 suspension bushings, I expect they will want to use them exclusively."

The second part launched by Drake Motorsports is a high-performance polymer transmission shift bushing machined from Torlon 7130. Prototypes were run in 3 different cars for the NASA Spec Miata Eastern States Championships at Sebring in September 2017 with excellent results. According to Bret Synder, lead crew member for Drake Racing and driver himself, "the shift bushing is almost a forgotten part until it becomes a problem from excessive wear or breakage." The thermoplastic bushing maintains the impact-absorbing characteristics of the OEM Mazda bushing other aftermarket metal replacements cannot. This means internal gearbox components remain isolated from severe hard-shifting impact as designed by Mazda. Torlon 7130 is one of the strongest and most durable polymers making what is generally accepted to be a consumable part one which now lasts indefinitely.

For more information:
Drake Motorsports Development, LLC
Phone: (281) 255-6855
www.drakemotorsportsdevelopment.com



B&R Automation

SIMPLIFIES MANAGEMENT OF MACHINE VARIANTS WITH SOFTWARE TOOLS

Modular applications can now be implemented even more easily. B&R's new software component, *mapp IO*, makes it possible to add I/O modules at any time. This can happen before a machine is delivered or even at runtime, thereby greatly simplifying the task of managing variants of machinery and equipment.

With *mapp IO*, I/O configurations can be generated directly from an ERP or order management system. No engineering tools are required, even if third-party drives or modules are added. Additional variants and options are configured directly on the machine using *mapp IO* and then programmed using *mapp CodeBox*. With *mapp CodeBox*, you can program options in ladder logic without affecting the machine's primary application. The machine can be commissioned without having to modify the original machine software.

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

Aerotech

INTRODUCES ECO SERIES LINEAR STAGES

Aerotech´s ECO-LM and ECO-SL series linear stages combine high performance and rugged mechanical design in a cost-effective, economic package. A comprehensive choice of direct-drive linear motor, rotary servomotor, or stepping motor versions is available across 44 models with travels from 50 mm to 800 mm, plus vacuum and cleanroom versions.

The ECO-LM series direct-drive linear motor stages are optimized with high precision, noncontact linear encoders. The precision noncontact encoders enable minimum incremental motion to 10 Nm with micrometer-level repeatability. The optional HALAR factory calibration improves positioning accuracy to ±1.5 µm. The ironless forcer coil provides high force with zero cogging for smooth velocity and position control, ideal for applications requiring outstanding contour accuracy and smooth velocity profiling. The linear motor has zero backlash, no windup, zero friction, and excellent dynamic responsiveness. ECO-LM stages are available in 17 different models with travels ranging from 100 mm to 800 mm and

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These new generation CD® Couplings feature zero backlash precision and high torsional stiffness. They answer today's demanding needs in servo motor applications with high reverse loads and positioning requirements. New clamp style hubs handle increased torque on shafts without using keyways. Manufactured of RoHS compliant materials.

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speeds up to 2 m/s. Configurable cable management solutions are available for single and multi-axis systems as standard options.

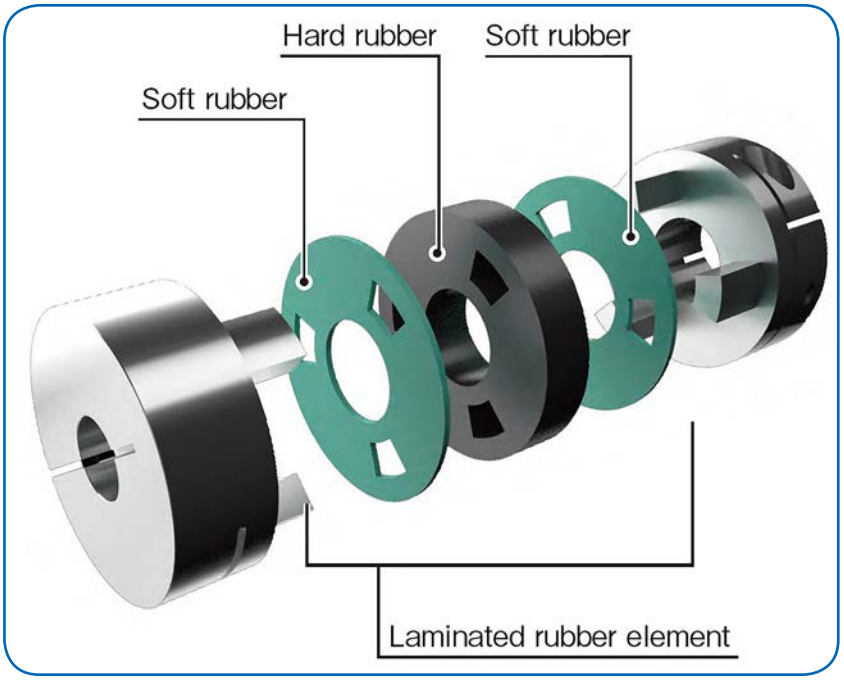
For even more cost-sensitive applications, the ECO-SL series includes several NEMA 23 stepper motor and brushless servomotor options. The ECO-SL series is designed with many standard features and options that make the design adaptable to specific applications. Several encoder options provide electrical resolutions ranging from 0.5 µm down to sub-nm. A holding brake can be added for vertical applications. A motor fold-back kit is available for space-constrained applications to reduce the overall stage length. ECO-SL stages are available in 27 different models with travels ranging from 50 mm to 800 mm and speeds up to 300 mm/s.

For more information:
Aerotech, Inc.
Phone: (412) 967-6854
www.aerotech.com

Miki Pulley

STEP-FLEX COUPLINGS ELIMINATE RESONANCE IN BALL SCREW ASSEMBLIES

Miki Pulley's Step-Flex Couplings improve ball screw performance while solving resonance and vibration problems. The Step-Flex is an altogether new class of shaft coupling. The Step-Flex coupling design has a two-part elastomer element combination. This assembly dampens vibration caused by the actuator carrier when struggling to find its home position by making small adjustments in rapid sequence.



With this design, the hard (black) element is separated from the aluminum alloy hubs by a softer (green) elastomer disc. This combination maintains adequate torsional stiffness for precise positional accuracy while still allowing for minimal angular and parallel misalignment, and absorbing vibration. The power-transmitting element, consisting of different hardness layers, also achieves a reduction in counter force generated by misalignment. This can greatly reduce the load on the bearing – resulting in reduced heat load.

Another key feature is the electric and temperature isolation provided by the coupling's elastomer element. This mitigates conductive heat transfer from motor to output shaft, important in rotary motion applications. Plus, it also halts stray voltage traveling on the shaft. Applications include automation of all types where ball screws are used including packaging systems, semi-conductor assembly systems, laboratory automation and medical equipment.

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

Hansford Sensors

LAUNCHES COMPACT AND LIGHTWEIGHT TRIAXIAL VIBRATION SENSOR

Hansford Sensors, a developer and manufacturer of high performance industrial accelerometers, has launched a compact and lightweight 100m/Vg triaxial vibration sensor. Called the HS-173, the new accelerometer is a side entry device, can be used in both on- and off-line applications and has been introduced to enable OEMs, vibration analysts and end users to measure vibration in three axes simultaneously. This makes it ideal for use across a range of industries, including process, mining and quarrying, automotive, paper and metals manufacture.

With an operating sensitivity of 100mV/g and a transverse sensitivity of less than 5 percent, the HS-173 is one of the most compact triaxial accelerometers on the market and ensures measurement time can be reduced due to the simultaneous reading of three axes. This, combined with its excellent frequency response of 6 Hz to 6 kHz, makes it ideal for monitoring vibration in a variety of machines, from fans, motors, pumps, compressors and gearboxes, to conveyors, process equipment and spindles on machine tools.

The HS-173 is a robust and reliable industrial accelerometer, weighing just 250g, protected by a stainless steel casing that is sealed to IP67, and capable of operating at temperatures ranging from -55 to +140 ºC. Installation is quick and simple, via a standard M12 connector, either temporarily for off-line data monitoring with a handheld data collector, or online as part of an integrated condition monitoring system.

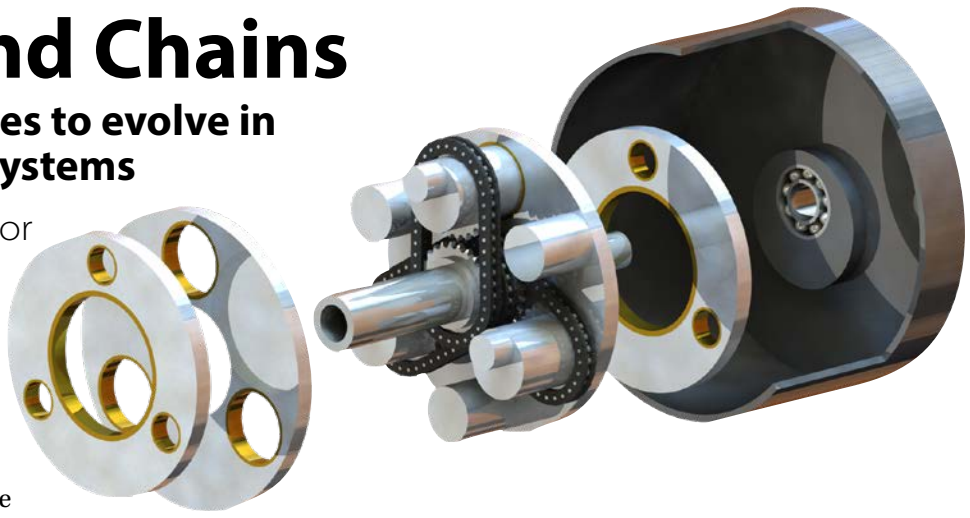
The HS-173 forms part of Hansford Sensors' extensive range of industrial accelerometers, which includes 4-20mA, AC and AC/Velocity sensors, vibration modules, enclosures, switch boxes and cables and connectors.

For more information:
Hansford Sensors
Phone: (888) 450-8490
www.hansfordsensors.com/us

Pushing Forward with Belts and Chains

The technology continues to evolve in chain- and belt-driven systems

Alex Cannella, Associate Editor



Orbitless Drives Epicyclic Chain/Belt Drive First Ever Epicyclic Chain- or Belt-Driven Solution

Orbitless Drives Inc. announced another innovation in the area of high performance gears with the introduction of the Orbitless Chain/Belt Drive, the first ever epicyclic chain or belt driven solution. Conventional planetary drives cannot use chains or belts because a sprocket or pulley cannot have internal teeth like a ring gear. The Orbitless Drive dispenses with the ring gear to marry the unique benefits of chains and belts with an epicyclic drive arrangement.

The Orbitless Chain/Belt Drive has co-axial drive shafts, high torque capacity due to load sharing, and very high, positive or negative speed ratios. The speed ratio can be as high as the number of teeth in the sprocket/pulley and as low as zero for an infinitely variable transmission if fitted with a progressive, variable pulley system. This drive easily supports ratios up to 50:1 or more in a single stage.

Multiple planets mean higher accuracy and less flexibility than a conventional zero-backlash timing belt system, with improved compactness due to co-axial drive shafts. It promises great potential in the high-precision motion control industry where high ratios, zero backlash and low cost are essential.

This inline single stage design can be configured for small-scale precision gear trains with plastic pulleys and belts, right up to large-scale industrial applications with high torque loads.

Orbitless offers design support services and license programs to enable your application engineers to design and build the ultimate Orbitless solution for your unique applications.

For more information:
Orbitless Drives
(604) 724-3719
www.orbitless.com

SKF Belts and Chains Portfolio Deliver Efficient and Reliable Power Transmission Solutions

SKF offers a comprehensive range of standard, high-performance belts ideally engineered to deliver efficient and reliable power transmission in drive-system applications across industries. All SKF belts benefit from innovative materials, designs and manufacturing to accommodate the most demanding working loads, provide extended service life and transmit power effectively from one component to another.

The extensive line of SKF belts joins a growing portfolio of power transmission products delivering optimized performance for equipment in the mining, automation, material handling, oil and gas processing, steel and food and beverage industries, among many others.

The standard SKF product line includes V-belts in a variety of constructions (wrapped classical, wrapped narrow wedge, cogged raw edge classical, narrow wedge and Xtra power wedge) and timing (or synchronous) belts with classical, HiTD or metric constructions. Timing belts uniquely integrate durable teeth enabling full engagement with pulley sprocket grooves to prevent potential slip and enhance accuracy and speed. All belts can be specified in various lengths and dimensions with speed ratios and power ratings

consistent with application requirements.

SKF belts install easily and are equipped to sustain proper tension, maximize rigidity and minimize potential stretch. Versions can be specified to handle especially high dynamic loads without compromising flexibility or generating excessive heat.

Designs can be optimized with the SKF belt drive calculation program to develop the most efficient and economical solution for a particular application.

SKF has also introduced an extensive range of roller and engineered chain solutions ideally suited to meet the demanding requirements of power transmission and conveyor applications in the food and beverage, mining and cement, and steel industries, among many others. The chains join a growing portfolio of SKF power transmission products offering optimized performance and long service life.

Standard SKF transmission, or roller, chains (pitch sizes .25 in. to 3 in.) feature through-hardened, shot-peened and ball-burnished inner and outer link plates with wide waist; case-hardened precision-ground pins; precision cold-rolled bushings; and through-hardened, shot-peened solid rollers. These features ultimately provide increased fatigue strength, higher resistance to damage from shock loads, maximum wear resistance and extended service life.

SKF chains can perform reliably in temperatures from –4° F to 300° F (stainless steel versions in temperatures from –4° F to 750° F) and can be supplied with rivet or cottered design. All comply with the appropriate ANSI, ISO, or DIN standard and are pre-stressed, run-in, and manufactured according to strict quality control. Non-stainless types are pre-lubricated.

Among other options, stainless steel chains offer corrosion-resistant solutions for food-grade applications, nickel or zinc coatings can add protection to carbon steel variants and a wide variety of attachment chains are available.

Custom-designed solutions, supported by more than 100 years of SKF power transmission industry knowledge, can be developed to satisfy particular demands.

For more information:
SKF USA Inc.
(267) 436-6000
www.skf.com

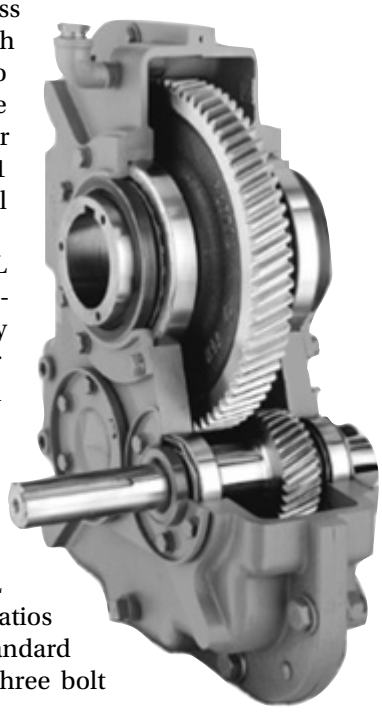
Dorris Gear Drives TR Product Line Tapered Bushing Easy to Install and Remove

The TR Product Line offers eight standard ratios from 5:1 to 40:1. The quick release tapered bushing is easier to install and remove than any comparable bushing system. Dorris offers a total quality management system that assures excellence from customer contact to delivery. They offer a two-year warranty and everything is American made.

The Dorris TR Design has a narrow "thru-the-bore" dimension, a bushing design that mounts from the open (motor) side, and requires a drive shaft that only needs to extend partially through the gear drive. With these features, the TR Design only requires approximately half the driven shaft length of its leading competitors.

The quick release tapered bushing is easier to install and remove than any comparable bushing system. This is because the flexible sleeve and threaded collar conforms to the driven shaft with greater gripping power. It is designed to avoid crevice or fretting corrosion, localized welding, binding and many of the problems that exist in other bushing designs.

Dorris's 30:1, 35:1 and 40:1 ratios allow for many new options in selecting a drive system. Among these are lower output speeds; higher speed, lower cost motors; smaller, less expensive sheaves and enough ratios within the gear drive to directly couple to a C-Face Motor. The 415 and 507 offer triple reduction ratios to 250:1 and 200:1 respectively, as well as double reduction gearing.



Dorris also offers the TL Product Line, which conform to the highest industry standard for screw conveyor drives and components. All drives and components conform to CEMA standards. The TL Series consists of a component gear drive, drive shaft kit and trough end adaptor. The 107– 407 TL series offers eight standard ratios from 5:1–40:1. CEMA Standard Drive Shafts have two and three bolt configurations.

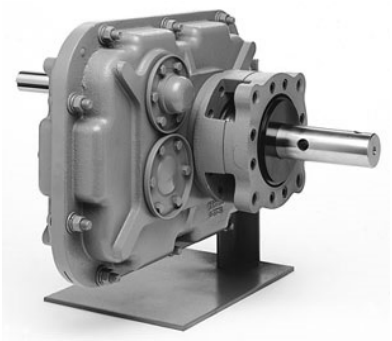
The TL Gear Drive is equal to the TR Gear Drive, adding a gear drive adaptor and removing the torque arm assembly.

The trough end adapter kit contains a removable shaft, locknut, lock washer and key. TL drive shafts have a tapered output end to avoid binding. The kit also contains the trough end adapter and packing gland assembly. Dorris trough ends are available. A TR/TL Conversion Kit, along with a drive shaft kit and trough end adaptor kit is required to convert a TR to a TL.

The TL Drive Shaft kit contains a removable shaft, locknut,

lock washer and key. TL drive shafts have a tapered output end to avoid binding.

Both products include motor mount, high performance packing gland, grease air purge packing gland, 303 stainless steel output shaft and three-hole drilled output shaft. All products are versatile, efficient and cost-effective American-made products.



Dorris offers the same gear drive and hydraulic motor combinations as Dodge. Hydraulic motor mounting is available through Dorris, please consult factory for the adaptation.

Backstop extensions are standard on double reduction drives and can be supplied on Single Reduction Drives if specified when order is placed. The gear drive can be ordered from the factory to adapt a C-face motor. The required flexible coupling is available from Dorris. The maximum motor frame size is 256TC up to size 315, and from 326TC up to size 507.

Face mounting holes are not drilled on standard units. Please contact factory if face mounting is desired. The dimensions are typical for either face.

For more information:
Dorris Gear Drives
(586) 293-5260
www.dorrisco.com

Motion Industries: The Exclusive Distributor of Timken Belts

Timken Belts offers a comprehensive line of belts that are made in ISO registered manufacturing facilities in the USA in sizes ranging from 3" to 900" for anything and everything — fans, mixers, pumps, conveyors, machine tools, centrifuges, robotics, and all types of industrial machines.

The depth and breadth of Motion Industries' product line allows us to handle virtually any application in the key industrial markets of agriculture and mining, energy (oil and gas), forest products machinery, HVAC/R and industrial equipment.

The Gold-Ribbon Cog Belt combines the superior flexing of precision-molded cogs with the gripping power of raw edge sidewalls to provide high energy efficiency, increased power ratings and longer belt life. In addition, the Gold-Ribbon Cog-Belt is now made of EPDM (Ethylene Propylene Diene Monomer), a synthetic rubber with outstanding properties. EPDM is durable, oil- and heat-resistant, static conductive and resistant to hardening and glazing. Most importantly, EPDM withstands a broader operating temperature range of –50°F to +250°F — key to extended belt life. The Gold-Ribbon Cog-Belt transmits up to 30 percent more horsepower than conventional belts, utilizing the same drive space. Even under adverse operating conditions such as reverse bends, backside idlers and constant starts and stops, the Gold-Ribbon Cog-Belt resists excessive heat build-up and related wear problems. Lengths: 23-332 in. and choice of four cross-sections.

The Super Blue Ribbon v-belt is a superior wrapped belt and workhorse of classical v-belts. It is the ideal choice for dependable and economical performance. Super Blue Ribbon v-belts assure dependable length stability and require less re-tensioning and take-up. The cord is coated with a special compound that produces a secure, long-lasting bond with the surrounding rubber. Impregnated with oil- and heat- resistant rubber, the heavy-duty fabric cover protects the core. Its extra flexibility permits the belt to bend more easily around the smallest pulleys with less strain on the fabric. Longer belt life results in less frequent replacement, less downtime and lower maintenance costs. Lengths: 22-664 in. and choice of five cross-sections.

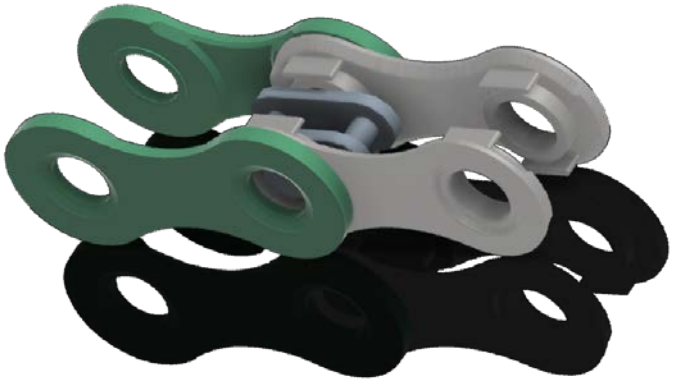
For more information:
Motion Industries
(800) 526-9328
www.motionindustries.com

Shown are the Gold-Ribbon Cog Belt and the Super Blue Ribbon V-Belt.

InfiGear Power Transmission Chain Reduces Peak Stress on Sprockets

InfiGear is developing a new type of power transmission chain set to reduce peak stresses on the sprocket by up to 80 percent. In turn, this will increase both sprocket and chain lifetimes by up to 10 times, compared with conventional roller chain technology.

By using this new technology, manufacturers will benefit from significantly reduced downtime, maintenance and



workload — in turn, allowing them more time to focus on growing their business.

Additionally, as mechanical wear will no longer be a primary consideration, different materials such as plastics and carbon fiber (with the added benefits of improved hygiene, cost and weight reduction) will now be viable options in chains and transmissions.

This summer, InfiGear is launching a limited number of pilots with selected partners. If you would like to learn more about joining InfiGear's pilot phase, please get in touch before July 31.

For more information:
InfiGear
+44 78 1441 9510
www.infigear.com

Iwis Transfer Chains Designed for Gentle, Clean Conveying

Transfer chains are used in many different industrial applications where goods need to be conveyed to the next stage of the production process — including situations that require particular cleanliness or especially gentle conveying of sensitive or fragile goods.

Iwis has developed a comprehensive range of transfer chains with durable plastic attachments to meet these requirements. The functional sections of the chain are completely enclosed, which offers a number of advantages: the product stays clean and undamaged, no dust or dirt can build up on the chain, goods are conveyed on a flat surface and there is no lifting of the load when the chain passes over the sprockets.

Iwis transfer chains are also extremely durable, thanks to the outstanding adhesive properties of the initial lubricant applied to the base chain before it leaves the factory. The three attachment versions — for standard, high-temperature and antistatic applications — are all made from extremely hard-wearing materials. Depending on the attachment and lubricant selected, Iwis transfer chains can be used in temperatures ranging from -50°C to 150°C. After prior consultation with Iwis, these chains can also fulfill food-grade (H1) or silicone-free (PWIS) requirements.

Besides the standard base chain, special chain versions such as nickel-plated or maintenance-free chains from the Megalife brand range are also available.

With this ideal combination of positive features, Iwis transfer chains are suitable for all conveying, transport and metering applications that require the gentle handling of sensitive goods, containers or workpiece carriers. Typical examples are foodstuff processing, the electronics and PCB manufacturing industries, medical technology and pharmaceutical production and glass and ceramics processing.

In addition to transfer chains, Iwis provides a full product range for all drive and conveying applications. This also includes precision and high-performance roller chains, conveyor chains, maintenance-free and corrosion-resistant chains, power and free conveyor chains, special-purpose conveyor chains, flyer chains, flat-top chains, modular belts, chains and accessories for agricultural machinery and timing drives for the automotive industry.

For more information:
Iwis Drive Systems, LLC
Phone: (317) 821-3539
www.iwisusa.com

Tsubaki RS Roller Chain and Heavy Duty Drive Chain Improve Service Life over Previous Models

The RS Roller Chain is Tsubaki's standard chain, designed to meet the needs of most applications. The Heavy Duty Drive Chain is an endurance chain with a high maximum allowable tension for particularly demanding situations.

The G8 RS Roller Chain offers a 20 percent improvement in service life over previous designs. A special corrosion suppressing oil is also applied to the chain in the final stage of manufacture to inhibit rust and improve durability. Developed in-house, this oil does not leave a sticky residue on the chain surface, making handling cleaner and more pleasant. The new G8 chain is available in 11 sizes from RS40 to RS240.

The new G8 Heavy Duty Drive Chain offers greatly improved performance and is aimed at applications requiring the movement of large loads at low speeds. This chain provides increased strength as a result of a new heat-treatment process, thicker material, and innovative geometry while remaining the same size as the standard type of chain.

It is available in three variants. The RS-HT Roller Chain, whose highly precise seamless bushes have doubled the service life. This innovation greatly reduces maintenance needs. The Super Roller Chain features a new link plate design which increases the load capacity by 5–10 percent. Super-H Roller Chain has a 20 percent increase in maximum load by providing a ring coin on the inner plate. It offers users the possibility of using smaller chains, which will reduce costs and save space.

The generational improvements to Tsubaki chains form part of the company's constant pursuit of ever-increasing quality. They have come at approximately 10 yearly intervals since the products were originally launched in 1953. In fact, the new G8 chains are being launched in Tsubaki's centenary year, the company being founded in Japan in 1917.

For more information:
Tsubakimoto Chain Co.
info@tsubakimoto.com
www.tsubakimoto.com

A Mechanical Healthcare Plan

Motor Operation Gets Big Boost from Smart Technology (Here's How to Take Advantage)

Matthew Jaster, Senior Editor

Let's say 100 motors are running in a mining, oil and gas, or metal refinement operation. These facilities are probably in the middle of nowhere; not exactly ideal conditions to have a full-time engineer on-site to make sure the mechanical assets are running properly 24/7. In the past, manufacturers had little choice but to be reactive when motor loss occurred or a mechanical system was in need of some troubleshooting for an application like this. From a cost and/or safety perspective, this was typically bad for business.

Often, these assets are spread out over the company's operating territory and managed by a smaller team that travels. Not only can truck rolls be interstate, but upon arrival the analyst may need to traverse catwalks or work in cramped, uncomfortable spaces to collect the needed vibration waveforms needed. In the case of power generation, energy contracts and possible regulations bring multiple sources of financial pressures making downtime all the more urgent.

The paradigm for motor functionality and efficiency has changed dramatically in recent years. Sensor data can report real-time motor functions, software can provide temperature profiles and machines can predict voltage changes at the push of the button. Smart technology is here to stay. How then, can manufacturers make the best use of the technology to make a significant impact to their business?

"Quite honestly, for years and years motors were relatively dumb," said Sherman Joshua, connected services global portfolio manager at Rockwell Automation. "What's changing today is the instrumentation and data that is now being built into these systems provides sensor, performance and field data that lets engineers know how their applications might be impacted both short and long term."

So we return to the mining facility with 100 motors in 2018 and find a predictive maintenance solution in place that gives engineers the flexibility to predict issues, pre-plan resources and schedule appropriate measures to keep the system running as efficiently as possible. It's a healthcare system for components.

In the future, National Instruments believes more motors will have automated, connected maintenance data collection systems installed.

Getting Better, Smarter and Easier to Operate

Brett Burger, principal solutions marketing manager at National Instruments, says that condition monitoring and preventive maintenance programs offer huge potential economic impact to businesses as they look to not be on the wrong side of disruptive technologies.

"McKinsey & Company sees predictive maintenance and equipment maintenance as major IoT application areas for factories and worksites by 2025. The prevalence of motors makes them a critical component in the drive to reap these economic gains and a wise asset on which to focus. Many challenges today are creating an environment where the status-quo will not be good enough and companies will look to technology, such as those used in online predictive maintenance solutions, to find a better way to operate," Burger said.

To improve condition monitoring, Burger says that customers need to be mindful of their workflow with regard to when and how they use data. By focusing on their workflow, they can better understand where the inefficiencies are such as excessive time spent collecting data or existing data that is currently unused. Workflows can also connect to other groups, leading to more opportunities for inefficiency.

"From my perspective, field monitoring today is beginning to focus less on the portable equipment carried by analysts, and more on intelligent technology used to automatically connect motor data to networks," Burger added. "Vendors traditionally known for handheld instrumentation are re-evaluating their product catalog and the trend of automated measurements is enabling new vendors to enter the industry. This dynamic is creating a wider variety of offerings to companies looking to monitor motors, but it is also creating a greater need to research technology and equipment since many of these solutions are enterprise-wide."

The Challenges of Predictive Maintenance Today

Being in the early stages of smart motor technology, customers looking for analytic and monitoring solutions typically fall into two categories according to Joshua.

"You have the customer that knows what systems and analytics they need, but they're not sure if they can do it on their own or if they need help from a vendor. Then you have the customer that's completely overwhelmed. They see so many technologies and solutions available regarding condition monitoring and predictive maintenance they simply don't know where to start," Joshua said.

Add to this the fact that motor technology *feels* like it's changing on a daily basis. Joshua explains how a customer might purchase a predictive maintenance system only to have better software or hardware available three months down the road.

"Do you need this technology every time something new hits the market? Is it necessary to changeover so quickly? These are the questions Rockwell Automation customers ask. We want our customers to focus on the '*what*' and let us focus on the '*how*.'"

NI sees several challenges as they work with turbomachinery maintenance professionals including time spent manually collecting data, data gaps (route adherence), dark data, as well as a workforce that is at or near retirement age.

Burger said that manually collecting data does get the expert into the plant to use the human sensors, but it comes at a great efficiency cost.

As an example, a recent case study released by IHS Markit examined how Duke Energy is using IIoT technology to replace monthly, manual data collection. "With almost 60,000 collections a month, analysts at Duke Energy were typically spending 80 percent of their time collecting the data and only 20 percent of their time analyzing it …" (Duke Energy Leverages IIoT for Predictive Maintenance Applications, Alex West, IHS Markit Technology, January 2018).

Looking at other examples and challenges, Burger says when routes are performed by on-site personnel it can be difficult to prioritize the data collection over other pressing plant issues. Lack of adherence to data collection leads to data gaps that could otherwise contain useful information that prevents the next outage.

Even when data is collected properly, Burger believes that doesn't always lead to an efficient use of a maintenance professional's time.

"Often, the team reacts to more urgent needs such as calls from operators that have noticed abnormalities in control dashboards or troubleshooting an important asset that is out of service," Burger said. "On top of all these challenges is the trend that many professionals in this industry are at or near retirement age and not being replaced at a sufficient rate meaning more assets need to be covered by fewer experienced maintenance professionals."

How Condition Monitoring & Smart Technology Can Help

So where do you start? How do you get the most from your motor applications by utilizing smart technology today? Companies like Rockwell Automation and National Instruments offer products and services that take ownership of the data and analytics so their customers don't have to.

Joshua said many large manufacturing organizations can handle the growing list of requirements needed when putting together a maintenance and condition monitoring plan. They have the skillsets and the sheer numbers to look at everything from analytics and the Cloud to cybersecurity, I. T. and software. Medium and small-sized companies don't have the infrastructure in place to handle implementing this technology in most cases.

"It's the 90-percent of the iceberg that's underwater that they don't see at the beginning," Joshua said. "If they're going to buy all the equipment to monitor motors, for example, they're going to need to connect all the pieces to make it work effectively. This costs time, money and effort."

Rockwell can do the grunt work for the customer. They will collect the data locally, store it in the cloud, leverage the software, develop predictive and remote engineering tools and essentially build the analytics from the ground up. It's a hardware/software platform with engineering expertise on-hand to solve a variety of challenges. The Dynamix 1444, for example, integrates machine protection with a standard control system and *Studio 5000 Designer* software lets customers configure the system within a single-design environment.

Burger said NI's core offering for condition monitoring applications is also a single platform with hardware and software. *NI InsightCM* can measure asset health data from any type of sensor technology (wired vibration and temperature, wireless vibration and temperature, motor-current/vibration, infrared, electromagnetic, and so on) and aggregate that data, including the full waveform captures, onto the *InsightCM* server.

SMEs can set intelligent triggers for data collection and perform analysis on the real-time or historical data. Aside from SMEs, *InsightCM* can connect to 3rd party software tools such as OSIsoft's *PI System* historian database or any software that uses *OPC UA*, meaning maintenance teams have more freedom to operate using their existing tools. Finally, *InsightCM* has a development kit available so in-house analysis, data from 3rd party hardware, and new communication protocols can be added to fit custom requirements of the end user.

The Toolbox is Expanding

Burger says the Industrial IoT megatrend includes several technologies that can help with field monitoring for motor applications. Sensing and processing technology continue to improve in performance and value helping to move much of the analysis that would typically happen on a laptop or a server to the field right next to the asset being monitored.

"Instead of walking routes to each motor to gather data, the motors are connected to the plant's network by intelligent measurement devices and screen the data 24 x 7 sending

only relevant, useful data to the plant server where SMEs can log in for further analysis. Wireless sensors are improving in communication bandwidth, measurement capability, and battery life, reducing the cost of connecting assets to a network. Since much of the cost of a system is in the installation of conduit/cabling for power and wired network a fully wireless solution can speed time to an ROI greater than one. Finally, a possibly most important, software technology to help manage and analyze automatically captured data is improving and helping maintenance teams better plan asset servicing during outages," Burger added.

In the future, Burger believes more motors will have automated, connected maintenance data collection systems installed (eventually they will be built-in to almost every motor of modest criticality). Data from automated measurement systems will be increasingly consumed by artificial intelligence using machine learning to detect pre-failure patterns in the data. Monitoring technology equipment will move to the "set top box" model allowing companies to reduce up-front cost and focus more on the data and less on maintaining measurement equipment.

Joshua says that while motor monitoring and preventive maintenance today is still being purpose-built on a case-by-case basis, he sees an evolution of sorts coming to the industry in the future.

"Let's look at the facility again with 100 motors. They have a 90 percent efficiency rate, but the customer wants it up to 98 percent. Down the road, we'll have libraries of analytics, algorithms and off-the-shelf solutions to increase uptime. And the monitoring will go to a performance-based model instead of a one-time engineering cost on top of the fees to maintain and support the system. I think these changes will deliver high value to the customer and provide a more cost-effective approach."

The end game with all this technology is to create more efficient, reliable mechanical systems. NI and Rockwell Automation are just two of the companies that can provide the resources necessary to fulfill these requirements.

"We're bringing industrial automation knowledge to the customers," Joshua said. "We have the engineering expertise, the support system and the technology in place, so our customers can focus on what they do best. This saves time, money and resources and could ultimately change what their staff looks like in the future." **PTE**

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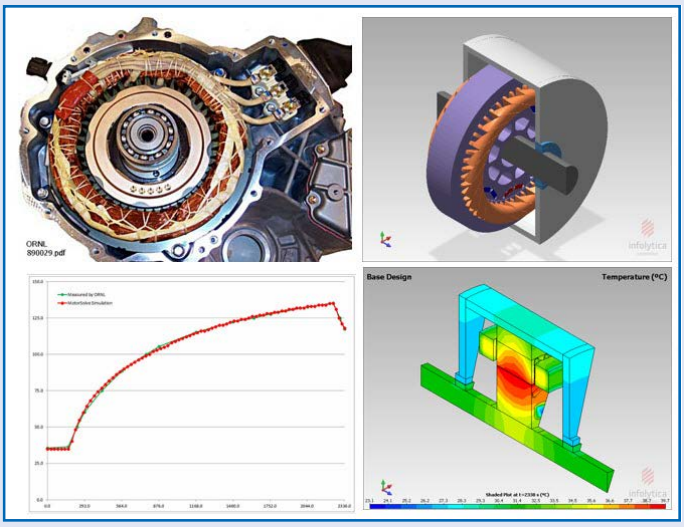
Simulation Software Provides a Different Set of Tools for Motor Efficiency

While some organizations focus on real-world analytics and data collection for predictive maintenance, simulation tools and virtual prototyping can be another solution for motor efficiency.

"The development of highly efficient, robust (fault tolerant) and cost effective electric motors for application in many industries including, but not limited to the transportation, aerospace, defense and consumer products industries have gathered urgency due to current and future regulations. These regulations govern their efficiency levels and other design criterion such as the speed range and noise pollution level," said Tanvir Rahman, Ph. D. R&D consultant, (engineering) at Infolytica Products Line Mentor Infolytica, a Siemens Business.

As most commercial electric machines are already highly efficient (~90%), designing for even higher efficiencies poses a challenge and requires a systems level approach that include the simultaneous consideration of different machine topologies, materials engineering, thermal system design, acoustic analysis and machine drive component design.

"A prototype-based design approach is impractical because making design changes and re-prototyping is time consuming and costly. Only through simulation and virtual prototyping can the impact of changing multiple design parameters be studied effectively. This enables the non-linear behavior of a model to be understood, the optimal design for multiple objectives and large parameter spaces to be discovered, and the impact of faults arising from electrical sources and manufacturing tolerances be taken into account," Rahman said.

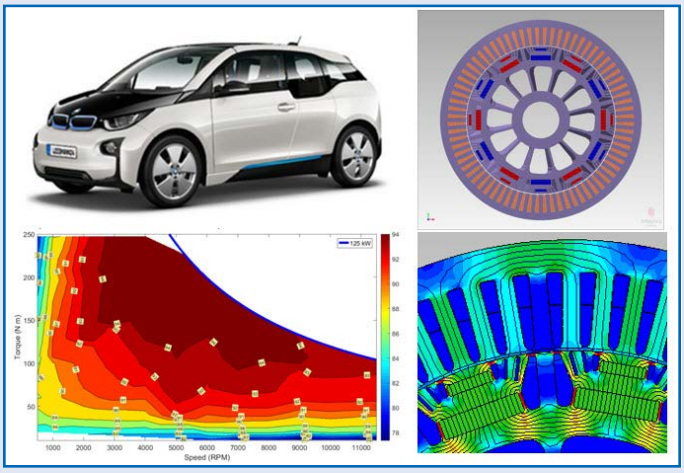


Infolytica's software suite has been utilized on the Toyota Prius.

Simcenter from Siemens PLM Software has various applications for system simulation of electrical powertrains, as well as detailed simulation of electric motors from a multiphysics perspective. For example, Mentor Infolytica's suite of

electromagnetic, multi-physics and optimization software in 2D and 3D, allows the implementation of virtual prototyping of modern electric motors covering each of the aspects mentioned. Infolytica's design suites include a template-based design software (*MotorSolve*), multi-objective optimization tool (*OptiNet*), coupled electromagnetic-thermal simulation software (*ThermNet*) and a general purpose modeling and analysis software (*MagNet*).

"This software has been used to simulate the BMW i3 motor, the Toyota Prius and many others. The accuracy of the virtual models have been correlated with dynamometer test results and other industrial standards," Rahman said.



Infolytica's software suite has also been utilized on the BMW i3 motor.

Siemens entered into an agreement to acquire Montreal, Canada-based Infolytica Corporation, expanding the company's simulation suite into electromagnetics (EM) in 2017. Infolytica was one of the original pioneers in the field of simulating low-frequency EM and its market-leading simulation software is used by manufacturers worldwide to predict EM and thermal performance.

This accelerates the development of reliable and optimized solutions for electric and electromagnetic devices such as electric machines - including motors, generators and transformers – as well as sensors, induction heating, MRI, and shielding. The Infolytica business was then incorporated into the Mechanical Analysis Division of Mentor, a Siemens business.

The addition of Infolytica enhances Siemens' *Simcenter* portfolio for simulation and test, which covers mechanical, thermal, fluid dynamics and electromagnetic simulations. Infolytica's products are widely used in the design of high-performance electromechanical products across industries such as aerospace, automotive, consumer electronics, electrical appliances, medical equipment, heavy industry and power generation. **PTE**

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Custom Machine and Tool Co., Inc.

Bolsters Accuracy and Efficiency for Vande Berg Scales

Charlotte Stevens, Marketing Manager, Custom Machine and Tool Co., Inc.

If you can find that magic bullet that will reduce the machining process, you can achieve meaningful efficiency gains. It is imperative that checkweighers or in-motion weighing systems remain both accurate and efficient while attaining a consistently smooth operation because they dynamically weigh products as they move across the belt. One such challenge David Vande Berg, president of Vande Berg Scales (VBS), encountered was to make sure the company's in-motion weighing systems were equipped to move with less vibration and smoother transitions.

Based in Iowa in a 15,000 square foot facility, Vande Berg Scales manufactures a number of systems that employ motor driven belts and chains. The company designs and fabricates weighing and automation equipment including in-motion checkweighers, weight price labelers, box/tote weight labelers, and monorails. Accuracy through automation enables Vande Berg Scales to achieve the highest of quality standards. Add to this, their measurement and advanced design capabilities, VBS is able to facilitate custom projects and challenges with the same ease as standard products. For more than 30 of it 54 years, Vande Berg Scales has built a solid presence in the meat, dairy, food, and manufacturing industry as a driving force in dynamic weighing and automation.

Igniting the Passion for the Next Generation

In 1964, Don and Wilma Vande Berg tapped into their entrepreneurial spirit by converting their home and garage into small workshops to launch the Vande Berg Scales brand. VBS began to produce weighing, measuring and automation systems. The payoff came as the company quickly grew, thanks to their relentless ingenuity and dedication to their clients' needs. This leap of faith laid the groundwork for the second generation. In 2001, David Vande Berg, son of Don and Wilma Vande Berg, purchased the company.

With an upbringing in the scale industry and a degree in mechanical design, David Vande Berg, president of Vande Berg Scales, was inspired to design intricate custom systems. His knowledge of programming and electronics coupled with decades of weighing system and weights and measures experience served him well in every aspect of the growing business. And so he began a new era by spearheading the drive into automation.

Company Alignment

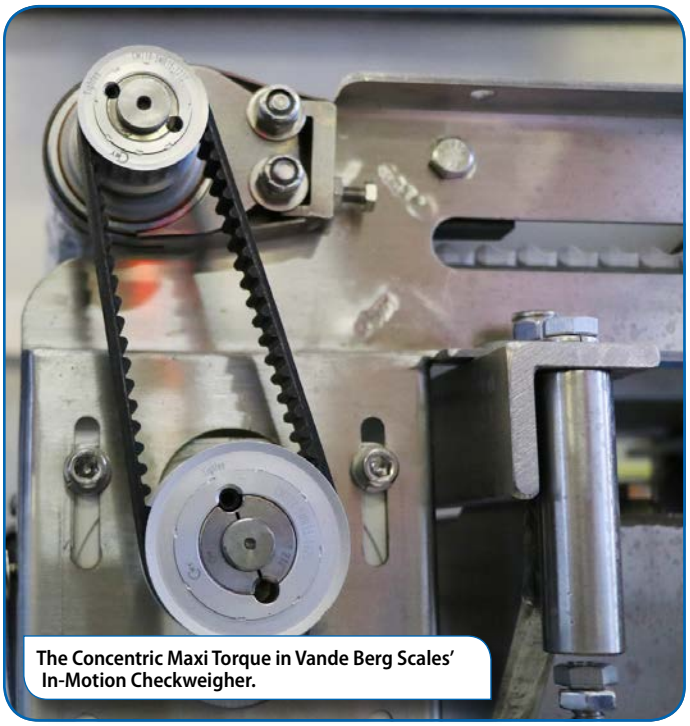
After discovering Custom Machine and Tool Co., Inc. (CMT) on the Internet, Vande Berg Scales recognized the advantages of CMT's Concentric Maxi Torque line of products. Custom Machine and Tool Co., Inc. had designed and patented a more reliable connection format, the Concentric Maxi Torque bushing system, which offers zero backlash and high clamping torques. These features, unique to the industry, would prove to enhance and strengthen VBS' product line. Along with its low profile design, the benefits allowed for direct coupling to the motor shaft, reduced costs by dismissing the need for a custom length shaft and eliminating a bellows coupler on the motor.

With its ease of positioning and the fact that it virtually defeats shaft damage due to its mechanical shrink fit, this connection system is the perfect fit for in-motion weighing systems. The Concentric Maxi Torque System was integrated so as to satisfy these precise pulley requirements.

After discovering Custom Machine and Tool Co., Inc. (CMT) on the Internet, Vande Berg Scales recognized the advantages of CMT's Concentric Maxi Torque line of products.

How the Concentric Maxi Torque System works

Pulley and bushing are sold together as an assembly. There is a mechanical shrink fit affected by using a setscrew, axial to the shaft, as a lever to force the tapered bushing into the matching taper in the hub. As the lever forces the two tapers together, the slot in the bushing is compressed, thus clamping the pulley to the shaft with a mechanical shrink fit. That same set screw is removed and used on the opposite hole, which acts as a jack, releasing the shrink fit and allowing for removal or re-positioning.



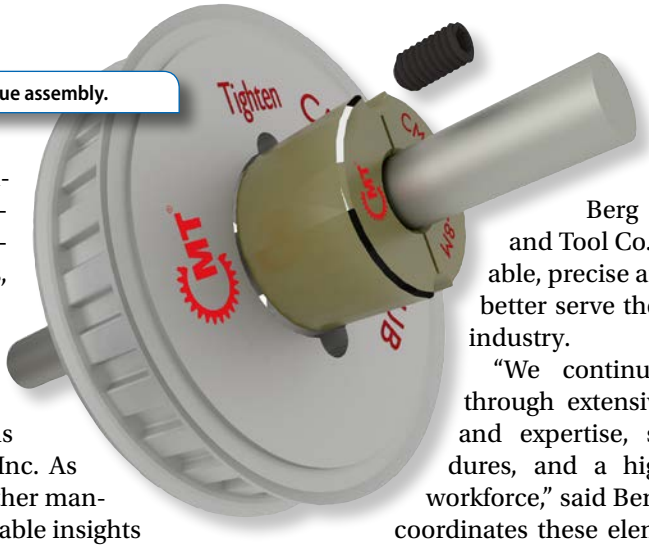
The Concentric Maxi Torque in Vande Berg Scales' In-Motion Checkweigher.

"It is a fantastic and very innovative product that makes complete sense for our needs," said David Vande Berg of VBS. "The Concentric Maxi Torque's smooth running power is key to the in-motion weighing system's performance. Finding or building these attributes into components can be time-consuming, expensive, and difficult to repeatedly achieve. By implementing the Concentric Maxi Torque, it allows us to focus our resources on other areas to gain further improvements in our product offerings."

Vande Berg added, "The increased benefit in performance with the Concentric Maxi Torque design enables us to fabricate the components we need without long searches and outsourcing. With CMT's product, resources can be diverted to improve other areas of our designs while achieving a reduction in needed machining time. The keyless hub-to-shaft connection device has superior features and benefits compared to other connection systems such as keyways, pins, set screws, clamp collars, and other tapered shaft locking devices."

A similar recipe for success

In 1964, Edward Bennett, founder of Custom Machine and Tool Co., Inc. took the skills and creative savvy he acquired at an early age to begin manufacturing his unique line of screw machine products in the basement of his Scituate, Massachusetts home. Bennett quickly gained a reputation for his dedication to precision and quality which, in turn, spawned



The Concentric Maxi Torque assembly.

customer confidence and loyalty, endowments that would serve as a template for son, Robert, and his future-forward thinking inventions, patents, and endeavors.

"Precision isn't just a watch word… it is your core value." That's what Robert Bennett envisioned when he took over the reins of Custom Machine and Tool Co., Inc. As Robert apprenticed alongside his father manufacturing sprockets, he gained valuable insights and began to develop ideas of his own on how he could grow the business through innovation. Remaining true to the values taught to him, Robert expanded the product lines to include timing pulleys, drive systems and components for the motion control and power transmission industries. Robert went on to invent and patent a revolutionary hub-to-shaft connection device, the Concentric Maxi Torque, which allows for precise component positioning and tight runout control on demanding applications, while at the same time retaining installation simplicity and without risk of shaft damage.

Weighing in together, Vande Berg Scales and Custom Machine and Tool Co., Inc. are producing more reliable, precise and cost effective equipment to better serve the needs of the motion control industry.

"We continue to achieve our mission through extensive manufacturing experience and expertise, strong administrative procedures, and a highly skilled, quality-oriented workforce," said Bennett. "Our management team coordinates these elements into an efficient manufacturing production system." **PTE**

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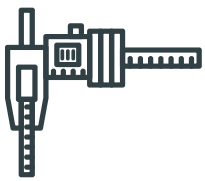

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Machine Parts No Longer in Production?

Solutions for Hard-to-find Bearings and Parts

Steven Katz, president, Emerson Bearing Boston

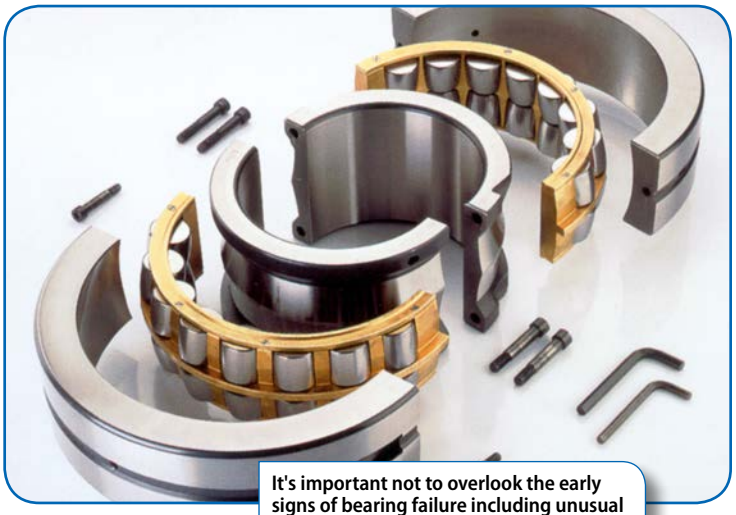
Good machinery can last a lifetime. But, replacement parts for older equipment may be near impossible to find. So, what do you do when you're looking to replace hard-to-find bearings and related parts for older machines?

Finding obsolete or hard-to-find-bearings and related parts is more advanced than ever before with today's search algorithms. But finding certain bearings, for instance very large bearings such as tunnel-boring 15-foot-diameter giants, is still a challenge. Custom work is often the only option.

To give you an example, a local elevator repair company working on a 100-year-old elevator contacted us for replacement parts. The roller chain and sprocket that were needed were just as old as the elevator, raising concerns that the parts wouldn't be available anymore. The customer brought the parts in and, through our extensive line of partners, we were able to identify someone who still made the chain and had it in stock. No one mass-produced the sprocket anymore, but custom work was still an option. Our team was able to reverse-engineer specifications from the old sprocket itself. Those plans turned into a new sprocket that would fit the lift perfectly.

When bearings and their related parts fail to work properly, all related processes have to shut down. Our goal is to improve machinery life, and when certain bearings or parts are no longer being mass produced, we're able to provide engineering assistance and custom parts development to ensure our customer has the right part to keep their equipment rolling for years to come. Of course, there are other factors that contribute to bearing longevity, including proper design, internal clearance and more as we've outlined below.

Factors that contribute to bearing longevity include proper design and internal clearance.



It's important not to overlook the early signs of bearing failure including unusual noises or increased temperature.

Application Changes Affect Bearing Design

Rarely do we come across a bearing that has been improperly designed into an application, but it is possible if factors within the larger application change.

How long a bearing lasts before it fails is known as bearing "service life". It is generally considered in terms of hours and is based on load and speed conditions.

Overloading and early bearing fatigue are often the result when loads become too high. Skidding and improper loading of the rolling elements will occur if they are too low. These issues will also occur with improper internal clearance. In all of these instances, early failure will be the result.

Early Signs of Failure

Don't ignore the early signs of bearing failure, specifically unusual noises or increased temperature.

Abnormal bearing sounds are indicative of specific issues in the bearing application. For example, hearing a buzz to roar noise, where the loudness and pitch changes with speed indicates issues such as poor fit, deformed bearing rings, vibration of raceways, balls or rollers and brinelling. Screeching or howling sounds generally indicate too large an internal clearance or poor lubrication on a cylindrical roller bearing. Crunching that is felt when the shaft is rotated by hand often indicates contamination of the raceways.

A desirable bearing temperature is below 100 C. At start-up, the temperature will rise, but then stabilize at a temperature slightly lower than at start-up, but somewhere between 10 to 40 C higher than room temperature. Increased temperature is another early sign of bearing failure.

Operational stresses in the applications can impact bearing life as well. It is critical to isolate vibrations in

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associated equipment as they can cause uneven running and unusual noises.

Improving Bearing Performance

What do you do if performance is less than optimal? Lubrication plays a critical role in bearing performance. Grease is the lubricant most often used because it is easy to handle and simplifies the sealing system. Oil is more appropriate for high speed or high temperature operations.

There are a couple of ways to upgrade bearing performance for a particular application. One efficient way is through lubrication, specifically, the use of high-end synthetic greases and solid lubricants that sit within the bearing cavity. What many don't realize is that it is important to use grease/lubrication that has an equal or better service life than the bearing. If the grease or lubrication used does not have the same life potential as the bearing, then the bearing will fail sooner than its service life expectancy. Replacing the grease with a high-end lubricant will vastly improve bearing performance and extend its service life.

Another way to improve bearing performance is by upgrading to a bearing made of higher quality material.

Machinery manufacturing and automotive industries still use bearings of a standard style in terms of envelope dimensions. But, what has changed is the range of choices in material. A number of industries have upgraded from traditional 52100 chrome steel to various styles of stainless steel, ceramics and even titanium races in severe applications with optimum results.

Asking the right questions is key when addressing the issue of bearings not meeting expectations. Is there too much stress on the bearing? Is the operating temperature too high? Is rotation lagging? Oftentimes, we find that by upgrading the bearing itself to one of higher quality or by upgrading the lubrication, we can better the running accuracy, lower operating temperatures, and improve overall performance while extending the service life of the bearing. **PTE**

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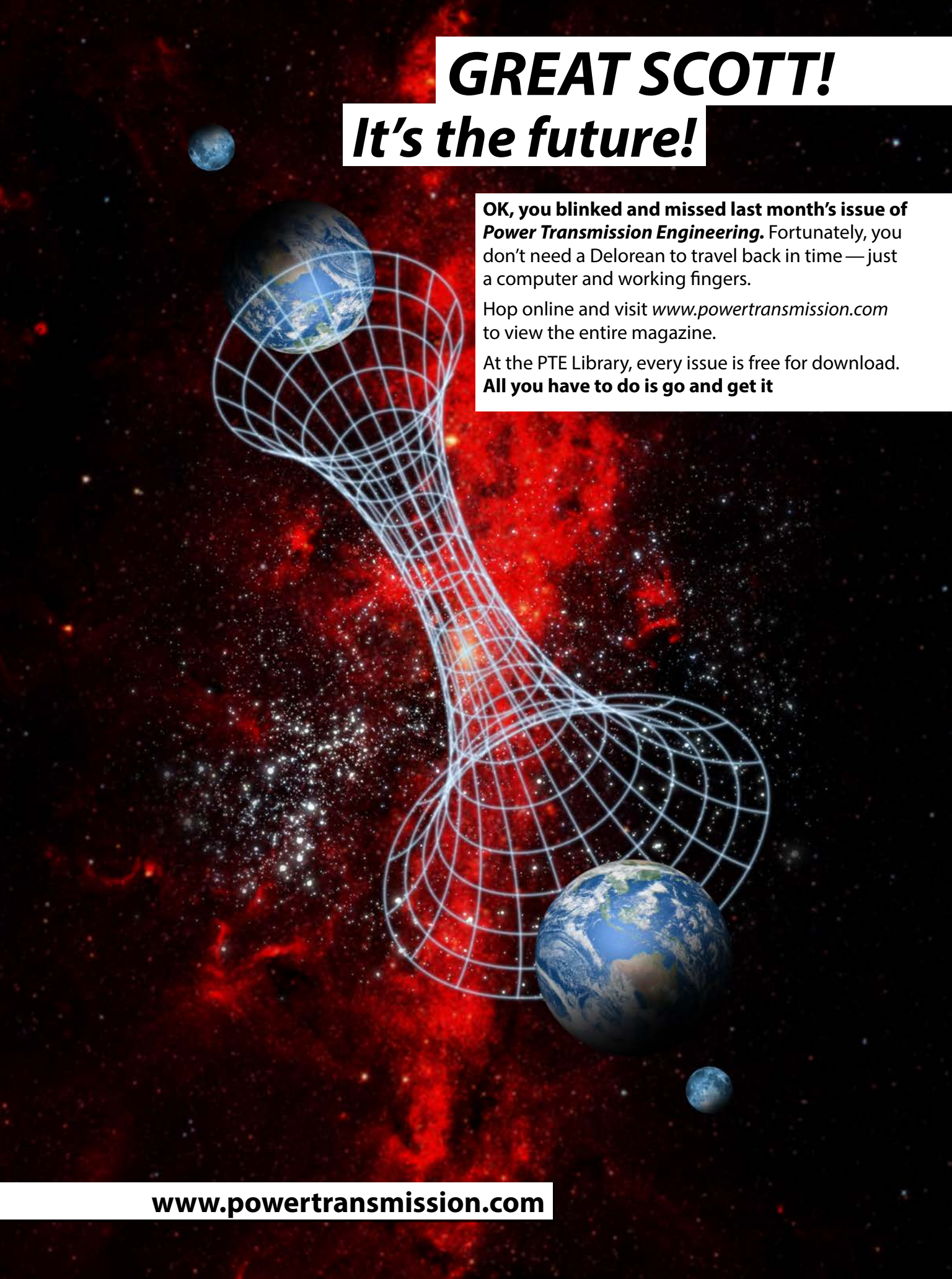

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Keeping the Lights on — Machine Monitoring Basics

Predictive Maintenance Helps Reduce Process Downtime

Stewart Thompson

Introduction

As manufacturers continually search for ways to cut costs and increase ROI, machine monitoring and predictive maintenance (PdM) solutions are an increasingly cost-effective way for plants and factories to help reduce process downtime.

One of the most common data logger applications is machine monitoring for all types of commercial, industrial, utility and construction equipment. In the processing industry, condition monitoring of business-critical machines and electrical equipment is critical to help avoid process downtime and to maximize ROI.

If you're a factory manager or plant supervisor, you can use sensor-based data acquisition to stay on top of developing problems with your electrical equipment. Both management and technicians can benefit from these cost-effective solutions.

In this white paper, CAS DataLoggers discusses the basics of condition monitoring and predictive maintenance for your invaluable process machinery.

With the advent of the Internet of Things (IoT), heavy industry is turning to sensor-based data collection to solve its greatest problems, chief among them being process downtime in the form of process delays and shutdowns.

Machine monitoring, aka condition monitoring or predictive maintenance, refers to the practice of monitoring electrical equipment via sensors to collect diagnostic data. To this end, data loggers and data acquisition systems are used to monitor all types of equipment including engines, motors, boilers, and more — all with an eye toward ROI.

Condition monitoring is a steadily growing business practice, with the market totaling nearly $11 billion, according to a 2017 report from *Research & Markets* magazine forecasting opportunities for OEMs, plants, and factories. Industry leaders mentioned in the report include Caterpillar, Dell, General Electric, IBM, Microsoft and Siemens.

These applications also encompass many different types of needs aside from condition monitoring:

- Runtime/uptime measurement
- Preventative maintenance
- Performance tracking
- Energy monitoring/conservation
- Fault isolation
- Quality control

How Does Condition Monitoring Help Prevent Downtime?

As a plant manager or technician, you always need a heads-up regarding developing conditions in your facility's equipment. Likewise, if you're a purchasing agent, you'll want to select the most appropriate monitoring device for your customer.

Machine monitoring can be either periodic or continual:

Periodic. Periodic measurements are performed according to either a regular schedule or are taken erratically. Periodic monitoring is reliable only if it is done according to a set schedule, for example by a supervisor at a set time every day, or automated by a data acquisition system.

Continual. Continual measurements are performed constantly by data acquisition systems via automated, sensor-based data collection. Continual monitoring has the considerable advantage of being more dependable and a clearer indicator of developing machine damage or impending process downtime.

Condition monitoring applications:

- Heavy Machinery
- Oil & Gas
- Energy
- Automotive & Transportation
- And many other industries

If you're the person using the data acquisition system, you'll want to be sure that any prospective device not only suits your needs, but is also easy to learn and operate. Meanwhile, if you're a purchasing agent sourcing a control system, you can help to decrease your client's downtime hours (in the form of process delays and shutdowns) by sourcing a machine monitoring solution.

Machine Monitoring Basics

Condition monitoring solutions include:

- Data acquisition systems
- Data loggers
- Portable measurement systems
- Current/voltage loggers
- Vibration monitoring systems

Data acquisition/machine monitoring systems:

Two major categories of products are used for condition monitoring:

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1. Dedicated data loggers designed for a specific function such as temperature recording or AC voltage measurement. These solutions are ideal when you know beforehand that you only need to measure one or two values, or if you need to save on cost.

   For example, we provide dedicated event loggers to track machine run-time or parts count, AC power loggers to record incoming voltage and/or current, and vibration analyzers to look at the dynamic behavior of rotating or moving equipment.
2. Universal input data loggers — which can be outfitted with a variety of sensors to record many different parameters simultaneously, such as temperature, current, voltage, pressure, flow — or nearly any other value to track machine conditions in real time. While universal solutions are more flexible, they are also more expensive than single-purpose devices.

   As an example of general-purpose, universal input data loggers, Series 4 dataTaker systems include models with 2 to 16 input channels, local alarm notification, and *Modbus* capability to interface with other equipment.

Sensor arrays:

Data acquisition systems incorporate various internal or external sensor types (temperature, current, voltage, etc.) to continually acquire machine data and compare it to user-set parameters such as normal operating temperatures, energy, power factor, etc.

For example, to monitor a boiler, the user might first attach a type-K thermocouple to its metal side, with leads trailing back to the data logger or data acquisition system. Then the operator configures the system to sample a reading from the thermocouple sensor, say once every 15 minutes. This step, often called data acquisition or data sampling, must be performed using accurate sensors and an accurate monitoring system to ensure reliable condition monitoring.

The monitoring device then stores this temperature data in its internal memory or, in the case of a wireless remote monitoring system, automatically transmits it to a remote PC or cloud storage server. Whether you're performing periodic or continual monitoring, once you've collected enough data this way, it's time to look at the condition of your machinery using specialized software.

Visualization and Analysis Software

Condition monitoring software allows users to visualize data from many distributed machines at once, and to analyze this data to identify faults before they can further develop and cause downtime.

For example, in the middle of a production run any sudden changes of any machine's operating values can be instantly detected and responded to. Most importantly, maintenance work and process downtime can be scheduled and carried out in time to help avoid process delays and shutdowns resulting in long-term ROI.

Data analysis is performed via specialized data acquisition software. Using a custom software application, data is analyzed according to user-set filters and portrayed in trend form via charts and tables showing what maintenance or repair actions are needed, if any.

A complete software system will offer you data acquisition, analysis, visualization and automation. The end-user should be able to get a clear and logical overview of all measurement systems, no matter how many machines are being monitored. Armed with this data, plant supervisors and technicians can then make presentations to management.

Which Measurement Value Should You Monitor?

Temperature: temperature is the most commonly measured value, and many machine monitoring applications require you to log temperature in tandem with another value.

Temperature recorders satisfy the needs of many different applications, including:

- Electrical equipment monitoring (motors, turbines, etc.)
- Oven temperature profiling (part finishing, batch ovens, etc.)
- R&D (climate chambers, test stands, etc.)

Temperature data loggers are suitable for use with all common types of temperature sensors, including thermocouples, RTDs and thermistors. The market offers a broad selection of temperature data loggers with a wide variety of features, communication options, storage and notification capabilities to meet your project needs. Temperature recorders are available with or without displays, with wireless and LAN communication, and multi-channel systems with hundreds of inputs.

AC/DC. A common data logging application is measuring voltage and current flowing into or out of a piece of equipment, such as a user monitoring current in wind turbines. These measurements can be broadly classified into two groups: AC and DC.

AC voltage and current: A common voltage measurement application involves taking readings to ensure that a given piece of equipment is operating within its manufacturer's recommended voltage range.

A variety of AC voltage and current data loggers are available with built-in transducers to support a specific voltage and/or current range. However, with a few exceptions, most data loggers cannot measure AC voltage or current directly and so require external transducers to convert the parameter of interest into a signal that the data logger can measure.

AC current data loggers include models for 10 to 5,000 amps for equipment monitoring and metering.

AC current measurements:

- ***AC current transducers*** – A standard method of measuring AC current for a power line-connected device is to use an AC current transducer (single- or multi- phase) which converts an AC current to a DC voltage or a 4-20 mA signal that can be measured with the data logger.
- ***Clamp-on current sensors***. Clamp-on current sensors are easy to use and available in a variety of models and

current ranges, with either DC or AC voltage outputs.

- ***Split core transformers.*** Split core transformers are very similar to clamp-on current sensors but are intended for semi-permanent installations.
- ***Rogowski coils.*** Rogowski coils are suitable for measurement of currents up to thousands of amps. They're easy to place around the conductor, and can provide accurate phase response.

AC voltage measurements

- ***AC voltage transducers.*** If your application involves tracking incoming line voltage, standard AC voltage transducers are available in both single- and multi- phase versions and with standard or True RMS calibrations.
- ***AC voltage signal conditioner modules.*** If you need to measure small AC voltages or a large number of channels, 5B series signal conditioner modules are available with 100 mV to 300V inputs.

DC current/voltage. Many data loggers are specifically designed for measurement of DC voltage and DC current. Some are designed for specific measurements that are easier to set-up but offer less flexibility. There are also general-purpose data loggers that can measure DC voltage, current and other input signal types.

Depending on the levels involved, some data logger models can directly measure DC voltage and current. For example, the dataTaker DT80 family of data loggers can accept DC voltages up to ±30 volts and DC currents up to 30 mA directly.

DC voltage and current data loggers. For DC applications, there are data loggers specifically designed for taking voltage and current measurements using probes that can be directly connected to the signal source. These models typically cost less and are easier to set up, but in turn they offer less flexibility.

If you think that your range of measurements may change in the future, use a data logger with an external transducer that will allow you to change the input range by connecting a different transducer.

DC current measurements:

- Current shunts. These conductors are available in ranges to handle 5 to 1,000 amps, and to provide an output from 0-1 volts.
- DC current transducers. DC current transducers often utilize a Hall Effect sensor to allow current measurement without direct contact with the conductor. They work very well for higher currents.

DC voltage measurements:

- Attenuators. The simplest method of measuring a DC voltage that is outside the measurement range of the data logger is to use an attenuator, which is a few resistors wired together to divide the incoming voltage to a range compatible with the data logger.
- DC Voltage Transducers. Many companies offer packaged DC voltage transducers that convert the incoming voltage to a range that is compatible with the data logger. These units can measure very small (< 0.1) and very high (> 1,000) volt inputs, and can also provide an output either as a voltage or as a 4-20 mA signal.
- Signal conditioner modules. Standard signal conditioner modules such as the ubiquitous 5B series provide up to 1,500 volts of isolation and amplification or attenuation in compact packages that are suitable for multi-channel systems. They are available in a wide range of input voltages and provide a DC voltage output.

Universal input. If you must monitor a mix of AC and DC voltage and/or current inputs, or if your voltage/current ranges are beyond standard input ranges, you can use a universal input logger. These loggers allow measurement of most voltages and currents found in industrial applications.

These loggers also allow the measurement of other input signal types besides voltage and current, and can be outfitted with transducers suitable for up to hundreds or thousands of amps that work with general-purpose data loggers. This also enables the simultaneous measurement of multiple input signal types. Users can measure almost any type of input — from mV and uAmps, to thousands of volts or amps.

These versatile solutions can measure voltage, current, thermocouples, strain gauges, and many other sensor types. While universal dataloggers are more expensive than single-purpose loggers, they can greatly simplify more complex data logging projects, saving both time and money. This flexibility provides you with several convenient advantages:

- You can move the logger from project to project without having to reconfigure the hardware
- Simultaneous monitoring of multiple variables with one data logger — for example, recording temperature using a thermocouple, logging voltage using a pressure sensor, and monitoring the pulse output using a flow meter
- No matter what signal you're logging, you use the same software without needing to purchase additional packages or modules.

Remote Monitoring and Data Transmission in Plants

To transmit and store all this data, many factories and plants opt for a remote data acquisition system capable of continuous data acquisition and evaluation. If you plan on replacing your facility's legacy systems or redundant equipment, you'll find that modern, PC-based data acquisition technology is a convenient solution for predictive maintenance.

To get a heads-up on developing issues before they result in downtime, users rely on a variety of communications features to transfer data and alarm notifications to PCs or networks. This can be done via WiFi, Ethernet, Serial, FTP, cellular modem, and others; cloud-based storage is another viable option.

Remote monitoring systems can perform:

- Independent data acquisition
- Data recording of analog and digital signals
- Remote monitoring of data
- Data processing

Remote systems are also useful for immediate alarm notification via SMS text message in the event of limit violations, such as an overheated motor or a high tank temperature. For this crucial failsafe, first ensure that your prospective solution supports connection to your production and office networks,

and to the process control system (PLCs, etc.).

Plant application features:

- Independent data acquisition
- Online (remote) access to all measurement data and status information
- Instant alarm and fault notification via email and text messaging
- Automated offline data transmission at preset intervals via a scheduler

For example, in fault diagnostics in machinery and plants, typical remote applications include the evaluation of pressure pulses and surges, fast process monitoring and controller optimization, shock and vibration measurement, and materials research and environmental simulation. When every minute counts, make sure you're immediately made aware the moment your process is threatened.

Do You Need Control Capability?

If you need control capability for your machine monitoring application, many intelligent monitoring systems integrate this functionality. Recording in standalone mode, fully independently from the PC, a control system performs:

- Pre- and post-trigger functions
- Synchronized data acquisition (angular and chronological)
- Evaluation of limit values and alarm capability
- Data reduction by online calculation of condensed parameters

Machine and plant limit values can all be adjusted in the GUI (graphical user interface) on the PC. Likewise, multiple machine states can be controlled and visualized using the same user interface.

ADwin data acquisition systems are flexible, expandable and easy to program using a real-time development tool. Users connect the ADwin system to the process control system via its analog and digital inputs or via serial interface and bus systems. It's equally simple to transfer machine and process characteristics over to the device. Via Ethernet and a graphical user interface, the current machine state can be visualized on various PCs on the company network.

By integrating real-time data visualization into your production process, you'll have the data to see how any given operation conditions are impacting your equipment's characteristics. This setup also gives you a convenient way to instantly judge your compliance with specific process values (temperature, current/voltage, etc.).

Conclusion

Condition monitoring, i.e. — predictive maintenance — is a detailed but rewarding method to help prevent process downtime in your factory or plant. By closely monitoring your operation-critical machinery and providing process oversight, data acquisition systems can aid your company's long-term stability and ROI. **PTE**

For more information

CAS DataLoggers Inc.
8437 Mayfield Rd Unit 104
Chesterland, OH 44026
Phone: (440) 729-2570
Toll-Free: (800) 956-4437
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Finite Element Method Based Analysis of Planetary Gear Systems Considering Backlash and Manufacturing Deviations

A. Mihailidis, G. Korbetis, N. Drivakos and I. Nerantzis

The load carrying capacity of gear transmissions depends strongly on design, material and operation conditions. Modern analysis methods, e.g. — finite element analysis (FEA) — consider the above parameters with more or less sufficient accuracy. Yet it remains an ongoing challenge to account for backlash and manufacturing errors, despite a definite need to do so. There are in fact several difficulties to overcome; first, the contact footprints as well as backlash and errors are some orders of magnitude smaller than the dimensions of the gears. Therefore an extremely fine mesh is required. On the other hand, the total number of degrees of freedom (DOFs) should be kept as small as possible to keep the computational effort manageable. Less stressed areas should be coarsely meshed, while the transition must be as smooth as possible. Moreover, in order to generate and mesh three-dimensional tooth flanks taking into consideration the abovementioned geometrical deviations is extremely time consuming.

In this paper new techniques and tools are introduced, aiming to facilitate the modelling procedure. They include automatic generation of 3-D gear flanks and selective meshing. A simple planetary gear system featuring helical gears with backlash and manufacturing errors is used to demonstrate the effectiveness of the proposed procedure, since it features multiple contacts and floating members. Results shown include stress distribution and deformation, as well as load sharing under quasi-static conditions.

Planetary gear trains offer very high power density because of their internal power splitting. It is evident that manufacturing deviations have a strong impact on power distribution. Therefore simulations aiming at the prediction of the actual loading of real, non-ideal, planetary systems are very useful. A lot of research has been conducted in this field. Reference 1 contains an extensive literature review. Finite element analysis is, of course, one of the first available methods to be used. It should be considered that an adequate mesh must be generated to capture the influence of inaccuracies. This is quite challenging because of several reasons. For example, the gears themselves are quite complex and the deviations are some orders of magnitude smaller than the overall dimensions of the complete system. In a previous paper (Ref. 1), the influence of backlash and manufacturing errors of carrier and gears of a simple planetary system is demonstrated. Furthermore, the favorable impact of a floating, self-centering sun on the load distribution was shown. However, the model was 2-dimensional; this is an important drawback, as it restricts its application to straight spur gears. The current study advances one step further and introduces a 3-D model that makes possible the analysis of planetary systems consisting of helical gears.

Planetary Gear Train

In the current study a simple planetary gear system with helical gears is modeled (Fig. 1); it consists of a fixed ring gear mounted on the housing, a carrier with three equally spaced planets, and the sun. Two versions are studied; in the first, the sun rotates around a fixed axis or, put in another way, the input shaft is supported by two bearings; in the second version the input torque is transmitted to the sun gear by a double-articulated spline coupling. Therefore it is free to position itself between the planet gears. The planet gears are mounted on the pins by two roller bearings. The carrier is mounted in the housing also by two bearings. Torque

	Sun	Planets	Ring
Number of teeth z	13	24	–65
Addendum modification coefficient x	0.8	0.757	0.1017
Tip diameter d_a [mm]	28.65	16.85	67.6
Module m_n [mm]		1	
Helix angle β [degrees]		20	
Centre distance a [mm]		21	
Facewidth b [mm]		10	
Bottom clearance c_p [mm]		0.25	
Basic rack		DIN 867	

Figure 1 Gear data and simple planetary gear train with helical gears.

This paper was first presented at the International VDI Conference on Gears 2017, Garching/Munich [VDI-Berichte 2294, 2017, VDI Verlag GmbH] and is reprinted here with VDI approval.

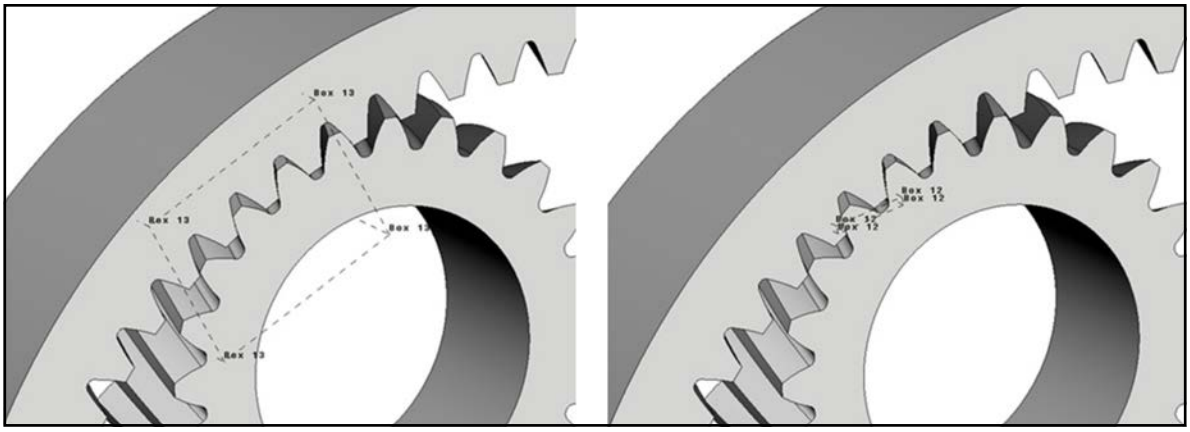

Figure 2 Refinement boxes at planet — ring gear mesh; (a) root fillet; (b) plane of action.

output is through the carrier. The carrier and the pins are considered very stiff compared to the gears, and therefore are not included in the model. All gears have the same facewidth and are made from case hardened steel; the gear data are included (Fig. 1).

Finite Element Model

At first, a geometrically perfect gear tooth profile is generated by rolling a rack of given geometry on the pitch circle of the gear. It is then simultaneously moved along the gear axis and rotated around it. In this way the helical flanks of a tooth are produced. The complete gear is then built as a circular pattern of the single tooth. Following this procedure, geometrically perfect gears are created. Backlash can be introduced to the gears by properly decreasing the profile shift.

The next task is to generate the mesh, which is done in three steps. In step 1 the 3-D surfaces of the gears are meshed using triangular shell (2-D) elements; in step 2, solid (tetrahedral) elements are automatically created in the volume defined by the previously created shell elements. The resulting mesh is unstructured. In the third step manufacturing deviations are imposed in the model.

The main problem that needs to be addressed is how to make the mesh as fine as possible at the most critical regions, while allowing it to be coarse at the rest of the model. Obviously, the most critical areas are in the vicinity of the contact line and the fillet between the flank and the root surface of the gears. At first approximation, one could consider making a fine mesh at the entire flank and fillet areas. But this approach would result in extremely high element numbers. Aiming at keeping the element number as low as possible — while maintaining the accuracy of the results — the fine mesh should be located near the instantaneous contact line and not over the entire active flank. Although it is possible to make this mesh manually, one should consider the effort and time needed. On one hand, even in simple planetary systems like the one considered in the current study, there are as many as 12 gear teeth contacting each other. On the other hand, to meet the requirements of a quasi-static analysis, many successive snapshots need to be generated and solved. Obviously, this process needs to be automated.

Models were created using the ANSA pre-processor's dedicated tools for automatic mesh generation ("Batch Mesh") in combination with the mesh refinement boxes ("BCBOX") (Ref. 2). Batch meshing makes it possible for the user to define both the meshing requirements and the quality criteria for every region of the model that should be automatically generated for every snapshot. The mesh refinement boxes are hexahedral boundaries defined by the user that enclose the regions, which must be extremely fine-meshed; in the current model these are: first, the contact lines, which are defined as the intersections of the active flanks and the plane of action of each mesh, and second, the fillet at the roots of the mating teeth. The decisive advantage of using these boxes is that they are fixed to the planet carrier and therefore they do not need to be repositioned when creating a new snapshot. Figure 2 shows the *BCBOX* of the plane of action of a planet — ring gear engagement. The final step is to introduce manufacturing deviations. In the current development stage, the pitch error is considered by modifying the tooth thickness in a way previously introduced (Ref. 1). The *ANSA* "morphing" tool is employed, thus allowing the introduction of pitch

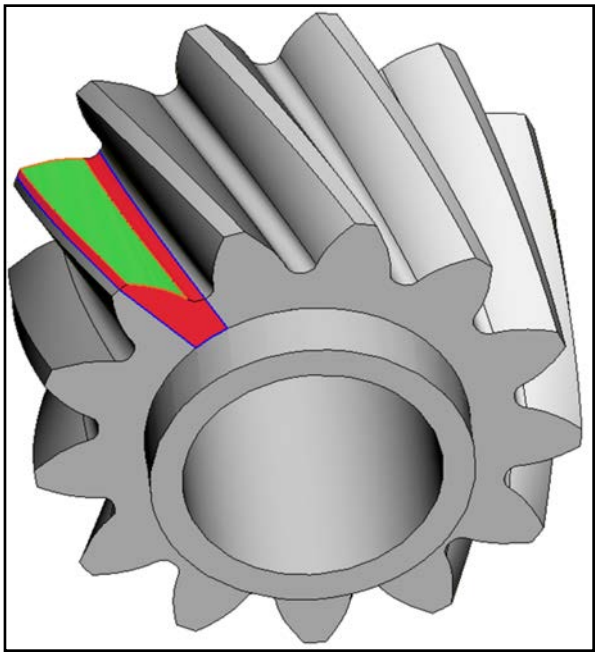

Figure 3 Modification of the tooth thickness by morphing. Only the active flank and the surrounding marked surface are affected, while the bounds are fixed.

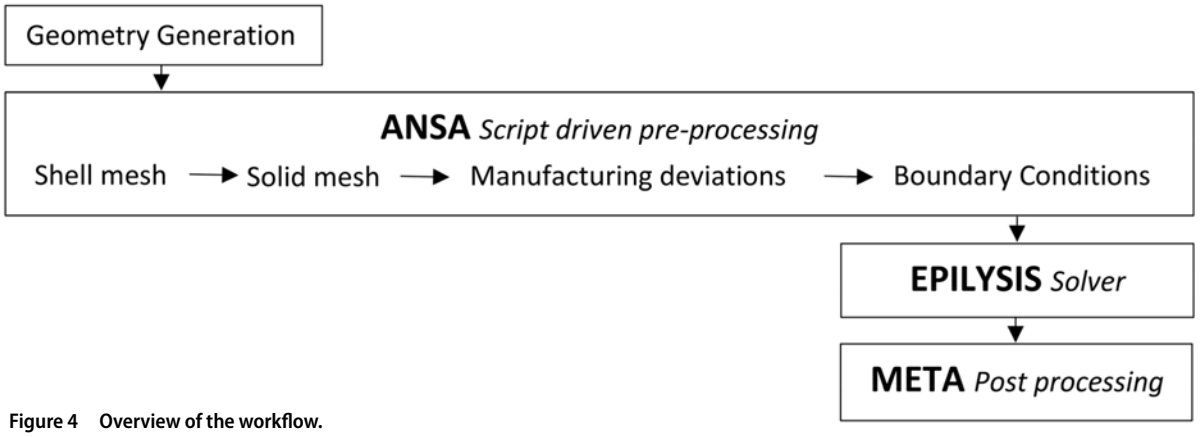

Figure 4 Overview of the workflow.

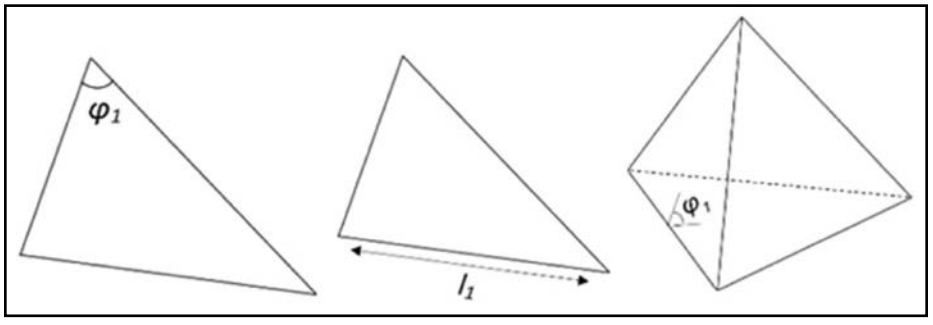

Figure 5 Mesh quality parameters.

error to the model (Fig. 3).

The third task is to apply the boundary conditions. Once the mesh has been automatically generated, contact pairs need to be defined. A contact pair includes all entities that might contact each other during the solution process. This step should also be automated because at every snapshot the entire mesh is regenerated and therefore the previously defined contact pairs are outdated. A custom script featuring the *ANSA* generic entity builder ("*GEB_SB*"), combined with the refinement boxes, is employed to define the contact pairs. In this way it is assumed that only the active flanks of the engaged gears may contact each other; contacts of other surfaces are excluded from the analysis. Since the model is quasi-static, the rotational speed is not considered. Therefore the planet carrier is assumed to be stationary. Torque is applied to the sun gear. Depending on the case solved, it is either allowed to rotate around the fixed planetary system axis or to rotate around its own axis and center itself between the planets. The planets are mounted on the carrier by rolling element bearings and are allowed only to rotate around the axis of their pins. Finally, the ring gear is fixed.

Solution Scheme and Results

Figure 4 shows an overview of the workflow. The entire analysis is carried out using the BETA CAE Systems suite, consisting of *ANSA* pre-processor, *EPILYSIS* solver and *META* post-processor. As mentioned above, quasi-static conditions are assumed.

To obtain a good quality mesh, target values for the minimum/maximum element angle φ_1, as well as for the maximum element length l_1, were set. Figure 5 shows the above quality parameters. For the entire model, φ_1 was limited in the range 45°–75°.

In the root fillet area, the target element length was set at 0.2 mm and the allowable range 0.1–2 mm. Along the contact line the target element length was set 0.08 mm and the allowable range 0.04–1.5 mm. In these areas the so-called "solids structural mesh algorithm" was applied, which resulted in

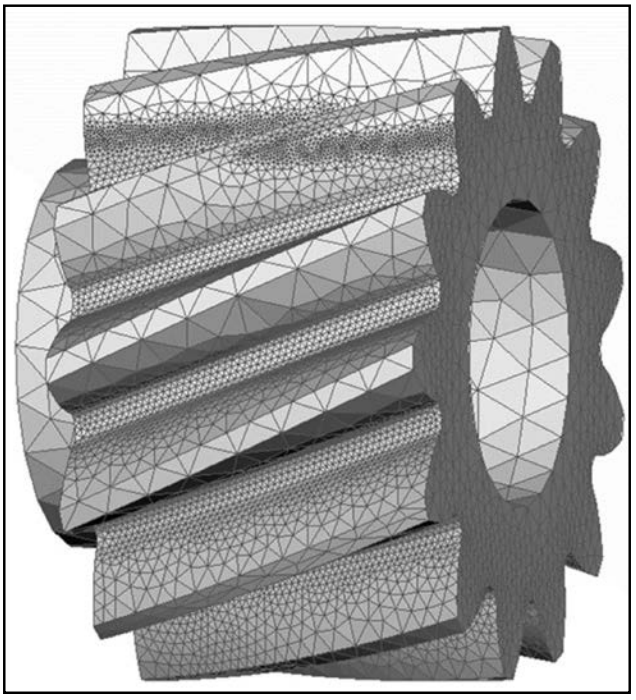

Figure 6 3-D FE mesh of the sun gear.

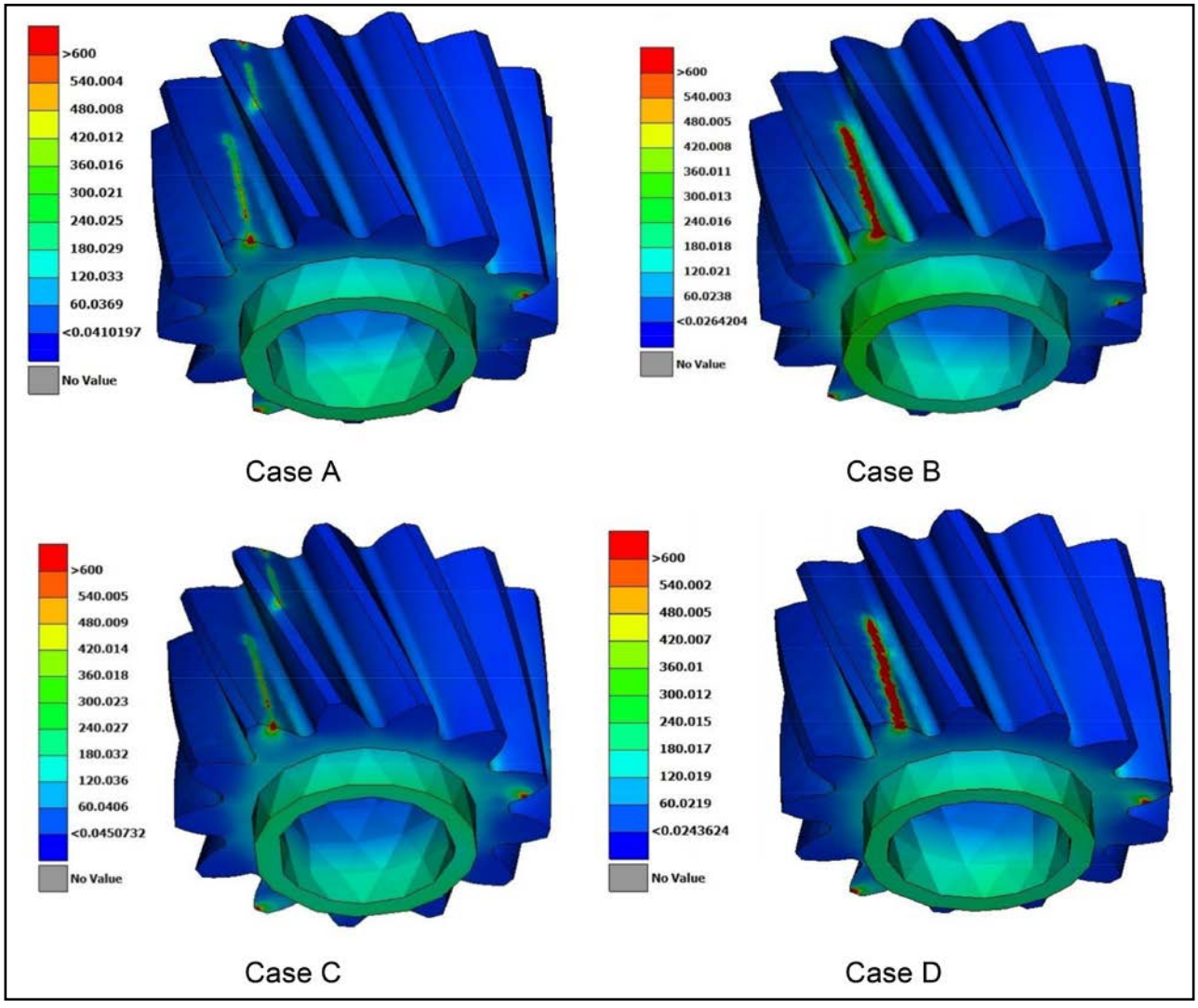

Figure 7 Resulting von Mises stress field of the above cases. The impact of the pitch error on the contact stress is obvious; the favorable effect of a free sun can be recognized at the fillet area.

a fine mesh of uniform density. In the remaining areas of the model, a special algorithm was implemented in order to generate a smooth yet fast transition from the fine to the coarse mesh. The growth rate was chosen 1.6. Figure 6 shows the 3-D FE model of the sun gear. It should be emphasized that the mesh in the unloaded areas is almost 20 times coarser than along the contact line. The following 4 cases were solved:

Case A: Geometrically perfect gears; sun gear allowed only to rotate around the axis of the planetary system.

Case B: Sun gear with 20-µm pitch error; sun gear allowed only to rotate as in case A.

Case C: Geometrically perfect gears, sun gear allowed to center itself between the planets. It can move as needed, meaning that its axis may reach an off-center and oblique position relative to the ring gear axis. Only movement in the axial direction is restricted. In real planetary gear systems, this model corresponds to a sun gear driven by a double-articulated joint.

Case D: Sun gear with 20-µm pitch error; sun gear floating as in case C.

In all cases the torque applied to the sun gear was 15 Nm, which results in approximately 1250 N/mm^2 contact stress.

Figure 7 shows the resulting von Mises stress field of the above cases; the impact of the pitch error on the contact stress is obvious. The favorable effect of a free sun can be recognized at the fillet area.

Table 1 Load sharing results

	Case A	Case B	Case C	Case D
Planet 1	0.9065	1.6993	0.9970	1.0011
Planet 2	0.9245	0.5439	1.0024	1.0017
Planet 3	1.1688	0.7566	1.0000	0.9993
Load mesh load factor K_γ, Overload	1.1688 +16.88 %	1.6993 +69.93 %	1.0024 +0.24 %	1.0017 +0.17 %

Load sharing is the most interesting result of the analysis; Table 1 shows the results obtained.

It should first be noticed that even in geometrically perfect planetary gear systems, the torque distribution is not uniform (case A). This should be attributed to the fact that the meshing stiffness varies along the line of action. Since the meshing points of the sun differ with each planet, it is evident that

differences in the load distribution will occur. When the sun can float (case C), torque is distributed almost uniformly. As expected, pitch errors have a strong impact on the load distribution (case B). Again, a self-aligning sun gear enhances significantly the torque distribution (case D). Figure 8 shows the deformation of the self-aligned sun in case D. It should be noticed that its axis is oblique relative to carrier axis.

Conclusions

A simple planetary gear train consisting of helical gears was analyzed in the current study using 3-D FE modeling.

The analysis was made possible by employing advanced meshing techniques, which helped to keep the DOFs manageable, as well as scripting, which automated the procedure — allowing easy generation of models for successive snapshots.

Results demonstrate the beneficial effect of a floating sun and the impact of manufacturing deviations.

Next steps of the research will include the analysis of a floating ring gear, as well as the impact of pin position errors. **PTE**

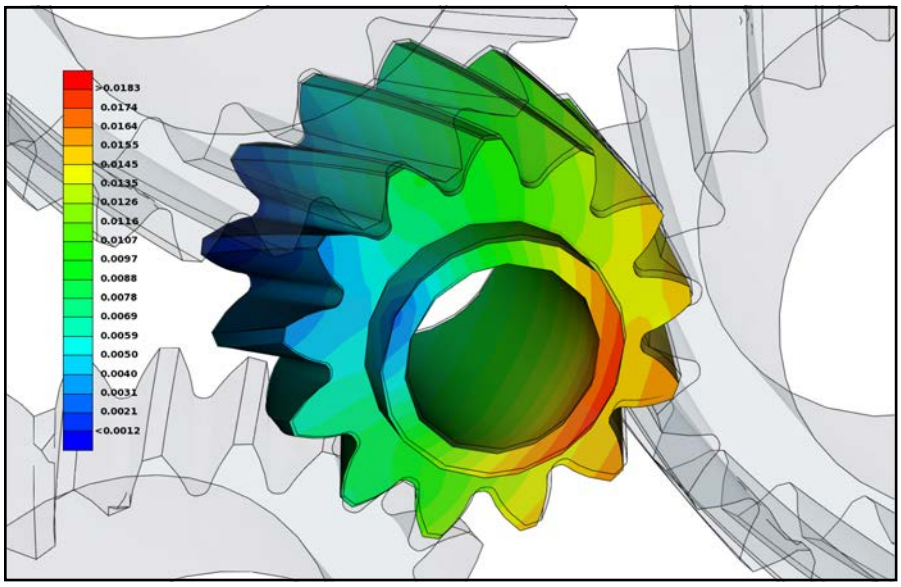

Figure 8 Deformation of the sun gear in case D (scale factor: X 20; non-deformed gears are shown in transparent grey).

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Athanassios Mihailidis is Professor and Director of the Laboratory of Machine Elements & Machine Design of the School of Mechanical Engineering of the Aristotle University of Thessaloniki. His research interests include machine elements, gears and power transmission systems, tribology and thermo-elastohydrodynamic lubrication, as well as automotive engineering. Mihailidis is a founding member of the Balkan Tribological Association as well as of the Balkan Association of Power Transmissions.

George Korbetis studied mechanical engineering at the Aristotle University of Thessaloniki. After working for several years in the machine design field, he joined in 2001 the BETA CAE's Customer Service Department. Korbetis is responsible for the morphing and optimization applications.

Nikolaos Drivakos, upon graduation from the School of Mechanical Engineering of the Aristotle University of Thessaloniki, worked as a Research Assistant in the Lab. of Machine Elements and Machine Design. He completed his Ph.D. thesis in 2006. Since then, Drivakos is a member of the Customer Service Department of BETA CAE, specializing in CAD input, meshing and assembly of models.

Ioannis Nerantzis worked as a research assistant in the Lab. of Machine Elements and Machine Design of the Aristotle University of Thessaloniki. After completing his Ph.D. Thesis in 2012, he became a member of the Customers Service Department of BETA CAE Systems. Nerantzis specializes in durability applications, including support for ABAQUS- related issues.

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Thrust Cone Bearings Provide Increased Efficiency for Helical Gear Units at Moderate Speed Levels

Indications for possible energy saving potential in an expanded field of application

Armin Lohrengel and Marcel Hess

Introduction

Thrust cone bearings are an elegant option to handle the axial forces generated by the torque transmission in helical-toothed gear stages. They have proven as an efficient and reliable bearing concept for integrally geared compressors but are nearly unknown in other fields of gearbox engineering. The presented investigations consider three aspects which appear relevant to extend the field of possible applications for thrust cones towards gearboxes constructed with roller bearings. Based on simulations and experiments design parameters were identified, which enable a significant reduction of the necessary velocity for full film lubrication. For a single stage test gearbox noticeable increases in efficiency were achieved by replacing tapered roller bearings with a combination of thrust cone and ball bearings, especially during partially loaded operation. The resistance to wear and the determination of limits for the bearable loads under mixed friction conditions for various thrust cone design configurations are investigated in a third test series. It appears that the few limit values known so far might be exceeded significantly for future applications.

Helical gears are a common solution to reduce noise and increase the transmittable torque in the construction of gearboxes. Unfortunately the pair of contact forces between the meshing tooth flanks is not perpendicular to the axis of rotation of the gear shafts, due to the helix angle. Transmitting torque between pinion and gear leads to an axial force component, which usually has to be transferred through the gears, the shafts and axial bearings into the housing of the gearbox (Fig. 1, left) or offset by the use of double-helical gears.

Thrust cone bearing concept. Figure 1 (right) presents an alternative-bearing concept, i.e. — the "thrust cone" bearing. Conical rims — denoted as thrust cones — are attached to

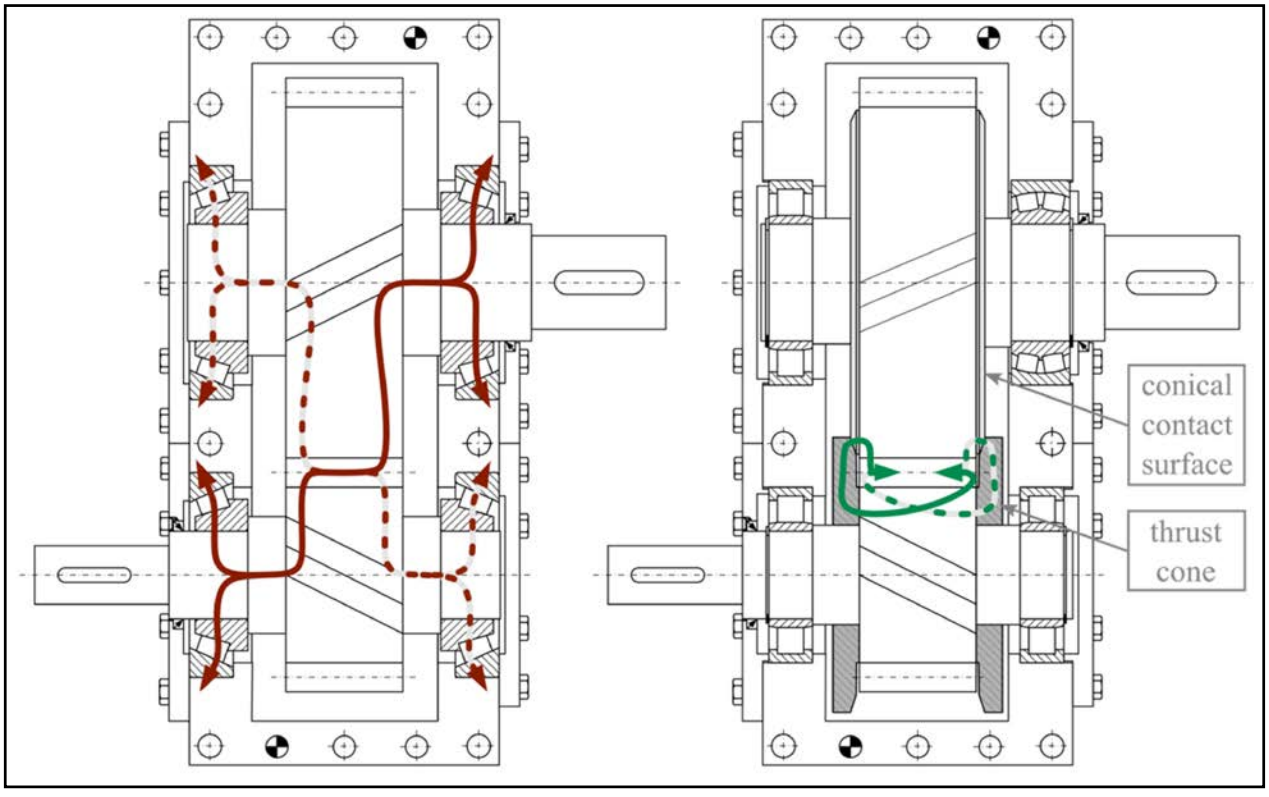

Figure 1 Axial force components in helical gear boxes: with conventional bearing concept (left) and thrust cone bearing setup (right) (Ref. 6).

This paper was first presented at the International VDI Conference on Gears 2017, Garching/Munich [VDI-Berichte 2294, 2017, VDI Verlag GmbH] and is reprinted here with VDI approval.

both sides of the pinion and flank the opposing wheel. Their conical shape and the contact surfaces ground to the sides of the wheel lead to a narrowing gap in the overlapping area. Lubrication fluid, sticking to the surfaces, is transferred into this gap and generates a hydrodynamic pressure film that separates thrust cones and the contact surfaces on the wheel. The axial force generated on the pinion tooth is transferred through the thrust cone and the fluid film onto the conical contact surface of the wheel; here it meets the axial force component created on the wheel's tooth. Since both force components obtain the same value — but with opposing directions — they "cancel" each other and no axial force is transferred to the shafts or the housing (Fig. 1, right). This load reduction enables a lighter construction for the machine components; the pinion shaft can be designed without an axial bearing, while the axial bearing on the wheel shaft operates only as positioning, i.e. — without load from the helical gear pair.

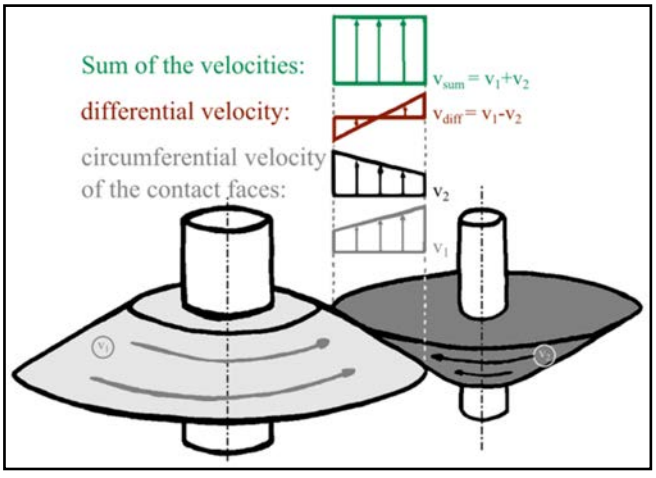

Figure 2 Contact velocities for two rotating cones: close to the pitch point favorable cinematic conditions for hydrodynamic lubrication occur (low differential velocity and high sum of surface velocities) (Ref. 6).

The frictional losses in sliding bearings rise proportionally to the square of the differential velocity between the contacting surfaces. In a typical axial sliding bearing, the differential velocity equals the circumferential velocity of the running surface. In a thrust cone bearing, a lower differential velocity occurs between the contacting surfaces since their contact region is located close to the pitch point of the gear pair (Fig. 2).

Aspects concerning an expanded field of application. Currently the main application for thrust cone bearings is in the field of integrally geared compressors (IGCs), which are characterized by a very high rotational speed on the pinion shaft (more than 10,000 rpm) and a nearly constant torque load at their point of operation. Since the first patent in 1924 (Ref. 2) the thrust cone bearing has proven to be an appropriate, alternative bearing concept for helical gear pairs. (Langer, Ref. 4) stated that a reduction of bearing-related frictional losses for thrust cone concepts to 10–20% compared to classical concepts based on tilting pads. Nevertheless, in special operational situations, such as emergency shutdown sequences, difficulties occur if the hydrodynamic carrying capacity of the lubricant film is not sufficient to separate the contact surfaces. Apart from IGCs the application of thrust cones in modern engineering is limited and nearly negligible.

To improve the reliability of thrust cone bearings and widen the field of possible applications, the following three main topics are within the scope of a research project currently conducted at the Institute for Mechanical Engineering (IMW):

Low-speed, full-film lubrication. Aiming for higher gearbox efficiency, it is a crucial condition that the friction losses in the thrust cone bearing are lower than the reduction of losses in the bearings of the housing. Since the friction coefficient under full-film lubrication is significantly lower than in the mixed-friction regime, the importance of the required reduction of the transition velocity becomes obvious.

Proof of efficiency. In ICGs, thrust cone bearings are usually combined with journal bearings where the axial load compensation supersedes one axial bearing. In gearboxes based on roller bearings, the benefit in efficiency is gained by a change of bearing types. Instead of tapered roller bearings, which are distinguished by their high axial load-carrying capacity but generate a relatively high-energy consumption, more efficient ball bearings might be used if axial loads are compensated by thrust cones. To prove that the suggested change in bearing types outweighs the additional friction in the thrust cone contact, a comparative examination of gearbox efficiency for both concepts is presented.

Determination of bearable load under mixed-friction conditions. Even though the transition velocity is reduced, there will remain situations (starting or breaking maneuvers, for example) with insufficient speed for full-film lubrication. A successful thrust cone design must safely withstand these mixed-friction situations during the product's life cycle. Unfortunately, at this writing there is as yet no available information on bearable loads for thrust cone bearings in open literature. To enable a wider use of thrust cone bearings as a resource-efficient machine element in gearboxes, a description of possible design influences on limiting load values under mixed-friction conditions is required.

Reduction of the Required Velocity for Full-Film Lubrication

Since full-film lubrication achieves efficient operation and nearly eliminates wear effects on the contacting surfaces, research activities were initially focused on influences on the transition velocity. In general the fluid film in a thrust cone bearing increases with the rotational speed and reduces with additional load — but for a certain operation point (combination of load and speed) various thrust cone designs generate different fluid film thicknesses. To predict the effect of design parameters on film thickness, a hydrodynamic fluid film simulation was developed. The algorithm — inspired by the work of (Barragan de Ling, Ref. 1) — allows solving the Reynolds differential equation for a thrust cone bearing, calculates the hydrodynamic pressure distribution, and determines the minimum gap size between the elastically deformed contact surfaces.

Figure 3 illustrates some design variations for thrust cone bearings, influencing the transition behavior. Besides

variations of cone angle and slip value (depending on the distance between pitch point and contact surface), macroscopic shape variations for the running surface geometry were within the scope of our examinations.

To validate the predictions made by simulation, experiments on the thrust cone test bench (Ref. 7) were carried out. For various thrust cone specimens, representing the shape designs used in the simulations earlier, the transition velocities at different load steps were determined.

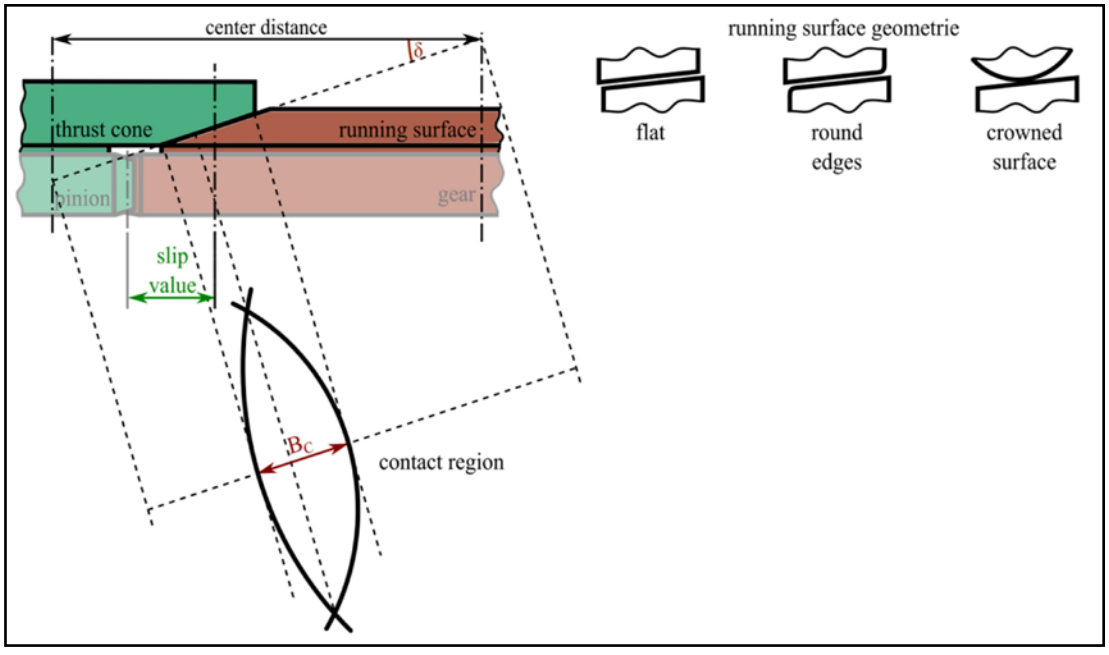

Figure 3 Design variations for thrust cone bearings (Ref. 6).

In the full-film lubrication region, contact surfaces are completely separated by the lubrication fluid. Due to its low conductivity, high electric resistance can be observed between the specimens. If the velocity is reduced the film thickness shrinks for a constant axial load. A drastic drop of the electrical resistance is notable when first metallic contact occurs between the peaks of the rough surfaces. The current combination of load and velocity is regarded as a transition point to the mixed-friction regime. Some of the determined transition points are plotted (Fig. 4) as an example of the experimental work. The data illustrates borderlines between mixed- friction and full lubrication for flat thrust cones with different inclination angles and slip values. Since low- transition velocities are desired for early full-film lubrications, optimal design configurations can be found in the lower region (Fig. 4). In accordance with simulations, low slip values and cone angles lead to an earlier separation of contact surfaces; nevertheless, a cone angle greater than zero is necessary to generate even the slightest hydrodynamic lubrication.

Figure 4 shows that a small geometric variation in the bearing design can have a great influence on transition behavior. The transition velocity for the best design (inclination angle: 0.5°; slippage: 10%) is about 50% lower than for the worst in the Fig. (inclination angle: 1.0°; slippage: 20%). Assuming constant acceleration during a starting maneuver, the distance to be run under mixed-friction conditions is reduced by the factor 4.

What's more, it becomes obvious that the transitions observed in the test occur within a speed range that is significantly lower than the operational velocities for thrust cone bearings in ICGs (> 100 m/s), and even relevant for gearboxes running with roller bearings.

Gearbox Efficiency in Dependency of the Bearing Concept

To investigate the thrust cones' ability to reduce friction losses in gearboxes based on roller bearings, a test gearbox (Fig. 5) has been set up. The gearbox is driven by an inverter-fed, asynchronous machine; a torque load can be applied by an adjustable mechanical break coupled to the output shaft. Input and output torque and the rotational speed are

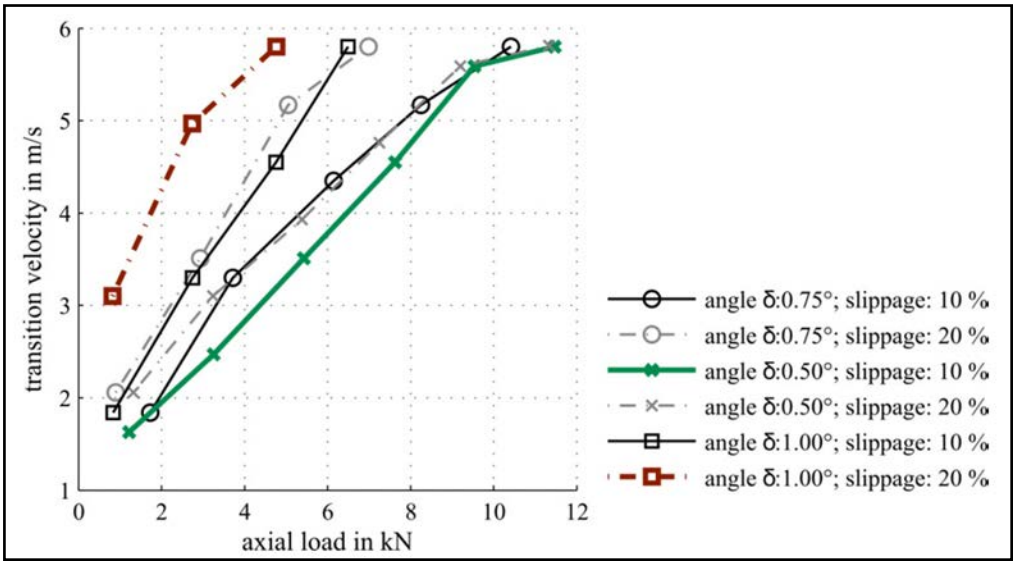

Figure 4 "Border lines" for the transition between mixed friction and full film lubrication for different flat thrust cones based on the experimental data.

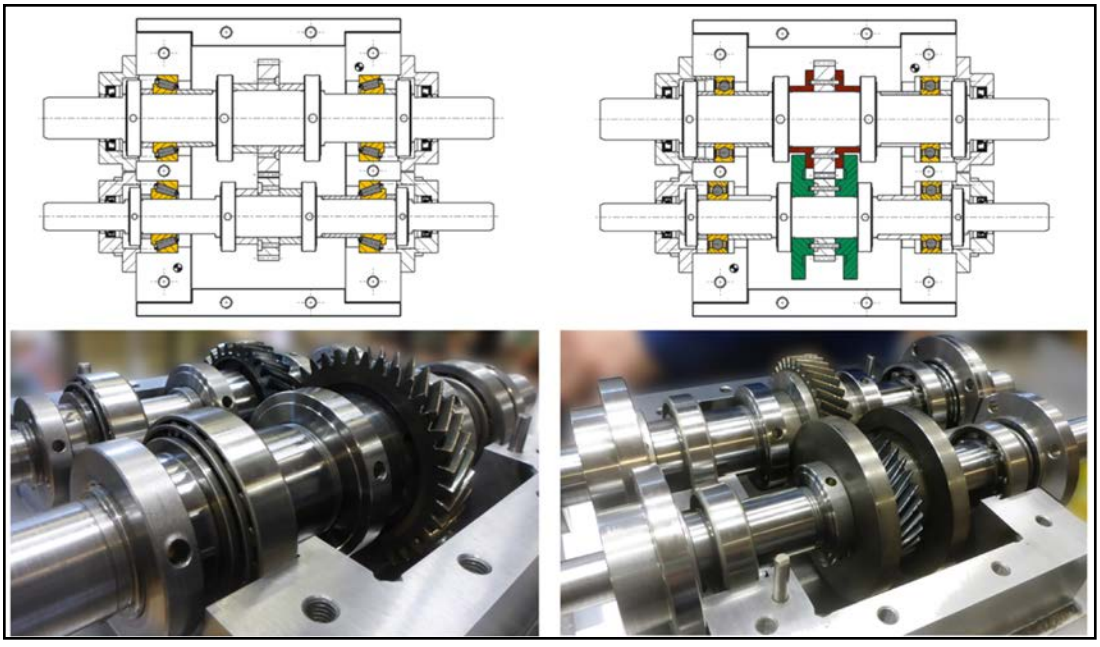

Figure 5 Test gearbox — equipable with tapered roller bearings (left side) or a combination of thrust cone and ball bearings (right side) as concept drawings (top) and assembled (bottom) (Ref. 6).

recorded via measurement shafts with integrated rotary encoders. Both power input and output can be calculated from the captured data. The difference between input and output is regarded as system losses of the gearbox and the reciprocal quotient as its efficiency. The system losses are the sum of losses caused by several gearbox elements. To evaluate the influence of the bearing concept on the system losses, the gearbox can be equipped with either a set of tapered roller bearings in O-arrangement, or with a combination of thrust cone and ball bearings. All other components contributing to the system losses — gearing, seals, oil level, etc. — are kept constant during the tests.

By varying torque load and drive speed, characteristic efficiency maps were determined for both bearing concepts (Ref. 6). As an example of the results gained in the comparative tests, efficiency values derived from recorded data at several load levels for drive speeds of 1,200 rpm and 2,400 rpm are plotted over the power input (Fig. 6). Even though the recorded input power values are not exactly the same for both bearing concepts, a benefit of the thrust cone solution is clearly recognizable. Interestingly, the difference between the power losses of the two bearing concepts is hardly varying with the input power. That indicates a nearly load-independent loss mechanism being responsible for the gap between the compared power loss characteristics. Such a mechanism might be explained by drag losses in the bearings, which are highly dependent on the roller geometry and nearly independent from load.

For all configurations in Figure 6 we can see that the efficiency increases with the transmitted power, since load-independent friction components gain higher weight only in partially loaded operation regions. The highest differences between the bearing concepts occur for both velocities in the lower loaded region. Assuming that other loss mechanisms, e.g. — the friction in the tooth contact — raise with the load, the importance of the nearly static difference between the bearing concepts due to the drag losses is shrinking. Nevertheless the use of thrust cone bearings leads to an average rise in efficiency for the plotted graphs of three to four percent; in the partially loaded regions ascents of about seven percent can be observed.

Bearable Load Under Mixed-Friction Conditions

Despite the achieved reduction of the transition velocity, there remains a speed range in which mixed friction occurs. A functional gearbox design demands thrust cone bearings that reliably endure the estimated mixed -friction phases in the product's life cycle.

Since, as mentioned, the availability of data on acceptable loads for thrust cone bearings in open literature is limited, a

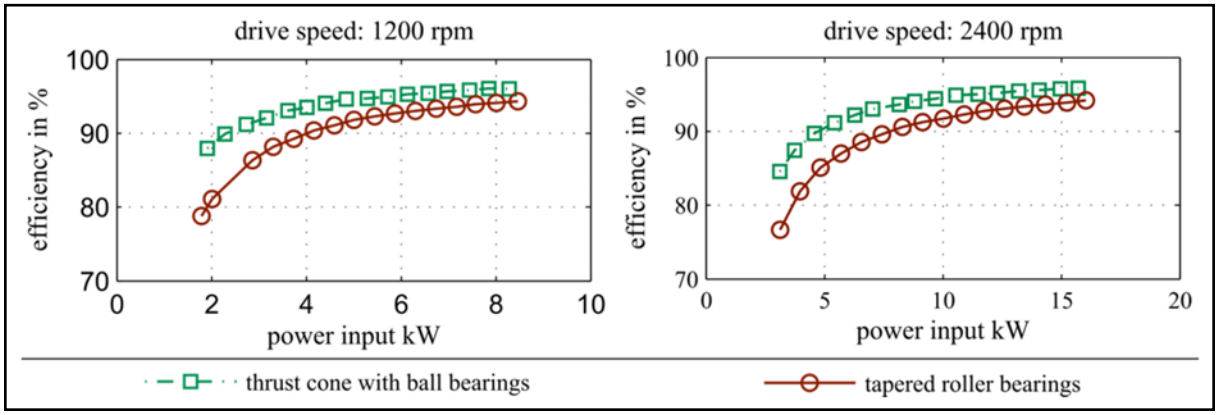

Figure 6 Comparison of the efficiency for a gearbox with tapered roller bearings and a gearbox with a combination of thrust cones and ball.

second test series shall provide further insight in bearable loads and influencing parameters. The tests, conducted as well on the thrust cone test bench, are carried out with a constant rotational velocity that belongs to the mixed-friction speed range for all specimens in the transition velocity tests. Starting with a minimum load of 2 kN, the axial force applied to the probes is raised every 50,000 turns by 2 kN until the destruction of the running surfaces is detected or the surfaces withstand the maximum load of 100 kN and passed 2.5 million turns. During the tests cone angle, slip value and contact width are varied for specimens made of 30CrNiMo8 and 34CrMo4. Nitriding of the running surfaces is another parameter in the tests. A high increase of axial accelerations or torque values indicates the surface destruction. To prevent fluid damages the temperature on the contact surface is monitored; if it reaches a critical value, the tests are interrupted for cooling; high temperature-time gradients might indicate a surface destruction as well.

Even though the test series is not yet finished, first observations are nevertheless available. Most of the tested surfaces did not pass the full test cycle without failure. Table 1 presents the maximum load reached in the experiments for 16 specimens arranged as fractional factorial design. Additionally, the equivalent Hertzian pressure is calculated for each test.

The equivalent Hertzian pressure is a common tool for the dimensioning of thrust cone bearings (Refs. 3 and 5). Therefore the flat, conical running surfaces are assumed to be a Hertzian contact of two parallel cylinders with a length that equals the contact width between the thrust cone and the surface on the wheel. The radii of the cylinders are the perpendicular distance between the center of the contact zone and the rotation axis of their shafts.

The only design value for the bearable load of flat thrust cones known from open literature is 50 MPa (Ref. 3). The 16 tests presented clearly exceeded that threshold. Only in one case surface failure occurred at a pressure below 80 MPa; in all other cases the surfaces withstood a load higher than 150 MPa and failed at values three to six times higher than the value known from literature. In four cases the specimen endured the maximum test load of 100 kN without failure. To illustrate the influence of the design parameters under investigation, a main effects diagram is presented (Fig. 7).

As expected, low slippage values and the nitriding of running surfaces have a clear, positive effect on the bearable equivalent pressure. The choice of material and the contact width seem to be less important for the contact pressure. Nevertheless the contact width is clearly connected to the absolute bearable load values, which can be seen by comparing the average axial force for both contact sizes (62.0 kN for the 10 mm tracks, and 87.5 kN for the 15 mm surfaces). The strongest effect on the equivalent pressure can be seen for the inclination angle. Interestingly, this parameter has a different emphasis than in the transition velocity tests described previously. While lower inclination angles appeared suitable for early full lubrication, contact with stronger inclined surfaces resists higher loads under mixed-friction conditions. A possible explanation for the observed effect could be seen in deformations induced by the high loads during the mixed-friction test. If the conical surfaces are flattened by the deformation, specimens with initially high inclination angles are hydrodynamically optimized, while the inclination disappears, or at least drops, under a critical minimum for specimens that already started with low angles. Further insight in interactions between the regarded parameters and a regression for their influence on the bearable loads shall be derived when enough tests are conducted to allow a full fractional analysis.

(Editor's Note: This paper was written in the Spring of 2017. Since that time, the series of tests referred to in the "Bearable Load Under Mixed-Friction Conditions section beginning on page 55 has been completed and results are now available at https://doi.org/10.21268/20170718-120141.)

It must be stated that the values gained thus far should be regarded as a design aid while considering possible extreme load situations for the contact. A permanent bearing operation under the tested conditions does not appear reasonable, since the higher losses in a thrust cone bearing under mixed-friction will not in any way contribute to an efficient gearbox. For "normal" load situations the bearing should be designed for

Table 1 Excerpt of experimentally determined failure loads under mixed friction condition for various thrust cone designs

parameters					results	
surface angle in °	track width in mm	material -	slippage in %	nitride surface -	max. axial force in kN	equivalent HERTZ'ian pressure in MPa
0,5	10	34CrMo4	5	yes	82	226.5
0,5	10	34CrMo4	10	no	40	158.2
0,5	10	30CrNiMo8	5	no	10	79.1
0,5	10	30CrNiMo8	10	yes	70	209.2
0,5	15	34CrMo4	5	no	92	195.9
0,5	15	34CrMo4	10	yes	60	158.2
0,5	15	30CrNiMo8	5	yes	100 (no failure)	204.2
0,5	15	30CrNiMo8	10	no	78	180.3
1,0	10	34CrMo4	5	no	76	308.3
1,0	10	34CrMo4	10	yes	64	282.9
1,0	10	30CrNiMo8	5	yes	100 (no failure)	353.7
1,0	10	30CrNiMo8	10	no	54	259.9
1,0	15	34CrMo4	5	yes	100 (no failure)	288.8
1,0	15	34CrMo4	10	no	70	241.6
1,0	15	30CrNiMo8	5	no	100	288.8
1,0	15	30CrNiMo8	10	yes	100 (no failure)	288.8

averaged equivalent HERTZ'ian pressure values:

parameter -	lower level -	averaged value in MPa	higher level -	averaged value in MPa
surface angle:	0,5°	176.4	1,0°	289.1
track width:	10 mm	234.7	15 mm	230.8
material:	34CrMo4	232.5	30CrNiMo8	233.0
slippage:	5 %	243.1	10 %	222.4
nitride:	no	214.0	yes	251.5

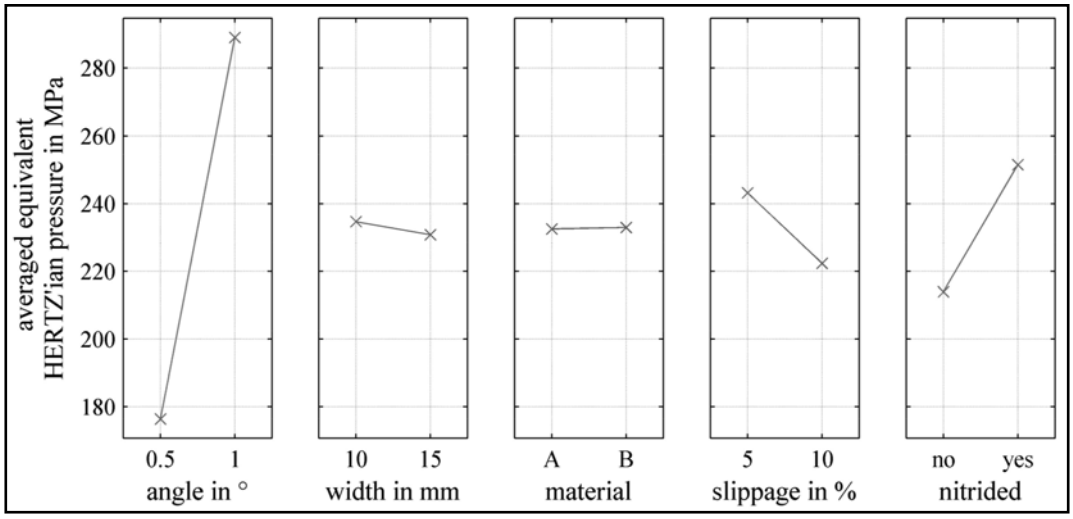

Figure 7 **Main effects on the bearable equivalent Hertzian pressure under mixed friction conditions based on data given in Table 1 for fractional factorial design of experiments. Note on material abbreviation: A stands for 34CrMo4; B represents 30CrNiMo8.**

full-film lubrication by using numerical simulations. The presented tests reveal a remarkable load reserve for thrust cone bearings running temporarily under mixed-friction conditions — which is important in enabling a reliable application design.

Conclusions

The conducted experiments on the transition behavior to full lubrication have shown that the transition velocity is highly influenced by geometrical parameters. For flat running surfaces, low inclination angles, and low slippage support early full lubrication.

Comparative efficiency tests on a gearbox revealed a remarkable energy-saving potential for lower-load situations by replacing tapered roller bearings with a combination of thrust cone and roller bearings.

Under mixed-friction conditions thrust cone specimens withstood higher loads than expected by common design values. Nitriding of contacting surfaces and low slippage are suitable to increase the bearable equivalent Hertzian pressure. The surface inclination angle generates an interesting influence, since significant higher load values could be reached with greater angles under mixed-friction conditions. This observation makes a constant value for the equivalent Hertzian pressure, as proposed by literature to date, a doubtable design base. The presented mixed-friction experiments reveal a need for geometry-dependent limits. Furthermore, since lower angles encourage full-film lubrication, an optimization problem results for the design engineer, which might be solved by numerical simulations.

(For more details on the work presented in this article, particularly those pertaining to numerical simulations, can be go to: Hess, Marcel, 2018. Einsatz von Druckkämmen zur Effizienzsteigerung von schrägverzahnten Getrieben. Dissertation TU-Clausthal. ISBN 978-3-86948-624-6.)

Acknowledgements. *Financial support from the German Research Foundation (DFG) Priority Programme 1551Resource Efficient Constructional Elements is gratefully acknowledged.* **PTE**

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Dr.- Ing. Marcel Hess studied (2004–2011) mechanical engineering at the Clausthal University of Technology. In 2017 his doctorate degree was awarded by the Faculty of Mathematics/Computer Science and Mechanical Engineering of the Clausthal University of Technology. He worked (2011–2017) as scientific assistant at the Fritz-Süchting-Institute for Mechanical Engineering of the Clausthal University of Technology. Beginning this year (2018), Hess has worked as management assistant at SincoTec Test Systems GmbH, Clausthal.

Prof. Dr.-Ing. Armin Lohrengel studied mechanical engineering at the Clausthal University of Technology and RWTH Aachen University. Until 1999 he was scientific assistant at the chair of machinenelements of RWTH Aachen University. The promotion took place over the life-oriented dimensioning of clutches. From 1999 he was head of machine development at Paul Hartmann AG, Heidenheim. Since 2007 Lohrengel has been a university professor (Department of Mechanical Engineering and Design) and director of the Fritz-Süchting-Institute for Mechanical Engineering of the Clausthal University of Technology.

Dana

UNVEILS CONSTRUCTION, OFF-HIGHWAY MARKET STRATEGY

Dana Incorporated recently revealed new technologies in support of the rapidly evolving development of hybrid- and electric-powered construction and other off-highway vehicles at Intermat, the international exhibition for the civil engineering and structural building industries.

Consistent with its approach in other vehicle markets, Dana's strategy enables original-equipment manufacturers to accelerate their hybrid and electric vehicle development programs. It starts with a modular approach that combines Spicer Electrified hybrid and electric drivetrain solutions into current vehicle architectures with internal-combustion engines.

From this foundation, Dana further supports the evolution of vehicle mobility through a continuum of innovations that provides a smooth transition to fully integrated electric-drive technologies optimized within a single package to maximize performance.

At Intermat, Dana showcased its technological capabilities through a hybrid-electric telescopic boom lift equipped with more than 30 Spicer drivetrain and Brevini motion products. This mid-sized aerial work platform performed a series of typical driving and working maneuvers to illustrate how Dana serves as a Tier One contributor to the performance, efficiency, safety, intelligence, and systems integration of hybrid and electric vehicles.

In addition to aerial work platforms, Dana is actively developing hybrid and electric drive solutions for numerous wheeled and tracked vehicles in the construction, mining, material-handling, and aircraft ground support industries.

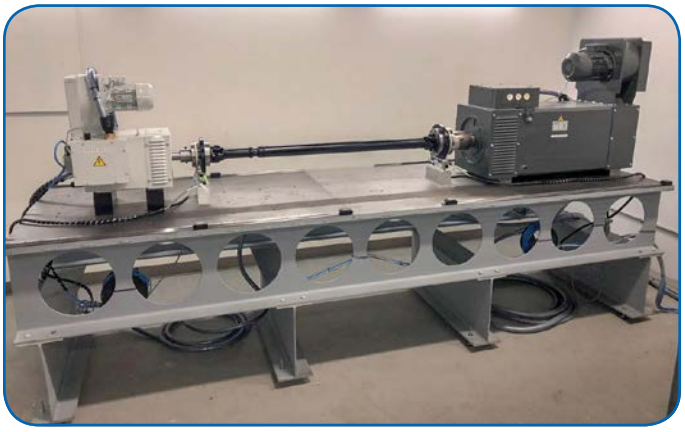
"Tightening emissions requirements, increasingly strict local government regulations, and accelerating market demand for vehicles that promote sustainability are driving the development of hybrid and electrified technologies," said Aziz Aghili, president of Dana Off-Highway Drive and Motion Technologies. "We are demonstrating our unmatched commitment as a top-tier supplier to OEMs by delivering solutions today while also developing next-generation innovations for the vehicles of tomorrow." (*www.dana.com*)

Drive System Design Inc.

OPENS TEST FACILITY ON IMPROVING DRIVELINE EFFICIENCY

A new test facility has been developed in Michigan to help vehicle manufacturers and their suppliers increase the efficiency of vehicle drivelines. Developed and operated by Drive System Design Inc., the North American subsidiary of U.K.-based driveline engineering consultancy Drive System Design, the facility will help manufacturers lower emissions, improve fuel economy and increase electric vehicle range.

"The current focus on real-world emissions means the efficiency challenge has suddenly become substantially more critical, yet parasitic and other losses are still draining energy unnecessarily," says Jon Brentnall, president DSD Inc. "Our parent company has developed what we believe is Europe's most advanced, commercially-available development center for vehicle driveline efficiency, with many test systems designed in-house to ensure that areas that have not previously received sufficient attention can now be investigated. It is our intention to build similar test capability tailored to the North American market."



The facility will initially house a loaded transmission efficiency test rig and will be developed throughout the year to finally include three pieces of driveline test equipment. The current rig, which is fully operational, is suitable for all transmission types, including engine accessory drives, such as supercharger gearboxes. It will largely be used for transmission efficiency testing and the data produced will also ensure that transmission efficiency math models produced in-house are well correlated.

Further expansion throughout the year will include a hydraulic test stand for hydraulic valve body development and a tilt rig, which provides enhanced lubrication flow analysis capability. "This will require a larger facility in the area, which we are already investigating," says Brentnall. "We are delighted to be offering this opportunity for the automotive industry in North America, but also for aspiring engineers looking for their next challenge – the initial expansion has already generated nine engineering vacancies."

The facility's first project is the test and development of a full parallel hybrid transmission for a front-wheel drive application for a North American vehicle manufacturer.

The new facility will also include extensive customer

accessibility, allowing DSD's engineers to work closely with its customers throughout design, development and validation programs. "Our consultant engineers in Europe found that they were able to produce designs that theoretically provided significant, low cost improvements in efficiency, but that the test facilities were not available to focus development attention in the appropriate areas," Brentnall explains. "The answer was to develop their own test systems, designed specifically for this increasingly important area of driveline engineering. With the accelerating trend to electrification, the test center is also designed for mild and full hybrid drivelines and full electric drivelines." (*www.drivesystemdesign.com*)

Forest City Gear

ADDS DIRECTOR OF SALES

Forest City Gear has hired Erik J. Spurling as director of sales to oversee the activities of the company's network of direct and independent sales representatives nationwide, and to lead sales strategies that meet the growing demands of a wide and diverse customer base throughout the world's gear-making industries.

Spurling brings a wealth of sales and marketing experience and a deep familiarity with all facets of inside and outside sales and customer service processes, along with a strong background in manufacturing. This background, combined with his extensive sales and marketing leadership skills, made him an ideal candidate for the new position, says Wendy Young. "Manufacturing the world's best gears has always been the company's focus – Erik will help to elevate our sales efforts to that same level," says Young. "Our sales force, and the customers they serve, will benefit greatly from new strategies and methodologies that make the sales process faster and more efficient." (*forestcitygear.com*)

Schaeffler

CELEBRATES 75TH YEARS OF MANUFACTURING IN CONNECTICUT

The Schaeffler Group celebrated the 75th anniversary of its Danbury manufacturing operations located in Connecticut. In just the past 15 years, the global manufacturer of precision components and systems for the automotive, industrial and aerospace sectors has invested over $55 million in its Connecticut operations.

Georg F. W. Schaeffler, family shareholder and chairman of the supervisory board of Schaeffler AG, as well as members of Schaeffler's global and regional management boards were joined at the festive event by numerous state and local dignitaries, including Connecticut Governor Dannel Malloy and Danbury Mayor Mark Boughton.

Founded in Danbury in 1942, Barden started out as a

manufacturer dedicated to the production and inspection of miniature and instrument-precision ball bearings for military applications. Approximately 17 years ago, the Barden brand and the Danbury facility became part of the Schaeffler Group, and today the site is known for producing super-precision bearings with exotic finishes and surface treatments for sophisticated aerospace applications. "The high-precision products that are made right here in Danbury are crucial to Schaeffler's success in the U.S. and around the world," said Dr. Stefan Spindler, CEO of Schaeffler's Industrial division. "Nearly eight decades of experience as a full-service supplier of super-precision bearings have made the Barden brand an indispensable anchor of Schaeffler Aerospace within our Industrial division."

Headquartered in Fort Mill, SC, Schaeffler Group USA Inc. has approximately 6,000 employees working at facilities spread throughout South Carolina, Ohio, Missouri, Michigan and, of course, Connecticut. (*www.schaeffler.com*)

Lafert North America

APPOINTS INSIDE SALES TEAM

Lafert North America, a manufacturer of metric AC Motors, metric gearboxes and coolant pumps, is pleased to announce the appointment of Joel Fernandes to the role of sales representative. Fernandes brings nine years of sales experience to Lafert with time spent in the construction and power distribution industry. A graduate of the University of Toronto, Fernandes brings the ability to problem solve and provide the support required to meet industry needs.

They are also pleased to announce the appointment of Jesse Sagoo to the role of sales representative, bringing 12 years of technical sales in the power distribution market segment. Sagoo holds an electrical engineering technology designation from Humber College; he uses this training and experience to build customer relations and deliver positive value. (*www.lafertna.com*)

GE and SEW Eurodrive

JOIN TO SELL CONTROLLERS AND DRIVE-BASED AUTOMATION PRODUCTS

Customers of GE Power's Automation and Controls business and SEW-Eurodrive will soon be able to benefit from each other's broad motion control and automation portfolios as the companies sell each other's products around the world. For customers, this means working with a single company to fulfill essential automation requirements.

GE and SEW-Eurodrive plan to provide complimentary solutions for drive and controller-based motion control solutions for discrete and process applications. These solutions can be used in applications including machine control, manufacturing, and a variety of infrastructure verticals.

"This collaboration marries our rich set of industrial control and computer products with the strong set of drive automation products from SEW-Eurodrive," said Rob McKeel, chief marketing officer for GE Power and CEO of GE's Automation and Controls business. "For our customers, this means easier and greater access to a wide range of products and automation solutions."

GE Power's Automation & Controls business recently launched the Industrial Internet Control System (IICS) combining both control and connectivity into a single device aimed at bringing traditional controls into the digital era. For machine builders looking to provide a new level of support services to their end customers, this IIOT infrastructure provides instant access to the health and quality of their equipment from anywhere in the world.

SEW-Eurodrive's robust portfolio, from standard- and servo-gearmotors and heavy industrial gear units to electronic drives, software, and complete drive-based automation systems, are based on modular components that can be assembled in millions of different configurations. This enables every drive solution to be built to customer specifications. (*seweurodrive.com*)

(Left to right) Rob McKeel, GE Automation and Controls and Udo Aull, SEW-Eurodrive.

June 23–26—EASA 2018 Milwaukee, Wisconsin. The Electrical Apparatus Service Association, Inc. (EASA) is an international trade organization of over 1,800 electromechanical sales and service firms in nearly 80 countries. Through its many engineering and educational programs, EASA provides members with a means of keeping up to date on materials, equipment, and state-of-the-art technology. The EASA 2018 convention features 23 education sessions, three general sessions, a three-day exhibition, two social events and more. Educational topics include root cause failure analysis, the interaction of pumps, motors and drives and motor replacement options. The new Product Theater offers the latest products and services of a select group of exhibitors. For more information, visit *www.easa.com/convention*.

June 26–28—Hydrovision International Charlotte, North Carolina. Join 3,000+ attendees and more than 320 exhibiting companies from around the world at the largest worldwide gathering of hydro professionals. Hydrovision International provides a week of informative hydropower focused meetings including perspectives on the role of hydropower and issues affecting hydro resources. It will also help participants develop a vision to meet challenges and ensure the future sustainability of hydro. Presentation topics include sustainability, equipment, market trends, operations and maintenance, regulations, water management and more. The exhibit hall serves as a one-stop-shop for face-to-face business in the hydropower market. For more information, visit *www.hydroevent.com*.

June 27–28—Dritev 2018 Bonn, Germany. Increased CO_2 discussions, sustainable mobility and electrified drives: The automotive transmission world is changing. Why the understanding of the transmission changes, how it is to be understood as part of the overall powertrain and why cross-component know-how becomes more and more important are the subjects of the Dritev in Bonn. Attendees can expect more than 1,500 developers, around 100 international exhibitors and 80 specialist lectures on one of the world's largest networking platforms for powertrain and transmission development. Thus, Dritev seamlessly connects to the long-standing tradition of the VDI Congress "Drivetrain for Vehicles." For more information, visit *www.dritev.com*.

July 30–August 2—CAR Management Briefing Seminars Grand Traverse Resort, Traverse City, Michigan. Initiated by the University of Michigan in 1965, the first Center for Automotive Research Management Briefing Seminars (CAR MBS) hosted only 30 people. When the industry was at its highest number of employment, the event grew to attract more than 1,400 attendees annually from more than 35 states and 15 countries–representing industry, academia, media and the government. CAR MBS leads the industry in providing a context for auto industry stakeholders to discuss critical issues and emerging trends while fostering new industry relationships in daily networking sessions. Seminars include targeted sessions on manufacturing strategy, vehicle lightweighting, connected and automated vehicles, advanced powertrain, supply chain, sales forecasting, purchasing, talent and designing for technology. For more information, visit *www.cargroup.org*.

August 6–8—SAE Fundamentals of Modern Vehicle Transmissions Seminar Troy, Michigan. Starting with a look at the transmission's primary function -- to couple the engine to the driveline and provide torque ratios between the two -- this updated and expanded seminar covers the latest transmission systems designed to achieve the most efficient engine operation. Current designs, the components and subsystems used, their functional modes, how they operate, and the inter-relationships will be discussed. For more information, visit *www.sae.org/learn/content/99018/*.

August 14–16—ABMA Essential Concepts of Bearing Technology Oak Brook, Illinois. This course will give you an overview of the bearing industry as well as basic bearing types and applications. Knowledge of the key players, bearing types and terminology will ensure that everyone has a basic knowledge of the industry upon arrival. This course is specially designed for engineers and others with technical backgrounds that have limited exposure to bearings and need to adapt their technical training to bearings or seek an upgrade to their technical knowledge. The Essentials Course focuses on understanding basic tribology, bearing types and applications and explores the basic concepts around manufacturing methods, loads, lubrication and failure. For more information, visit *www.americanbearings.org/?page=EssentialsCourse*.

August 21–22—Fraunhofer CMI: Fundamentals of Gear and Transmission Technology Brookline, MA. In this course on gear and transmission technologies, basic properties of gears as machine elements, gear manufacturing technologies, methods for quality control, as well as testing and analysis of load carrying capacity and running behavior are presented. The course focuses on methods of interpretation, analysis and solving challenges in the design, manufacturing and application of gears. The course is meant for designers and manufacturing engineers working in gear and transmission technology, as well as for shop floor and department managers involved with the production and sale of gears and gearboxes. Fee is $1,495. For more information, visit *www.cmi.fraunhofer.com*.

September 11–14—AGMA Basic Training for Gear Manufacturing (Fall) Hilton Oak Lawn, Chicago, Illinois. Learn the fundamentals of gear manufacturing in this hands-on course. Gain an understanding of gearing and nomenclature, principles of inspection, gear manufacturing methods, and hobbing and shaping. Utilizing manual machines, attendees will develop a deeper breadth of perspective and understanding of the process and physics of making a gear as well as the ability to apply this knowledge in working with CNC equipment commonly in use. Although the Basic Course is designed primarily for newer employees with at least six months' experience in setup or machine operation, it has proved beneficial to quality control managers, sales representatives, management, and executives. Instructors include Dwight Smith, Peter Grossi and Allen Bird. For more information, visit *www.agma.org*.

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The Final Puzzle Piece

The PCCP, one of the largest pumping station systems in the world, is finally fully operational, marking the completion of the last piece of New Orleans' countermeasures against another Hurricane Katrina.

Alex Cannella, Associate Editor

Saying New Orleans has a flooding problem isn't exactly a page-turning assertion. While Hurricane Katrina may be one of the greatest natural disasters to hit U.S. soil, it's also far from the only time New Orleans has been flooded. Needless to say, past anti-flooding measures haven't been cutting it, and Hurricane Katrina was catastrophic enough to convince the city it needs a new solution for what they call 100-year level storm surges (in other words, storms so massive you only see them once every 100 years; the 99th percentile of how bad a storm can get).

So New Orleans is upgrading. Enter the Permanent Canal Closures & Pumps (PCCP), one of several projects that have been in development in response to the Hurricane Katrina disaster and now one of the largest pumps in the world. Designed and built by the U.S. Army Corps of Engineers, it's a monumental project that is designed to replace the Interim Closure Structures, which as their name might suggest, were a stopgap measure until the PCCP came online. It will, hopefully, put some of the city's flooding issues to rest.

To say the PCCP is the "largest pump in the world" might be a little disingenuous, however. That honor goes to a pair of pumps in the Netherlands built by Pentair Fairbanks Nijhuis. In reality, it's an entire system made up of 17 pumps across three critical locations, and combined, the whole system is orders of magnitude larger than most pump operations. By working in concert, they're all capable of moving a staggering 24,300 cubic feet per second (cfs) of water. Combined, they could fill an Olympic pool to capacity in under four seconds. The pumps themselves are pretty impressive individually, as well. Ten of them are each capable of pumping 1800 cfs on their own. And, fun little tidbit: Baldor Electric's gearmotors will be powering them.

The PCCP system is designed to take water from three canals, Orleans Avenue, London Avenue, and 17th Street — two of which, not coincidentally, had major levee breaches that formed the epicenter of the catastrophic flooding during Hurricane Katrina — and pump that water into Lake Pontchartrain. Along with the pumping stations, the PCCP also boasts gates capable of fending off a 16-foot storm surge from the lake that can open and close depending on the situation, meaning the canals can still drain naturally in normal weather conditions and the pumps won't have to work 24/7.

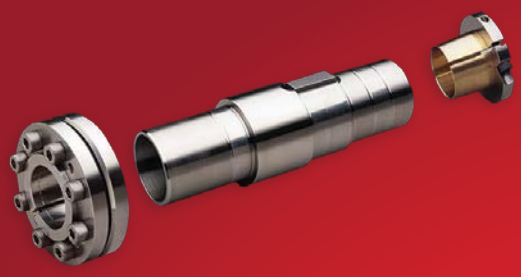
Almost as impressive as the pumping system itself were the cofferdams used to build them. Like the pumping system, they were also amongst the largest of their kind ever constructed, with the one used for the 17th Street canal pump station in particular measuring as large as a football field and 50 feet deep in some places.

The Army Corps of Engineers just finished work on the PCCP in May, and the project's completion was celebrated May 31. The PCCP is the last section of New Orleans' $14.5 billion project for building new defenses against flooding in response to Hurricane Katrina, the final puzzle piece in what Joe Hassinger, Southeast Louisiana Flood Protection Authority — East President, called "the most robust flood defense system" New Orleans' metro area has ever had during the May 31 ribbon-cutting ceremony.

Photo courtesy of U.S. Army Corps of Engineers

And while New Orleans' new defenses have yet to be put to the test by nature, the PCCP is a staggeringly massive system and a feat of engineering. Unlike the ICS before it, the PCCP has been designed to be a stable, lasting solution for New Orleans that will continue operation for a century to come. And if one of the biggest pumping station systems in the world can't solve New Orleans' flooding problem, we'll be hard-pressed to find something that can.

For more information:
U.S. Army Corps of Engineers
Phone: (504) 862-1495
www.mvn.usace.army.mil



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