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FEATURE ARTICLES

TECHNICAL ARTICLES

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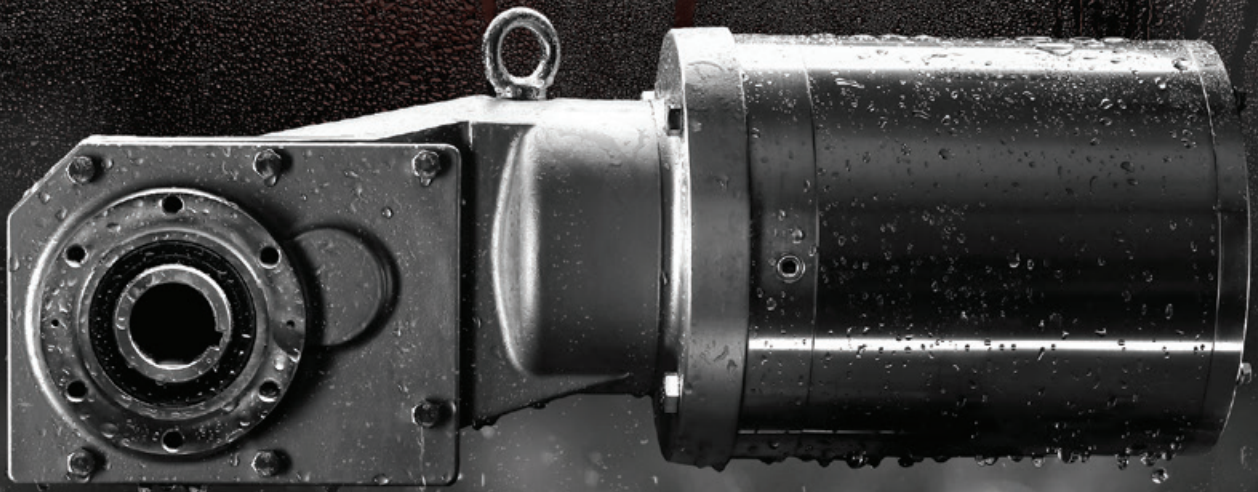
Power Transmission Engineering

VOL. 13, NO. 6

Cover image courtesy of NORD Gear.

Sumitomo Drive Technologies

WIN A GEARBOX AND PROTECT WHAT MATTERS



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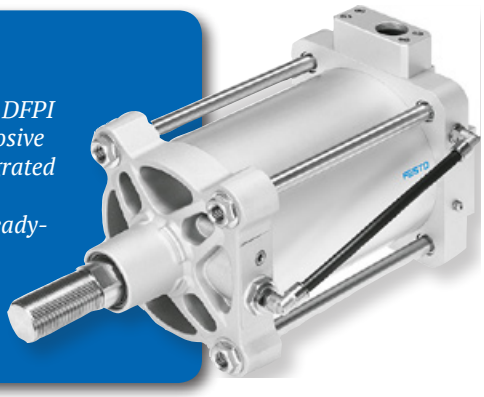
PTE Videos

Festo Linear Actuator

The robust and reliable linear actuator DFPI is an optimal choice for harsh and corrosive conditions. Now available with an integrated displacement encoder or even a fully integrated positioner. It's a compact, ready-to-install unit. See more here:

www.powertransmission.com/videos/Festo-Offers-Linear-Actuator-DFPI-/



Parker Hybrid Actuation System

Parker's new HAS 500 Hybrid Actuation System solution leverages electromechanical concepts but with a hydraulic actuator, which delivers three times more power density than electric cylinders. The HAS 500 offers energy efficiency, plug and play simplification and maintenance free operations for 8,000 hours or more. The HAS 500 is available in 2" to 8" bore sizes, for industrial and mobile applications. Learn more here:

www.powertransmission.com/videos/Parker-Hybrid-Actuation-System-/

Editor's Choice

Considerations for Choosing the Correct Rolling Element Bearing Characteristics

Daily experience in application engineering has proven that the selection of the correct bearing type can be successfully achieved by customers based on the documentation and tools provided by the bearing manufacturer and using comparable applications as a guideline. Learn more from NKE Bearings here:

www.powertransmission.com/blog/considerations-for-choosing-the-correct-rolling-element-bearing-characteristics/

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Randy Stott, Managing Editor

Planning Like Crazy

Putting together a magazine like this one takes a lot of planning. We begin the process for each issue months in advance, holding meetings, talking with potential contributors, identifying good technical content, interviewing sources, writing, editing and so on.

Around this time each year we map out a master plan we call our editorial calendar. We've just completed the 2020 calendar, and there are so many topics, it might be describe as a little ambitious. In fact, some members of my staff probably think I'm crazy.

But you don't get to be the best magazine on power transmission by sitting still. So, every issue, we'll continue talking about bearings, gears, gear drives and electric motors, just like we always have. But we're also planning to cover all the other related components throughout the year, as often as we can. Our goal is to continue bringing you the best information from the suppliers of mechanical power transmission components, so you know how to choose them, design them into your machinery, use them and maintain them.

In addition to talking about specific components, we're also planning detailed coverage about how they're used in key industries — construction & agricultural equipment, automotive, aerospace, oil & gas, food & beverage, power generation & energy, packaging & material handling. These are the industries most of you work in or serve. So our plan is to talk about them — a lot.

We're committing to more than we ever have, and as I said at the start, it takes a lot of planning. More importantly, it's going to take some help, and that's where you come in.

We believe many of you have stories to tell. We'd like to share those stories. If you or your company has done something relating to power transmission engineering that's cool or innovative or just plain smart, we want to tell the story.

We're looking for lots of different types of articles: application stories (case studies); feature articles; technical articles; Voices; Back-to-Basics; Product News; Industry News; Events; Power Play. Don't be shy if you have an idea. Our editors are pretty friendly and helpful.

We're using our 2020 editorial calendar to plan the next year. We hope that you'll use it, too, to plan how you can be a part of the story. Pick a topic (or two or three) where you think you can contribute, and then send me an e-mail to get the conversation started (*wrs@powertransmission.com*).

2020 EDITORIAL CALENDAR

ISSUE	FOCUS	EVERY ISSUE	FEATURED TOPICS	PRODUCT SPOTLIGHT	INDUSTRY HIGHLIGHT	SHOW COVERAGE	ADVERTISING DEADLINE
February 2020	Fluid Power	Bearings, Gears, Gear Drives, Motors	Mechatronics	Gearmotors	Agriculture & Construction	IFPE CONEXPO (March 10-14)	January 30
March 2020	Motion Control	Bearings, Gears, Gear Drives, Motors	Sensors	Couplings	Mining	Automate (May 17-20)	February 20
April 2020	Bearings	Bearings, Gears, Gear Drives, Motors	Clutches & Brakes	Gear Drives	Automotive	CTI Symposium USA (May 11-14)	March 19
June 2020	Motors	Bearings, Gears, Gear Drives, Motors	Gearmotors	Linear Motion	Oil & Gas		May 21
August 2020	Couplings	Bearings, Gears, Gear Drives, Motors	Software, Robotics, Automation	Maintenance Tools	Packaging, Material Handling	IMTS/Hannover Messe (Sept. 14-19); Turbomachinery & Pump Symposium (Sept. 15-17)	July 2
September 2020	Gears & Gear Drives	Bearings, Gears, Gear Drives, Motors	Condition Monitoring	Bearings	Food & Beverage	Pack Expo (Nov. 8-11)	August 20
October 2020	Lubrication & Seals	Bearings, Gears, Gear Drives, Motors	Belt & Chain Drives	Pumps	Energy & Power Generation	SPS (Nov 24-26)	September 24
December 2020	Buyers Guide	Bearings, Gears, Gear Drives, Motors	Linear Motion	Speed Reducers	Aerospace		November 19

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Igus

POLYMER BEARINGS PROVIDE LONGEVITY FOR PIANO BUILDER

An England-based piano builder is striking a new chord in the design of the centuries-old musical instrument by incorporating tribopolymer components from Igus in a unique hammer system that offers supreme longevity, climate resistance and improved playability and sound performance.

The components from Igus in Phoneix's D3D Hammer System are two-millimeter roller bearings that are used as center points for the bushless system. The pins offer smooth operation and with approximately a 30 percent increased diameter, are stronger, smoother and more dimensionally precise than traditional wire center pins. Extensive design and 3D printing work with Igus allowed Phoenix to create the new hammer system. Igus, based in Cologne, Germany, runs its U.K. operations from Northampton and its North American operations from Providence, R.I.

"These ultra-high-grade pins offer buttery-smooth operation, and with approximately a 30 percent increased diameter, are stronger, smoother and more dimensionally precise than traditional wire center pins," said Phoenix founder Richard Dain. "Igus was of the utmost help to us in their selection and provision of material for our hammer flange assemblies."

Improving the hammer assembly

Dain, an accomplished engineer, pianist and committed patrons to the arts, turned his attention to improving the inherent limitations of the traditional hammer assembly. A piano's hammer assembly consists of a "hammer flange" — the part that is fixed in place within the overall action — a hinged shank — which defines the flightpath of the hammer — and the hammer itself. The flange, shank and hinge are traditionally made from hornbeam, a type of hardwood that when well finished is very smooth and often compared to ivory.

Although relatively strong, hornbeam is prone to changes in temperature and humidity, like all other woods. It is also difficult to produce with consistent material properties. No two pieces are quite the same. Over time shanks can warp and drift and require regulation adjustments if a piano is to respond uniformly, predictably and with even sound.

No matter how good the regulation of a traditional wooden hammer assembly, the shanks, which are typically about 6 millimeters in diameter and 13 centimeters in length, flex considerably when under the duress of energetic pianism. The hammer wobbles from side to side, and twists chaotically as it is accelerated towards the strings, causing irregular strikes. This chaos gives rise to unpleasant overtones, when the hammer does not contact the strings with precision.

Bushless hinge assembly

The entire system in a traditional wooden assembly suffers from inefficiency due to flexing of the hammer shank. As a remedy, Phoenix chose a complex-weave carbon fiber shank to replace hornbeam. The material is superbly strong and uniform, offering superior, climate-resistant performance throughout the registers of a piano. There is also no increase in weight.

The hinged hammer flange is traditionally made of wood. Phoenix considered a range of materials to replace the flange, with a very specific aim in mind: to create a "bushless" hinge assembly. Traditional bushes are made from cylindrical felt inserts that provide an interface between metal journals (called center pins) and the wooden parts. They must provide enough "snugness" for the hammer not to wobble from side to side, but must also be sufficiently free from friction for the system not to feel stiff. High friction from a tight bearing will feel like "sluggishness" to a pianist and is another form of energy loss.

When a new hammer flange is correctly bushed, it is by definition already at a critical point with tiny margins of error. As wear inevitably takes its toll on the bushing, looseness impacts the system, causing a loss of fine control over the path of hammer flight, while noises and clicks are prone to develop as the pin rattles against the bushing. Swelling of felt in periods of high humidity cause stiffness and even seizure.

Enormous longevity with the new system

Any noises — no matter how seemingly inoffensive in isolation — can become a nuisance to a sensitive artist, and even more so to a recording engineer. Igus, with its unique tribo-

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polymer material, has enabled Phoenix to develop a bushless action. The D3D Hammer System offers all the advantages of a traditional system in prime condition, as well as climate resistance and, what designers at Phoenix confidently predict, enormous longevity. "Indeed, we expect these assemblies may well exceed the lifespan of the piano itself," Dain said.

Already formulated for industrial bearing applications, the tribopolymer material is perfect for this application for performance and aesthetics. Its ivory-white color perfectly complements the carbon fiber shanks, and black inner felt Abel hammers. Tuning technicians appreciate the cream color, which is easy to see in the confined space of a piano action.

"From building our prototypes we have been able to ream the Igus material with relative ease, ensuring a perfect fit for our center pins," added Phoenix's James Bacon, who advised on and built the prototype. "Our test piano, which is fitted with a prototype of the D3D Hammer System, offers a fabulous sense of control and immediacy, and superbly controlled hammer flight. Pianists report that D3D is like stepping into a Ferrari after driving a Ford Model T."

Once acclimatized, pianists find that they can produce more power with less effort, and that they have a sense of connection with the piano that they have never before experienced. "All of us on the Phoenix team are confident that we have not only remedied the age-old limitations with hammer assemblies, but that we have produced a world-beating system that is a joy for pianists to use," Dain said.

A new era in piano innovation

In the 19th century, there was an explosion of ideas within the piano industry. Reciprocity between piano builders, composers, pianists, patrons and audiences propelled enormous rates of innovation in both instruments and composition, and a variety of design concepts became available, each offering something unique to the world of music.

By the late 19th century piano building had largely converged on a design paradigm that continued throughout the 20th century, amid an atmosphere of increasing reluctance to explore new design concepts. Piano makers shifted their focus towards branding, value engineering and marketing, while innovation, if any, was skewed towards finding cheaper solutions for mass production.

In the absence of improved piano sound, which for 150 years had driven experiment with new styles, came stagnation in composing classical music. New genres of composition followed the same trend of stagnation, so much so that by the middle of the 20th century the future of classical piano came into question for lack of innovative interest.

The defining spirit of Phoenix Pianos is one of recapturing the innovative drive of the 19th century piano builders, specifically in challenging the numerous now-outmoded design limitations found in traditional instruments.

For more information:
Igus Inc.
Phone: (800) 521-2747
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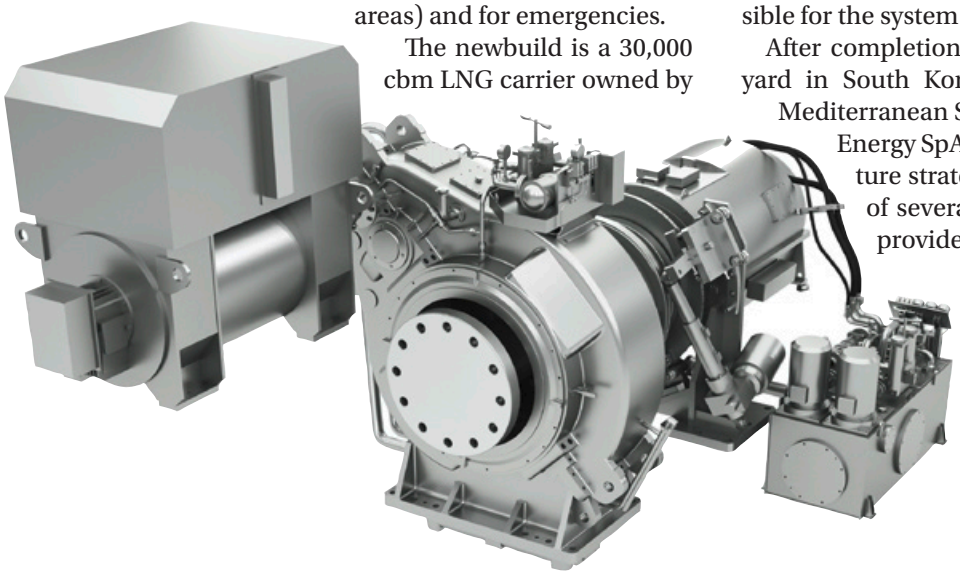
Renk

WINS MARITIME CONSTRUCTION PROJECT FOR HYBRID SYSTEM

At the end of March 2019, the maritime sales team of Renk's Rheine plant managed to win its first new construction project for the maritime hybrid system called MARHY. This system enables ships with 2-stroke engines to efficiently generate on-board power supply by using the main engine (PTO-operation). In addition, a fully electric drive (PTH- operation) is available for zones with low emissions zones (port areas) and for emergencies.



The newbuild is a 30,000 cbm LNG carrier owned by Knutsen OAS. It is equipped with a 6,00 kW strong 2-stroke main engine and is the first of this size. RENK's scope of delivery includes a tunnel gearbox (type SHHII-1600), a fully-automatic PSC-85 (Propeller shaft clutch), elastic couplings, and, for the first time, key electric components. These include a 1 MW generator/e-motor as well as the corresponding frequency converter. In addition, Renk is responsible for the system integration.

After completion of the ship at the Hyundai Mipo shipyard in South Korea, it will be stationed in the Italian Mediterranean Sea and operated by Milan-based Edison Energy SpA. The LNG carrier is part of an infrastructure strategy, which provides for the construction of several LNG depots along the Italian coast to provide a reliable energy supply.

For more information:
Renk AG
Phone: +49 821 5700-279
www.renk-ag.com

Regal Beloit

RELEASES LINE OF VARIABLE-SPEED REPLACEMENT MOTORS

Regal Beloit Corporation, a manufacturer of electric motors, electrical motion controls, power generation and power transmission components, announces the release of the new Genteq Evergreen VS product line of variable-speed replacement motors.

Genteq Evergreen motors are reliable, easy-to-install, electronically commutated motor (ECM) retrofits designed for use in residential and light commercial Heating Ventilation and Air-Conditioning (HVAC) systems. Evergreen VS motors are highly efficient, pre-programmed, dual-voltage, dual-rotation motors that provide both versatility and ease of installation.

The Evergreen VS motor and Evergreen VS user interface are designed to replace Genteq constant airflow (variable-speed) ECM indoor blower motors. The Evergreen VS product line is designed specifically to replace Genteq models 2.3, Eon and 3.0 motors. These motors represent the largest volume of variable-speed motors used in HVAC original equipment manufacturer (OEM) indoor blower motor applications.

"I'm excited about Regal's new line of Evergreen VS motors," said Birch Taylor, distribution business unit vice president, Regal. "They are versatile 16-pin and four-pin truck-stock ECM blower motors built to the Genteq quality standards found in OEM equipment. The Evergreen VS line is a proud member of the ECM Made Easy family of innovative aftermarket solutions."

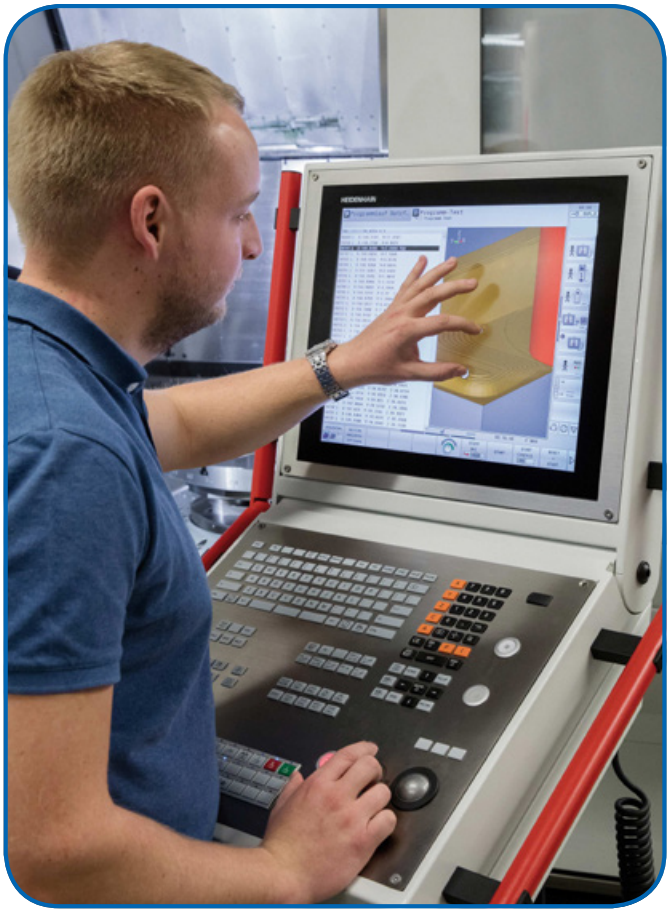
Millions of OEM variable-speed motors could be replaced with just five parts on a service truck. With the expansion of the Evergreen line with the new variable-speed motor solution, it is now even easier to reduce on-truck inventory and complete more calls on the same day without driving to retrieve a part.

The Evergreen VS motor and Evergreen VS user interface (5K010) are used together to replace the Genteq model 2.3 or Eon motor. The Evergreen VS motor is a direct replacement for the Genteq model 3.0 motor.

For more information:
Regal Beloit Corporation
Phone: (608) 364-8800
www.regalbeloit.com

Heidenhain

SUPPORTS MASTERCAM TO BETTER ENABLE 5-AXIS MACHINING



In a collaborative effort to best enable 5-axis machining for users with HEIDENHAIN TNC controls and *Mastercam* CAD/CAM software, a new collaborate post processor is now available. Called the *Heidenhain TNC 5X Mill post processor*, CNC Software, Inc., developers of *Mastercam* software, introduced it recently after coordinating development efforts between the two companies. Collaboration also included beta testers and industry resellers in order to best meet the worldwide demand of providing a consistent, high quality Heidenhain translation post.

All Heidenhain control users that use *Mastercam* CAD/CAM software can now benefit from this newly developed processor, including those using iTNC 530, TNC 620 and TNC 640 controls.

"Heidenhain is committed to ensuring that our control customers have the tools they need during any 5-axis machining application, and this collaboration post processor is just one example," explained Gisbert Ledvon, Heidenhain TNC business development manager. "We are now experiencing an increased demand in North America for our newest TNC 640 control for high precision 5-axis machine tools, and we want those customers to know that if they have *Mastercam* software, we are dedicated to providing ongoing translation updates as needed!"

For more information:
Heidenhain Corporation
Phone: (847) 519-4856
www.heidenhain.us

Applied Motion

ANNOUNCES RANGE OF ETHERNET/IP-ENABLED DRIVES AND INTEGRATED MOTORS

A range of servo drives, stepper drives and integrated motors from Applied Motion Products now conform to the ODVA specification for EtherNet/IP communications. The ODVA Conformance Program mandates that vendors use a common network interface to ensure interoperability with products from other vendors. Products must pass rigorous testing by an authorized Test Service Provider before declared ODVA conformant.

ODVA conformant servo drives, stepper drives, and integrated motors perform their specific positioning, velocity and other motion control tasks while simultaneously exchanging control, I/O and diagnostic data with controllers on the EtherNet/IP network. Customers who rely on EtherNet/IP as the backbone of their industrial Ethernet network can speed time-to-market for their machines and end products by specifying ODVA conformant devices. Customers have the freedom to choose products from an international vendor pool and the peace of mind that those products will interoperate in multi-vendor systems.

The line of ODVA conformant drives and integrated motors from Applied Motion Products includes:

SV200 Digital Servo Drives: advanced performance and auto-tuning with multiple control options.

ST Stepper Drives: step motor drives with stall detection, stall prevention, microstep emulation and anti-resonance.

StepServo Integrated Motors: high-resolution incremental encoders and closed-loop servo firmware combine to create integrated motors that offer the best performance available from a step motor.

For more information:
Applied Motion Products
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Zero-Max

GEARBOXES PROVIDE HIGH TORSIONAL STIFFNESS USING CD COUPLINGS

Flanged gearboxes are ideally suited for CD Couplings from Zero-Max. They provide high torsional stiffness in precision applications with fluctuating torque loads caused by aggressive acceleration/deceleration and reversing rotation.

A unique flanged hub on the CD Coupling attaches directly to the gearbox output flange. This direct connection and use of the torsionally stiff CD Coupling construction provides optimal system torsional stiffness and performance.

The CD Coupling's high torsional stiffness is due to the coupling's unique composite disc design. The precision composite material and disc pack design provide a high degree of torsional stiffness while also handling inevitable shaft misalignment in the system.

CD Couplings are designed to withstand the punishment and stress of flanged gearbox applications. In comparison, other couplings may have high torsional stiffness specifications but can be too brittle to withstand the punishment of high speed reversing loads typically seen in these applications.

Also important, the coupling's composite disc withstands all types of environmental elements, including temperature extremes from -70° to +250°F, as well as moisture and a wide range of chemicals. The robust disc and overall coupling design help increase the longevity and reliability of the motion system in which the coupling is used.

Additional operating features include: zero backlash, smooth operation at high speeds, maintenance free operation and compact size that fits most applications. CD Couplings are durable and have very long life cycles, helping to ensure uptime and throughput for the machines they are used on.

CD couplings are available in many models and sizes, including custom designs for unusually high speed and dynamic applications such as high speed packaging machinery and automation equipment. Standard models and sizes include single and double flex models with clamp style hubs with or without keyways. The torque capacities range from 20 Nm to over 10,000 Nm with maximum speed ratings from 3,000 rpm to 14,000 rpm or higher for custom designs.

All CD couplings are environmentally friendly and are manufactured of RoHS compliant materials.

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

NORD

EXTENDS LINE OF SINGLE-STAGE HELICAL GEAR UNITS

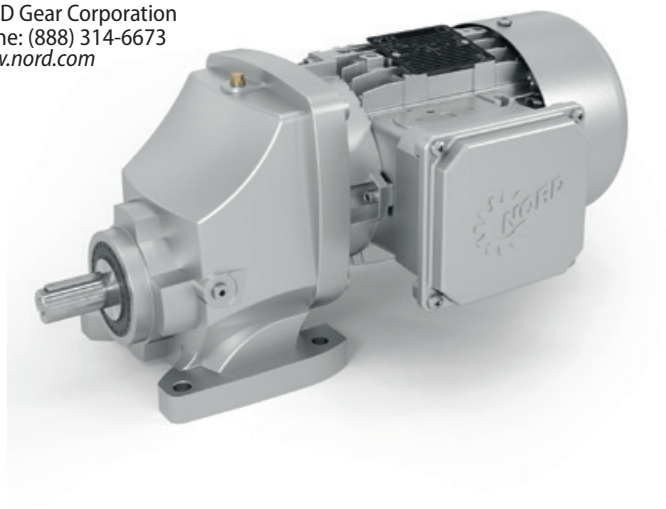
NORD Gear Corporation has announced the addition of three single-stage gear units to its NORDBLOC.1 line. The new SK 871.1, SK 971.1 and SK 1071.1 represent the three largest single-stage NORDBLOC gear units manufactured by NORD and provide industry-leading thrust load capacity per case size.

The new products have a power range of 30 to 60 hp, a torque range of 3,540 to 8,850 lb-in. and a ratio range of 1.41 to 8.09:1. With durable UNICASE cast iron housing and optimized bearings, they can reliably handle large axial and radial forces and are perfectly suited for pumps, mixers, conveyors and industrial fans.

Since NORD added single-stage units to the NORDBLOC.1 line in 2017, more than 65 OEMs in the United States have specified the single-stage units for a host of customer applications in food and beverage, oil and gas, and chemical industries. The newly expanded line will enable NORD to capture greater market share by providing a wider selection of configurations at a lower cost than competing gear manufacturers.

"The primary reason for extending the single-stage product line is to provide customers in our target markets a full offering to cover all of their operational requirements," said Tom Koren, director of engineering at NORD.

For more information:
NORD Gear Corporation
Phone: (888) 314-6673
www.nord.com



Send YOUR product news to Senior Editor Matthew Jaster, via e-mail at *mjaster@powertransmission.com*. Please include a high-resolution photo and contact information. We'll consider your press releases for an upcoming issue as well as our continually updated news feed on the home page at *www.powertransmission.com*.

Driving Gears 2019

Matthew Jaster, Senior Editor

Efficiency, power-loss reduction and enhanced performance are just a few examples of what the PT community wants from their gears and gear drives in 2019. Some companies are doubling down on service and assembly capabilities while other others are integrating components in an effort to increase flexibility and control. The following article contains gear drive technology for winch systems, cooling towers and welding turntables in addition to the latest industry and product news in this growing market segment.

Bonfiglioli

OFFERS PLANETARY DRIVES FOR EXCAVATOR WINCH SYSTEM

The Falcon Winch Assist is a winch system for excavators from the New Zealand engineering and manufacturing company DC Equipment and is achieving international success because of its outstanding safety, reliability and efficiency. Due to its many advantageous characteristics it is predestinated for tethered earthmoving machines to haul felled trees on slopes up to 45 degrees.

The hydraulic winch uses a pair of high-performance Bonfiglioli 715C crawler drives, which can be fitted to a broad range of excavators over 30 tons. The hydraulic winch assist machine is housed in the rear of the crawler vehicle where Bonfiglioli compact but torque-dense, 85,000 Nm capacity 715C crawler drive is the perfect fit for challenging tasks. In addition to being used in tethered applications for felled trees, it can be used for digging, loading and shoveling in demanding situations, with high levels of safety achieved by features and operating alerts built in to ensure the security of operators and enable them to concentrate on the task in hand.

The twin drives 715C in each Falcon Winch Assist unit are incorporated into an open loop, single-drum hydraulic system featuring brake safety. The Falcon Winch Assist has a primary hydraulic braking system for maximum control to achieve consistent rope tension minimize tension spikes. An emergency backup braking system utilizes two Bonfiglioli integrated planetary gear box brakes for a double redundancy backup braking system. The hydraulic and electrical safety system of the Falcon Winch Assist were designed to ensure the system remains in a safe operating stat and to prevent shock loading, thanks to a system communication monitoring, drum speed control and alerts that warn of machine failures and activate automatic emergency braking.

Reliability of the multipurpose Falcon Winch Assist is advanced by the use of twin Bonfiglioli 715C planetary gearboxes proven globally in tough industrial applications, including mobile cranes and milling machines employed in industries including agriculture, construction equipment, mining and energy, forestry, food processing, primary production, land and water transportation, power generation and transmission and renewable energy. Bonfiglioli drives are designed to withstand the widely varying operating conditions you may have in New Zealand region, including temperature fluctuations and particularly demanding applications, where reliability is paramount. The high reliability combined with the global reputation of these gearmotors has been instrumental in their choice by DC Equipment for this application.

The strong local presence and prompt delivery were the other important factors in the choice of Bonfiglioli drives. The company is expanding its organization in New Zealand with a focus on engineering and service to offer increasingly customized solutions tailored to the needs of individual customers.

The new CAE team, Customer Application Engineering, of Bonfiglioli operating in Australia and New Zealand, supported by a strong global R&D and a group with 3,770 professionals, 20 branches and 14 production plants, is able to better support the innovative companies New Zealanders, combining engineering skills for local applications with extensive global experience.

For more information:

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

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gear drives
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Rexnord

CT SERIES DELIVERS LOW-NOISE, RELIABLE OPERATION

Rexnord introduced the Cooling Tower (CT) Series earlier this year. Designed specifically for induced draft, wet cooling tower applications, the Falk CT-Series is capable of withstanding harsh cooling tower operating conditions. Combined with Addax Composite Couplings and Addax Mechanical Brakes, Rexnord offers customers a complete power transmission product solution. The Falk CTA gear drive is designed to directly replace comparable Amarillo double reduction gearboxes, with matching footprint and critical mounting dimensions to reduce installation costs. Featuring spiral bevel gears, finished using

a state-of-the-art hard cut process and precision-machined helical gears, the Falk CTA delivers low noise and reliable, low vibration operation. The vertically-orientated cooling fins, combined with standard marine grade paint, ensure long service life in the harshest of cooling tower environments. The Falk CTA gear drive is also a part of Rexnord's digital productivity platform, DiRXN (pronounced "Direction") — integrating the innovative Industrial Internet of Things and e-commerce technologies with Rexnord's leading portfolio of tools, products and services. The attached Smart Tag provides users with an intuitive experience designed to increase overall customer value through on-demand support, including maintenance and installation manuals, videos, troubleshooting guides and opportunities to register the product directly to expedite reorder and support asset management.

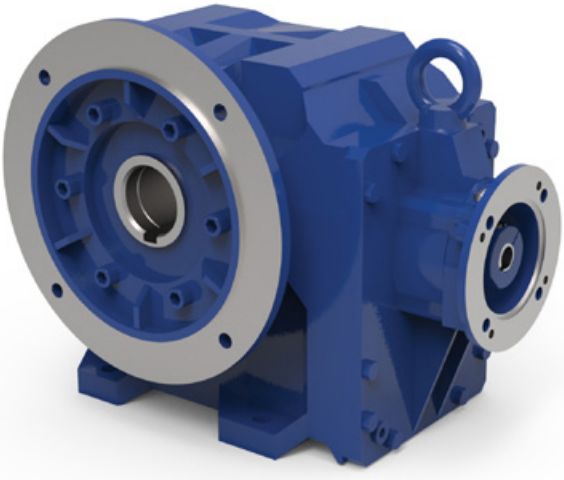
For more information:

Rexnord
Phone: (866) 739-6673
www.rexnord.com

Bauer

GEARBOX WITH CUSTOM ADAPTER OFFERS BENEFITS TO WELDING TURNTABLE DRIVE

A leading global aircraft engine manufacturer needed a robust replacement gear drive for use on a large plasma welding turntable. The table's 12 ft. diameter bed rotates and tilts to accommodate various sized parts. The bed is laser-aligned to ensure precise angles are established for accurate welds. The problem was that the original competitor worm gearbox's backlash allowed the welding bed to slip occasionally, causing the weld to be misaligned. The inability of the old gearbox to consistently hold the welding turntable in place created costly rework and reduced productivity.



The original gearbox manufacturer could only supply an identical replacement unit, which would eventually fail and not address the real problem. Faced with a tough challenge, the OEM's distributor contacted Bauer Gear Motor to help solve the problem.

After a review of the welding turntable requirements, Bauer engineers designed a modified BK70 gear box. Compact BK Series units feature helical gearing for increased torque capacity. BK models provide robust, backlash-free performance, which was critical for this demanding application.

A custom adapter was integrated into the design to allow fast and easy mounting directly to the table's servo motor drive.

For more information:

Bauer Gear Motor
Phone: (732) 469-8770
www.bauergears.com

Dana

TO OFFER NEW EXPANDED SERVICE AND ASSEMBLY CENTER FOR GEARBOXES

Dana Incorporated broke ground earlier this year on a nearly 32,000 square-foot facility in Slidell, Louisiana, for the repair, service, and assembly of industrial gearboxes.

The company's current operations in Slidell will transition to the larger facility in the nearby Fremaux Park to meet the growing demand for industrial gearbox service, repair, and refurbishment. Dana's service and assembly centers provide custom solutions for gearboxes used in a variety of applications such as mining, steel and metal, pulp and paper, power generation, food processing, marine, cement, wind power, water treatment and much more.

"Our industrial gearbox customers come to Dana for custom, highly engineered solutions that are able to handle the unique requirements of their applications," said Aziz Aghili, president of Dana's Off-Highway Drive and Motion Technologies. "Dana's service and assembly centers enable us to provide critical support for our customers throughout the lifecycle of their machinery to ensure maximum performance and uptime."

Dana offers customized gear drive solutions for special purpose applications, as well as drop-in replacements for obsolete units. From upgrading to higher quality or larger capacity, to completely reverse engineering for manufacturing new gears, Dana's service and assembly centers are equipped to address each of the challenges faced by its customers.

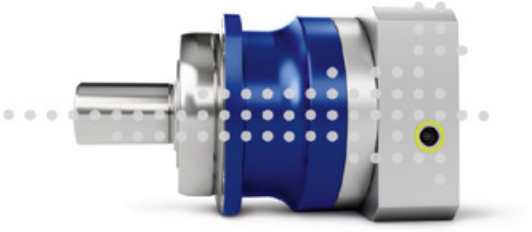
"Dana in Slidell has a highly experienced team of service and repair professionals who are committed to meeting the needs of our customers," said Dave Hunt, director of service and manufacturing operations for Dana Off-highway Drive and Motion Technologies. "This new facility will grow our service and repair business, while expanding our capabilities to manufacture gears on-site, reducing lead times for our customers."

As the original-equipment manufacturer for both Brevini and PIV brand products, Dana is able to offer an extensive inventory of service components, including bearings, seals, shafts, and gearing. The company also provides service and repair for a broad range of industrial gearbox brands ranging from small applications to large, 40,000-pound industrial gearboxes.

For more information:
Dana Incorporated
Phone: (248) 623-2020
www.dana.com

Wittenstein

OFFERS LATEST GEARBOX TECHNOLOGIES DURING EMO HANNOVER 2019



The following is a round-up of some of the latest engineering technologies from Wittenstein featured at EMO Hannover 2019:

The Galaxie Drive System performs exceptionally well in all key technical disciplines compared to the market standard — from freedom from backlash, synchronous running and stiffness to torque density and overload capacity. Dynamic teeth instead of a rigid gear ring, tangential and hydrodynamic tooth contact over the full surface when loaded and a new type of bearing with a segmented outer race ring are the decisive attributes of this radically redesigned gearbox. In most cases, Galaxie is more than simply a component: innovative machine concepts and generations are developed around its performance features and Galaxie forms the nucleus. Examples include the compact Galaxie D in size 085 for smaller cutting heads or handling axes where special requirements apply regarding torsional rigidity and freedom from backlash and the ultra-flat Galaxie DF in sizes 110 and 135.

Smart gearboxes with "cynapse" functionality have attracted considerable attention since making their debut at the Hannover Messe 2019. This functionality — comprised of a fully integrated sensor module, the data output using IO-Link and the resulting I4.0 connectivity, — comes hand in hand with logic functions for monitoring the actual and threshold values of selected parameters. Gearboxes with "cynapse" are capable of recording and storing different influencing quantities in the process and the environment which impact on gearbox operation, and communicating them to automation systems as well as to all standard IIoT platforms. Gearboxes with "cynapse" are identical to the existing models, so that a drive solution which has already been designed needs no further modification — an important argument for designers.

Matching the gearbox, pinion, rack and lubrication system enable optimized performance of the complete system. Three performance classes adapted to different smooth running, positioning accuracy and feed force requirements ensure a technically and commercially efficient design in the most diverse applications. **PTE**

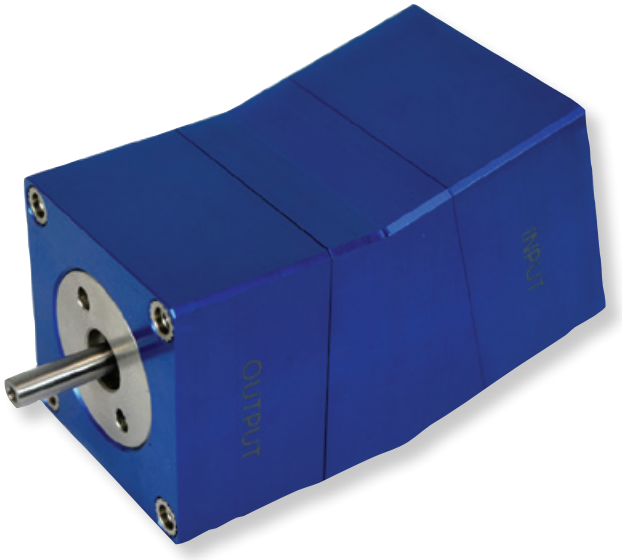
For more information:
Wittenstein North America
Phone: (888) 534-1222
www.wittenstein-us.com

Stock Drive Products/Sterling Instrument

Engineered Mechanical Solutions

Stock Drive Products/Sterling Instrument (SDP/SI) manufactures mechanical components for varied product applications. Our precision gears, machined parts, molded components, and drive assemblies can be found in high-tech operating rooms, movie sets, military operations, space exploration, and even on Mars. Partnering with OEMs around the world we manufacture and manage supply chain of components required for medical, surgical robotics, aviation, satellites, defense, automation, and commercial industries. SDP/SI sets ideas into motion.

Established in 1950, SDP/SI provides exceptional services, inch and metric component choices, and design solutions. Completed December 2016, our 96,000 square foot state-of-the-art Hicksville, NY facility houses the latest manufacturing, industrial automation, and inspection equipment. Employing skilled machinists, CNC programmers, inspectors, engineers, and customer service personnel, we meet the highest-quality standards your business deserves. Standard catalog components can be found and purchased online where free 3D CAD models and part specifications can be easily downloaded.



Facing a design challenge? SDP/SI supports many Fortune 500 companies in new and exciting projects. Applying years of experience, product knowledge, and design acumen our engineering and manufacturing teams provide innovative solutions through part selection, modifications, or custom design. Sometimes the best solution is the simplest. Standard components are a cost-effective option and with 87,000 inch and metric, machined and molded components offered, SDP/SI is the engineers preferred source.

- Timing Belts and Pulleys
- Precision Gears
- Precision Gearboxes
- Bearings
- Couplings
- Hardware
- Precision Machined Components
- Molded Components
- Mechanical Assemblies
- Contract Manufacturing

With the focus on our customers, SDP/SI recently acquired a 3D printer. Primarily used for prototypes and low volume production, our customers are already benefiting. Printing high-quality components and assemblies, we are getting their designs into production faster.

Our manufacturing capabilities include precision gear cutting, 5-axis milling, 9-axis Swiss turning, and world class quality. Custom material and finish options are available. For prototypes to large scale production, see what SDP/SI can do for you. ISO 9001:2015 + AS9100D certified, ITAR, Reach, and RoHS compliant.

SDP/SI is an award winning company located on Long Island, New York.

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Fax: 516-326-8827

Email: sdp-sisupport@sdp-si.com

www.sdp-si.com

Motion + Power Technology Expo 2019 Booth Previews

What to Expect from Power Transmission Exhibitors in Detroit

Alex Cannella, Associate Editor

MPT Expo takes place October 15–17 at TCF CENTER (formerly the Cobo Center) in Detroit. Here are booth previews of some of the exhibitors most relevant to buyers of mechanical power transmission components.

American Gear Manufacturers Association

BOOTH 3426

The American Gear Manufacturers Association will be in the center of the inaugural Motion + Power Technology Expo (MPT Expo). Everyone is invited to the booth where people can discuss not only the thought process behind the all-inclusive show but the future direction of the power transmission industry. You can direct questions to AGMA's staff or board about standards, education, emerging technology, membership, committees and the strategy that AGMA and its members are using to move the future.

And although they want everyone to stop by their booth, AGMA encourages attendees and exhibitors to walk the entire show floor to see all the new and different companies that have come to showcase their importance in our industry. With the new Fluid Power Pavilion, the Emerging Technology Pavilion and 250 exhibitors — including over 50 new companies — attendees will be connected to the top manufacturers, suppliers, buyers and experts in the mechanical and gear power, electric power and fluid power industries. This is the place where you can do real business.

When attendees and exhibitors need a break from making deals, AGMA highly encourages them to take an educational seminar, attend a Fall Technical Meeting session or sign up for the new Motion + Power Technology Conference (MPT Conference), where they will learn from the experts. Whether you are new to the business and want to take the

"Basics of Gearing" course or are looking to expand your knowledge by taking the "Fundamental Understanding of Electro Fluid Power Technology" class, there is something for everyone across all industries. Not an engineer or operator? That is okay, the two-track MPT Conference boasts presentations from leaders on cybersecurity, IIoT, workforce, supply chain management, 3D printing, automation, economics and more. These development tools make taking that extra person an easy choice when you can check off training for the year in just three days.

Everyone knows that historically, this tradeshow (the former Gear Expo) has always had some incredible networking opportunities and MPT Expo is no different. Some of the best deals, the greatest connections and future business is done off the show floor over food and drinks. Join AGMA, NFPA and ASM International during the evening hours for some fun. There is the FTM Fun and Games Reception on Monday night, Opening Night Welcome Reception (come hang out at AGMA's booth for this) on Tuesday, the new Young Professionals Reception also on Tuesday night, the Heat is On event Wednesday night (for a taste of Detroit) and the new Women in Manufacturing Breakfast opened to all on Thursday morning. Trade shows are unique because you can do business face-to-face, make sure to make the most of it by coming to the networking events too.

With emerging technology, a global supply chain and steep competition, change is rapidly occurring in manufacturing. Motion + Power Technology Expo is not just a tradeshow but a strategy for the future.Industries all over the world are teaming up to offer a consolidated platform where customers can get all their needs in one place. AGMA and its partners thought it was time to have a show that represents all

MOTION + POWER
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VISIT US AT BOOTH #3418

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forestcitygear.com

power transmission sectors: mechanical, electric and fluid power. Make sure to come by and share your thoughts on the future of our industry. See you in Detroit!

For more information:
American Gear Manufacturers Association
Phone: (703) 684-0211
www.agma.org

Bevel Gears India

BOOTH 4210

Bevel Gears India Pvt Ltd has been manufacturing bevel gears and bevel gearboxes for over 40 years. The range of bevel gears, from 0.40" to over 70", is broad by international standards and serves several industries. They also manufacture a select range of fine pitch spur, helical and worm gears.

The bevel gear expertise has broadened over the years from custom gearing to include stock bevel gears and standard cube bevel gearboxes.

The stock bevel gear program is offered in both metric and imperial versions. Customers can select from ground or lapped spiral bevels, ground or lapped zerols and soft or hardened straight bevel gears. Customization of stock products is an option to provide more flexibility.

Bevel gearboxes are available in standard ratios and sizes with the option to customize gear ratios, gearbox mounting requirements or housing materials for demanding applications. For power dense applications, Bevel Gears India provides customers with high ratio hypoid gears with very high single stage reductions. Their engineering department will be glad to review your requirements.

Applications range include medical, robotics, packaging, positioning to name a few. They invite you to vist them at the MPT Expo and learn how they could be your gear and gearbox sourcing solution.

For more information:
Bevel Gears India
Phone: +91 80 2841 0239
www.bevelgearsindia.com

Circle Gear

BOOTH 4318

Circle Gear is a leader in quality custom gearing, specializing in small to medium lot production. They are one of the only companies in the country that will reverse engineer and manufacture spiral bevel gear sets. Circle Gear services include bevel gears (straight and spiral up to 36" diameter), spur gears, helical gears, herringbones (up to 60" diameter), internals, racks, sprockets, worm and worm gears and all other types of power transmission products. Circle provides servicing on splines (involutes and straight-sided, internal and external). They offer reverse engineering as well as breakdown services on many products. Circle Gear currently resides in a 125,000 sq. ft. full service production facility. They also house a full service gearbox rebuild division, QRS (Qual-

ity Reducer Service). QRS specializes in rebuilds of all major brands of gear reducers as well as manufacturing of custom designed units.

For more information:
Circle Gear and Machine Company
Phone: (800) 637-9335
www.circlegear.com

Forest City Gear

BOOTH 3418

Forest City Gear is a family-owned and operated business and has been in the gear manufacturing industry since 1955. Industries across the globe have placed their trust in Forest City Gear and their ability to do what others can't. Every day they manufacture custom gears across a diverse array of industries covering an equally diverse range of applications. These applications span land, sea, air and space. Forest City Gear was chosen to produce all the gears and splines in the Mars Rover where failure simply wasn't an option. Forest City also regularly supports everything from telescopes, artificial elbows, aircraft, automotive, racing, medical implants, industrial equipment, marine applications and more. Be assured that when your gears made at Forest City arrive on your dock, they will not just meet your expectations; they will exceed it.

If you'd like to learn more of what they can do for your organization, contact them to arrange a "walk through the forest," where you can tour their plant and see for yourself the difference a Forest City Gear will make in your application.

For more information:
Forest City Gear
Phone: (815) 623-2168
www.forestcitygear.com

FVA

BOOTH 4237

The FVA-Workbench is a manufacturer-neutral software solution for the modeling, parameterization, and calculation of transmission systems. It bundles more than 50 years of research and development from the FVA (German Research Association for Drive Technology) expert network into a single platform and makes this accumulated knowledge directly available for practical application

This unique software includes the latest results from the FVA research network—new calculation methods for fast, precise results. Thanks to powerful performance and intuitive operation, the new FVA-Workbench is easy to use and accelerates development processes significantly. Individual gearbox components and complete systems can be developed in the shortest time possible.

For more information:
FVA GmbH
Phone: +49 69 6603-1663
www.fva-service.de

Gleason/KISSsoft

BOOTH 3400

At this year's MPT show, Gleason Corporation will showcase a wide array of new design, manufacturing and inspection technologies for cylindrical and bevel gears. Highlights include: Closed Loop Hard Finishing Cell with integrated In-Process Laser Measuring, Gear Noise Detection and Analysis Systems, new Chamfer Hobbing Technology, and the latest release of KISSsoft Transmission Design Software.

The market leader will demonstrate the current KISSsoft Release 2019 with numerous new highlights: Among other things, KISSdesign, an instrument that allows intuitive concept design at system level, is now available. SKF and KISSsoft have also created a new interface to simplify the gear development process. This interface enables engineers to perform calculations using the latest bearing data from SKF via a direct connection to the SKF cloud. The manufacturability for Power Skiving can now also be evaluated in KISSsoft. After generating a special report with workpiece and tool data, this report can be transferred to Gleason if required, which makes data exchange between the designer and the tool supplier much easier and less error-prone.

The interface between GEMS and KISSsoft provides an exchange of gear and system information between the two software packages. This allows the user to realistically evaluate and optimize every type of bevel and hypoid gear — with a closed loop between the design and manufacturing software.

For more information:
KISSsoft AG
Phone: +41 55 254 20 53
www.kisssoft.ch

GWJ

BOOTH 3934

Focusing on mechanical engineering, GWJ Technology stands for high-quality products and professional software development for mechanical engineering to support engineers and designers in their daily work. GWJ's product range of innovative calculation software is wide — from standard software for classical machine elements with 3D CAD integration modules to the determination of whole systems up to a complex special software for 5-axis milling of gears. There are common features that all GWJ solutions share — intuitive design, a sleek interface, ease of use and suitable ap-

SDP/SI

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ENGINEERING
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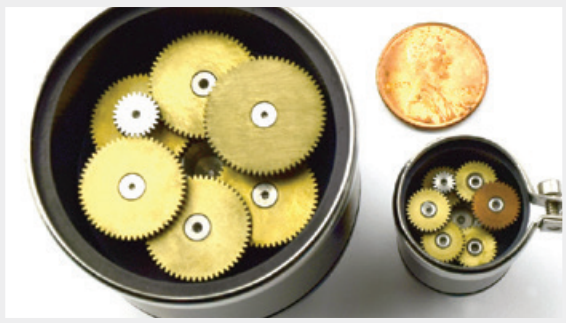

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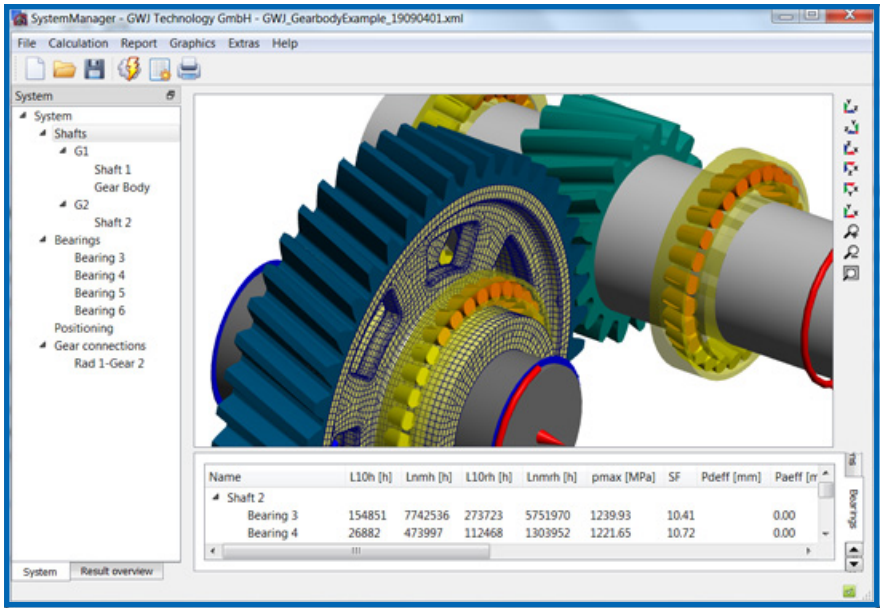


plications for all users from beginner to very advanced. GWJ is constantly working on software enhancements and adding new features to the system in order to keep the applications up-to-date. They are also committed to providing high-quality customer services, including engineering services and workshops. Several of GWJ's various software suites will be on display.

At the Motion + Power Technology Expo, GWJ will introduce a lot of new features. For example, a new and enhanced calculation for cylindrical gear pairs. The new version now supports the strength calculation of plastic gears. Ultra-clean steels and plastic materials were also added to the material database. In addition, the profile modifications can be dimensioned and the user gets recommendations for the flank modifications. The definition of load spectra has been extended and new options for the dimensioning of the profile shift coefficients were integrated. A calculation with a fixed center distance independently of the profile shift sum is also available. Additionally, the calculation of the load capacity according to AGMA has been updated.

Furthermore, a new calculation module for Hirth coupling will be introduced. Besides the generation of several gears and shafts, the 3D CAD plugins offer the possibility to import shaft geometries in the calculation.

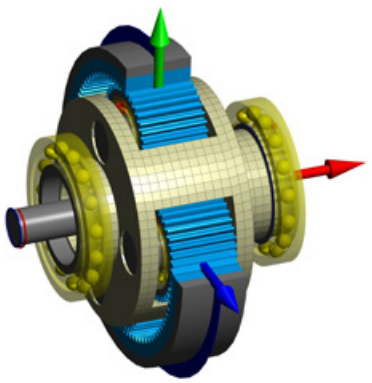
There is also a new version of the SystemManager software. The new version provides multiple enhancements that make the life of engineers easier than ever before. For example, the support of 3D elastic gear bodies and 3D elastic bearing rings, the import of background graphics of shafts, the import of shaft geometries such as 2D DXF, 3D STEP or the direct link between the face load coefficient with load capacity calculation with the load spectrum, extended parameter variation, new diagram functions, template file directory, periodic gear forces in the harmonic response, advanced results for planetary gear trains, and updated bearing database for SKF and Schaeffler (INA/FAG) bearings or the new exchange format REXS for the data exchange of systems between different software solutions like Bearinx, SystemManager and, in the future, e.g. multiple-body simulation tools.

During the exhibition, GWJ will give insight into the new calculation module for face gears, a part of the special software GearEngineer. With all these new features in place, GWJ Technology will underpin its global market position for professional tools to calculate gears and gearboxes.

For more information:
GWJ
Phone: +49 531-129 399 0
www.gwj.de

Mesys
BOOTH 3933

Mesys will show new features of its shaft system calculation version 07/2019. The fully coupled system calculation has new features in its FEA integration which allows elastic gear bodies and elastic bearing rings in addition to elastic housings, shafts and planet carriers. In the latest version centrifugal expansion and contact for elastic bearing rings were added.



Harmonic response can now be calculated using periodic displacements in addition to periodic forces. One use case is the calculation of dynamic gear forces based on transmission error. Another use case is considering a base excitation from the housing.

The parameter variation has a new optimization step allowing to maximize or minimize parameters based on multiple constraints. This can be used to let the software calculate maximum permissible forces for example.

The REXS data exchange format version 1.1 allows to exchange data with other CAE programs.

Bearing databases with catalog data from Schaeffler and SKF were updated, several databases for spindle bearings including internal geometry are available on request from GMN, IBC, CSC and HQW.

For more information:
Mesys
Phone: +41 44 455-6800
www.mesys.ag

McInnes Rolled Rings
BOOTH 2922

McInnes Rolled Rings specializes in seamless rolled rings from 4”-144” diameter and forged discs up to 54” diameter in carbon, alloy and stainless steel. Their ISO 9001, AS9100 and ABS certified plant in Erie, PA combines the latest in ring rolling technology with experienced people, resulting in the best value and the fastest deliveries in the industry.

For more information:
Mesys
Phone: (800) 569-1420
www.mcinnesrolledrings.com

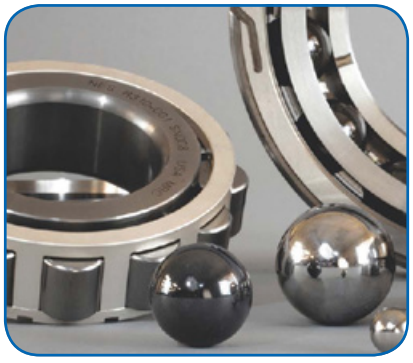
Napoleon Engineering Services
BOOTH 3620

Napoleon Engineering Services (NES) specializes in custom bearing manufacturing. NES is the largest independent bearing inspection and testing facility in North America. Their goal is to empower you with specialized bearing solutions related to custom bearing manufacturing, inspection and testing.

Many of the benefits to NES’s bearing solutions include: corrosion resistance, temperature extremes, load extremes, high fatigue life, high life materials, cost effective solutions, bearing size range of 20-350 mm, shorter lead times, small production runs, high precision capabilities, advanced design technologies, over 100 years combined application experience and engineering knowledge,

products made in America and custom bearing manufacturing.

NES's design engineering and manufacturing capabilities provide you with custom bearings without long lead times. Their knowledge and expertise allows them to analyze your application conditions and develop an advanced product that will meet or exceed your needs.



Custom ball bearing designs by NES include the following features: deep groove, deep-groove fractured race, angular contact, two-piece inner ring gothic arch, double-row self-aligning and thrust. NES can also make custom needle, cylindrical and thrust roller bearings.

NES is the creator of inspection and testing programs supporting global bearing sourcing and bearing qualification. They have been leading OEMs through the global bearing qualification process for 22 years. They provide technical information through bearing inspection, modeling and testing programs to evaluate bearing design, manufacturing capability, overall quality of workmanship and the relationship these attributes have to bearing life. No other source has the experience, capacity or capability to expertly service your bearing qualification needs.

Industries and applications include: aerospace, defense, oil and gas, power generation, marine, industrial, transportation, gear drives, medical, food processing, agriculture, pumps/yurbines, generators and off-highway. NES's certifications include: ISO 9001:2015, AS9100D and NADCAP Chemical Processing.

For more information:
Napoleon Engineering Services
Phone: (877) 870-3200
www.nesbearings.com

Philadelphia Gear

BOOTH 4033

Philadelphia Gear and other experts that are a part of the Timken Power Systems team join forces at the Motion and Power Technology Expo to feature seven brands that combine to provide an entire industrial drivetrain solution. Drawing on a global pool of engineering expertise and technological advancements, Timken Power Systems provides end-users with a single trusted source for comprehensive electro-mechanical equipment support. From designing custom control systems to gearbox expertise to comprehensive bearing repair solutions, they can maximize your powertrain and rotating equipment's reliability and performance.

Through a network of independently ISO-certified regional service and manufacturing centers, they focus on providing local expertise at a national level to minimize your downtime and reduce your cost of repair.

For more information:
Philadelphia Gear, a Timken Brand
Phone: (800) 766-5120
www.philagear.com

Power Transmission Engineering and Gear Technology

BOOTH 3826

Take part in the live version of our Ask the Expert column!

GEAR TECHNOLOGY and POWER TRANSMISSION ENGINEERING are proud to offer four sessions of our popular ASK THE EXPERT column, live and in-person. We've lined up a number of high-profile experts to answer your questions at our booth. So bring your toughest gear-related technical challenges to Booth #3826, and we'll get your questions answered.

There will be four sessions at our booth, with appropriate experts sitting on the panel in each session:

There will be four sessions at our booth:

- GEAR MANUFACTURING — Tuesday, October 15, 10:30 a.m. — featuring Dr. Hermann J. Stadtfeld of Gleason, Dr. Hartmuth Mueller of Klingelnberg, Dr. Andreas Mehr of Liebherr and Tom Ware of Star SU.
- GEAR DESIGN — Tuesday, October 15, 2:30 p.m. — featuring Chuck Schultz of Beyta Gear Services, Dr. Karsten Stahl of the Gear Research Center (FZG) at the Technical University of Munich, and Frank Uherek of Rexnord.

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- LUBRICATION — Wednesday, October 16, 10:30 a.m. — featuring Thomas Tobie of the Gear Research Center (FZG) at the Technical University of Munich, Sib Hamid of Lubriplate and Paul Conley of SKF
- BEARINGS — Wednesday, October 16, 2:30 p.m. — featuring Chris Napoleon of Napoleon Engineering Services, Jitesh Modi of Schaeffler, George Lutzow of SKF and Mike Allega of Timken.

Come to the booth and ask our experts your toughest questions! Or just sit in the audience and absorb the knowledge!

In addition, our editors will be conducting live interviews on our stage throughout the show. Stop by and learn what some of the other exhibitors have to say!

Thors

BOOTH 2928

Your organization must make decisions every day, and the quality, speed and accuracy of those decisions are directly impacted by the knowledge a company possesses.

Thors provides your team with the technical information they need to make the best decisions for your organization; works with you to create a learning path that addresses your knowledge gaps; and objectively measure the knowledge gained by every user so you can understand the ROI of the program.

They have worked with industry experts to capture their knowledge and put it into engaging interactive gear courses. Here is a small portion of what their gear courses can help you do: recognize what gears are, why they are used and why they are important for both power transmission and motion control; understand how to read a gear chart; apply the proper techniques to correct the most common manufacturing errors; recognize the different types of spur and helical gears; and describe the gear metal cutting and forming processes.

The following courses are available from Thors's library: Engineering Drawings for Spur Helical Gears, Gear Manufacturing: Bevel and Hypoid Gears, Gear Manufacturing: Spur and Helical Gears, Gears: Cylindrical Gear Manufacturing Troubleshooting, Gears: Spur and Helical Gear Terminology [2nd Ed.], Gears: Bevel and Hypoid Gear Terminology [2nd Ed.], Gear Chart Interpretation: Elemental Measurements on Cylindrical Gears [2nd Ed.], Gear Classification and Terminology: Worm and Worm Wheels, Gear Fundamentals [2nd Ed.] and Gear Manufacturing: Worm and Worm Wheels

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Tips for Lifting Large Bearings

Special tools and bearing modifications can make removal and installation much safer and easier for plant technicians.

The Timken Company

Large bearings deserve extra consideration when removing and reinstalling components in heavy machinery. Particularly in rolling mills and manufacturing plants where a single bearing can weigh thousands of pounds, it is paramount to follow industry standards for lifting bearings properly and safely. The Timken Company repairs thousands of bearings a year for customers worldwide and often observes damage that is attributable to lifting and handling mistakes that could have been avoided.

The service life of any bearing depends greatly on the care and maintenance it receives. This is especially true in industrial applications, where operating conditions tend to be harsh, loads are heavy, and contamination from dirt and scale are common. Following correct lifting practices is a critical step to ensuring long-running bearings that minimize the cost of ownership.

Even the most experienced plant technicians and maintenance professionals are encouraged to review the following recommendations for lifting large bearings. Lifting standards have changed in recent years, and legacy lifting devices may not be as effective as some might think. Brushing up on the basics only takes minutes and costs nothing compared to the expense of repairing a damaged bearing.

Different Methods for Different Bearings

There are many types of bearings, and each has its own removal process. Smaller bearings can typically be extracted by hand or with the help of a mechanical puller device that can be obtained from the bearing manufacturer or approved vendor. For bearings installed with a press fit or that cannot be removed with a puller for other reasons, often the inner ring of the bearing can be heated to ease removal. This is usually accomplished using a heat lamp or similar device. (NEVER use a torch to heat the inner ring as it can alter the properties of the bearing steel.)

Handling larger bearings requires a crane and some simple fixtures — typically a variety of slings, hooks, chains and mechanical devices — to safely conduct maintenance. Some large bearings are manufactured with tapped holes in the face of the inner or outer rings to allow eyebolts or hoist rings to be inserted (Figure 1). Other bearings have threaded lifting holes in the cage ring that can be used to lift the inner ring assembly.

Thus, it is risky to assume that any one removal method or device will work for all bearings. Always be sure of the manufacturer's exact requirements for lifting large bearings, and exercise added caution when handling bearings that are equipped with a cage, as the cage tends to be the component of the bearing that is most deformable and susceptible to damage.

Lifting Large Bearings

Two ASME standards — BTH-1-2017 and B30.20-2018 — govern the lifting industry with concern to below-the-hook devices. In simple terms, ASME states that a below-the-hook lifting device is "a device used for attaching a load to a hoist. The device may contain components such as slings, hooks, and rigging hardware… " Bearing lifters fall into this category.

Most heavy industrial facilities own some type of lifting equipment, having used the same rig for decades or, in other cases, a fabricated solution that takes advantage of the available tooling at the plant. While these lifting fixtures may function effectively, many such legacy or custom-built devices may not adhere to today's lifting standards.

Investing in a purpose-built lifting assembly is a wise choice when it comes to large bearing maintenance, especially in plants where several bearing lifts a week are required. Two lifting devices are common across all industries — three-legged fixtures and sliding-foot fixtures (Figure 2). These fixtures can be used to remove bearings from the housing and reinstall them after completing maintenance.

Three-legged fixtures are used to lift the entire bearing or to handle one subassembly at a time while maintaining concentricity of the bearing components. Keep in mind that certain fixtures may work for certain types of bearings but not others. For instance, in an application where a bearing changes from an open to a sealed design, there is the potential for bearing seal damage to occur due to the length of the

Figure 1 Tapped or threaded holes in bearing faces allow attachment devices for safe, easy lifting.

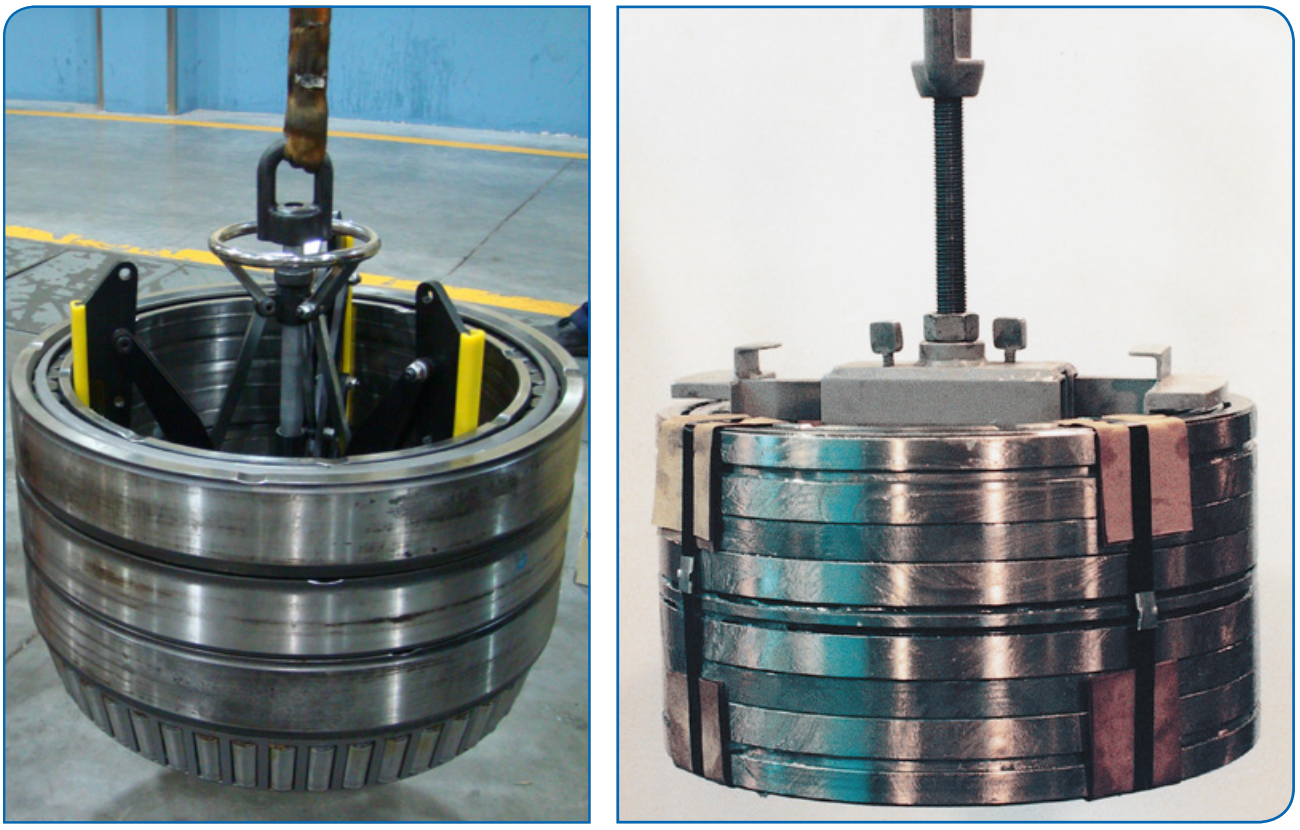

Figure 2 A three-legged (left) and sliding-foot fixture (right) for lifting complete bearing assemblies.

legs of the old fixture.

A sliding-foot fixture, meanwhile, engages the bottom row of the bearing assembly, allowing removal of the entire assembly at once, which can then be stacked outside the housing, thus reducing the risk for raceway damage to occur. This method does require ample overhead crane capacity and the availability of machined reliefs in the chock that will allow for the feet of the lifting fixture to properly engage the bottom row of the bearing assembly. Hence, the use of a sliding-foot fixture can be limited in some instances.

Bearing Features for Easy Lifting

As noted above, bearing features can make lifting individual components much easier and safer when removal of the entire assembly is not required. These features typically include tapped holes in the face of the bearing race for eyebolt and chain lifting, blind holes in the bore of the inner ring allowing the use of turnbuckle-style lifting devices.

It is advisable to consult bearing makers directly about the features that will provide the optimal lifting arrangement for a given application. Depending on the bearing design, adding lifting features may in fact compromise a bearing's integrity. At the same time, proper lifting practices are essential for safe handling.

Consider what can happen when correct procedures are not followed, where a large four-row cylindrical roller bearing having eight tapped lifting holes in the cage (set up as four pairs to accommodate a crossbar through the eyebolts) is lifted using only two eyebolts, causing fracturing of the welds that join the roller pins to the cage. This can require the assembly to be repaired before the bearing can be used again, or where damage is severe, the assembly may even come apart, causing components to fall to the ground.

Also, be sure to lift bearings only from a level, stationary position to avoid potential problems. During installation, for example, large bearings are sometimes propped at an angle or may be resting against a table in preparation for handling. Hence, the eyebolts may not bear the load of the lifting chain evenly, which can result in broken eyebolts and stripped lifting holes, creating a serious safety hazard.

A Little Care Goes a Long Way

It is critical to follow proper lifting practices for large bearings to attain reliable operation with the lowest possible ownership cost. Tools for lifting bearing components and assemblies should be evaluated during the early stages of a facility upgrade or maintenance cycle, and plant technicians should engage bearing makers in conversation about product modifications that can make their lives easier. With simple planning, additional safe handling features can be implemented before bearings are shipped and installed, saving potentially tens of thousands of dollars for every accident or incident avoided. **PTE**

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NORD Gear

Offers Drive Solutions for Intelligent Brewing

The following article examines two breweries—one in Hamburg, Germany, the other outside of Madison, Wisconsin—that utilized drive solutions from NORD to optimize their facilities. Worm, bevel, and parallel shaft gear units were installed to provide the necessary process control needed to maintain the highest quality at both locations.

Landgang Brewery

The Landgang Brewery—headquartered at Hamburg, Germany—specializes in brewing craft beer. The wide variety of craft beers comprises top and bottom fermented varieties – pilsner, ale, porter, stout and non-alcoholic beer. Additionally, the brewery develops beers for customers. All beers – "Helle Aufregung," "Weizheit," "Dunkle Macht," "Prollbock," or "Tutti Frutti" – are brewed, bottled, served fresh on draught and sold on site at the Landgang brewery.

Project Requirements

Like most craft beer producers, Landgang started out as a brewery without their own production background, a so-called gypsy brewery. As Landgang's products were well received and as sales volume increased rapidly the decision to establish a dedicated brewery was made. Rabek Engineering, a specialist company for high-quality, fully functional breweries, was responsible for the design and construction of the facility.

NORD was brought in to provide a variety of solutions for the brewery including: intelligent drives to reliably support management, angled gear units (worm and bevel) as well as parallel shaft gear units to assist in malt transport from storage to the brewhouse, parallel shaft gear units and bevel gear units for the Mash Tun (used in the mashing process to convert the starches in crushed grains into sugars for fermentation) as well as parallel shaft, helical gear units and bevel gear units for the Lauter Turn (a vessel for separating the wort from the solids of the mash, working much like a large sieve).

"NORD control units constantly adjust the system performance according to recipe specifications regarding consistency and weight of the ingredients. Absolute process control is guaranteed at any time," said Gabriel Rabek, proprietor of Rabek Engineering GmbH.

Traditional art of brewing and cutting-edge technology.

Each recipe requires different specifications on the brewing system and thus on the drives. In the Mash Tun, for instance, the agitator has to adapt to the different combinations of ingredients with their specific densities and volume changes. Even before the actual brewing, the process depends on the drive unit. It carefully controls the malt grinder so that husks are preserved during crushing, and can later perform their filtering function. A tube chain conveyor driven by a powerful NORD gearmotor gently transports the crushed grains into the brewhouse.

Individually configured inverter

In order to prevent the mixture from settling on the bottom, it is stirred continuously and carefully. Given the large weight, a drive designed for high loads with variably controllable speed is required. Additionally, the built-in individual frequency inverter makes sure that the different types of movement of the blade and agitator, such as lifting, lowering and rotating, can be decoupled. For this purpose, the drive unit was equipped with a hollow shaft. This special version facilitates the flexible combination of movements according to the recipe.

Application Solution

Dependable, low-maintenance brewery technology is the alpha and omega for consistently high beer quality and delivery reliability. Intelligent NORD drives significantly support the automation of the brewing process and manage the recipe diversity at the Landgang Brewery. During continuous operation, they ensure the products exceptional flavor and consistent quality all year-long.

Recipe-based production with NORD drive technology

All ingredients are fully prepared and processed automatically. The brewhouse is equipped with decentralized, intelligent NORD drives so it can be operated precisely. The drives are located where specific functions are required. The PLC implemented in the frequency inverter controls each drive unit individually. Each drive retrieves the applicable motion sequences for the respective recipes and adjusts them to the current weight and volume of the ingredients.

Reliable for the entire life of the brewery

NORD DRIVESYSTEMS has been providing drives for the food and beverage industry for many years. The NORD modular product range offers scalable electronics, motors and

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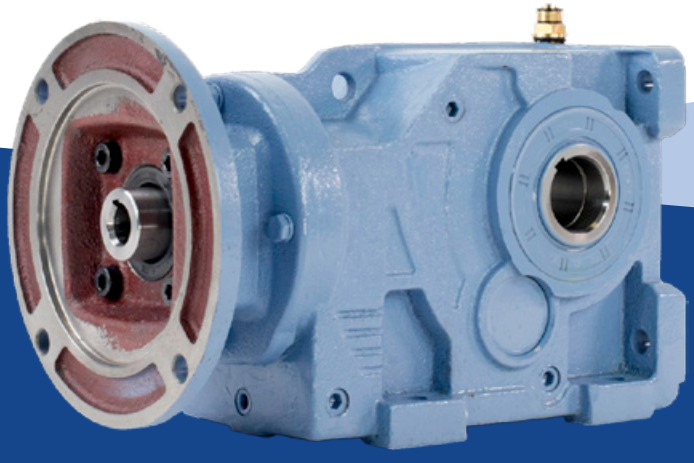

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drive units which can be combined to form customized drive modules for every application. Thus, they are always reliable during their long service life.

Octopi Brewing

As the demand for craft beer continues to grow, there has been a shift for brewers to begin turning to contract breweries as a cost effective alternative brewing option to help them break into the fast growing craft brewing market. Not only do contract breweries help reduce the cost of rent and eliminate high equipment purchase costs for new craft breweries, there are also many environmental advantages to having production closer to all the various places of demand.

Octopi Brewing, the leading contract brewery in the Midwest, recently opened a brand new 18,000 square foot brewhouse in Waunakee, WI (just outside of Madison). With state of the art equipment and skilled staff, Octopi Brewing is not only involved in the brewing process, they also provide comprehensive consulting and strategy development on how to succeed in the craft brewing world.

Octopi Brewing has three main goals; first is to produce high quality beer for new brands, existing breweries at capacity, and hospitality chains looking to develop their own brand. Second is to be the first ever contract brewery to offer a comprehensive range of services in brand development from concept to creation. And lastly to offer unparalleled customer service and brew beer with state of the art equipment catering directly to the needs of the modern craft brewer.

Isaac Showaki, president of Octopi Brewing, knows firsthand what it is like to not have control over your beer and your brand – having relied solely on contract brewers back in 2012 while launching his first brewery in Chicago.

Showaki holds Octopi to the gold-standard in contract brewing and enjoys helping each brand Octopi works with succeed in the craft beer community.

"We are really a one stop shop," said Showaki. "We're able to answer questions on marketing, design, distribution, accounting, brewing and working commercially. Our customer's success is our success. We really want to help young brewers get going."

Located in the same industrial park as Octopi is the U.S. headquarters of NORD Gear Corporation, a manufacturer of gearmotors, speed reducers, electric motors and AC Vector Drives.

NORD has been involved in the craft brewing industry for years, and was pleased to discover not only that the contract brewery was being built in the same industrial park, but also that a NORD SK9072.1 Helical Bevel and SK4282 Parallel Shaft clincher, each with a five hp motor, were turning the rakes in the Lauter Tun and rotating the agitator in the Mash Tun. "Of all the equipment we have, it's the best. It's reliable. It's been able to handle everything we've thrown at it, and we've really pushed the limits," said Showaki regarding the Mash and Lauter Tuns. Depending on the batch, Octopi will put anywhere from 2,000 to 4,000 pounds of grain into the Mash Tun, and it is critical that the equipment operates flawlessly to ensure the timeliness and quality of the beer they are brewing.

Additional Resources

NORD offers a variety of other components that can be utilized successfully in the food and beverage industry.

NORD's NSDtupH Sealed Surface Conversion System offers a cost effective weight saving alternative to stainless steel reducers. Through a revolutionary process, the aluminum alloy reducer housing and components are electrically catalyzed resulting in a molecular surface conversion. NSDtupH is exceptionally chemical, corrosion and abrasion resistant. The converted surface becomes very scratch resistant as it is 6-7 times harder than the original aluminum alloy as a result of this process.

The availability of either a decentralized or centralized VFD control is another advantage of the NORD solution. The SK200E, SK180E and the new SK135E AC Vector Drive series are all designed to be used in a distributed control topology. Each series has its unique benefits and advantages. When the drive is motor mounted, it replaces the motor's terminal box to create a combined, fully integrated motor/drive. Eliminating the need for expensive central control cabinets and costly wiring runs, distributed control VFD's offer a sustainable cost savings, decrease installation time and keep labor costs associated to a minimum. System modifications and upgrades are very inexpensive.

Several variations of NORD's heavy duty, spread bearing design are also available for reliable, worry free mixing. Each design offers additional features and advantages along with an increased degree of leak safety.

NORD has also expanded its motor portfolio to include smooth surface motors to provide a cost-effective, lightweight and easy to clean solution ideal for the beverage industry and applications where sanitation and cleanliness are essential. **PTE**

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Power Transmission Engineering
gear TECHNOLOGY

Gearbox Development for the Food and Beverage Processing Industry

Sandeep V. Thube

Introduction

The importance of Food and Beverage (F&B)-related businesses to the gear industry cannot be emphasized enough. The F&B industry has generated 11% ($1.2 billion) of total geared product revenue in 2016 (Ref. 1). The machinery demand driven by the general population will continue to grow so as to serve the increased consumption of processed and packaged food.

Food safety is the paramount concern for F&B industry; about one in six Americans are affected by food-borne diseases (Ref. 2). A study attributed by USDA's Food Safety and Inspection Services (FSIS) shows that *Salmonella, Listeria monocytogenes (Lm),* and *E.Coli O157:H7* are the most common bacterial pathogens to cause foodborne illness in ready-to-eat products that are mainly categorized under meat, poultry and dairy (Ref. 3). Food processing- and packaging-related practices are regulated by federal and state bodies; among them are the FDA (Food and Drug Administration), USDA (United States Department of Agriculture), NSF (National Sanitation Foundation), and 3A sanitary standards. The recently implemented FDA Food Safety Modernization Act (FSMA) dictates aggressive steps to curb such diseases in early stages. NSF standards establish minimum food safety and sanitation requirements for design, construction, materials and cleanability of food handling and processing equipment (Refs. 4–5). All these regulations uphold the best food safety industry practices and protocols, the compliance of which protects the manufacturers from penalties and product recalls.

Leaders in the F&B industry prefer equipment built with stainless steel material because of its versatility, including its corrosion resistance properties. Stainless steel withstands the chemicals utilized in cleaning and sanitizing procedures adopted by the industry.

The motivation of this paper is to understand and discuss the gearing system feature requirements for F&B equipment, and efficiently adopt those features in an existing gearbox currently offered by the company (Ref. 6). This paper describes a redesign approach to develop a new gearbox product that meets requirements laid down by food safety regulations. The existing gearbox design is analyzed against the needs and innovation using QFD, FMEA, FEA and 3-D printing tools. The selection and redesign of components shown in Figure 1 is the objective of this paper. The next section briefly describes the background of the product development method utilized to accomplish the mentioned objective.

Literature Survey

In the late 1960s, Japanese administration invested in finding a system to ensure that the final product would be linked to satisfying customer requirement. The outcome of it, called Quality Function Deployment (QFD), was implemented in building supertankers (Ref. 7). This method was perfected in later years, and adopted by Japanese as well as American industries. QFD is used to determine and focus on the essential functionality features of the product. It is usually implemented in the early stages of product development. It is a well-known communication and brainstorming tool (Ref. 8).

Failure Mode and Effect Analysis (FMEA) is a quality tool utilized for analyzing failure modes against the functionalities of the product. It was developed in the 1950s by reliability engineers to solve issues in military systems (Ref. 9). This

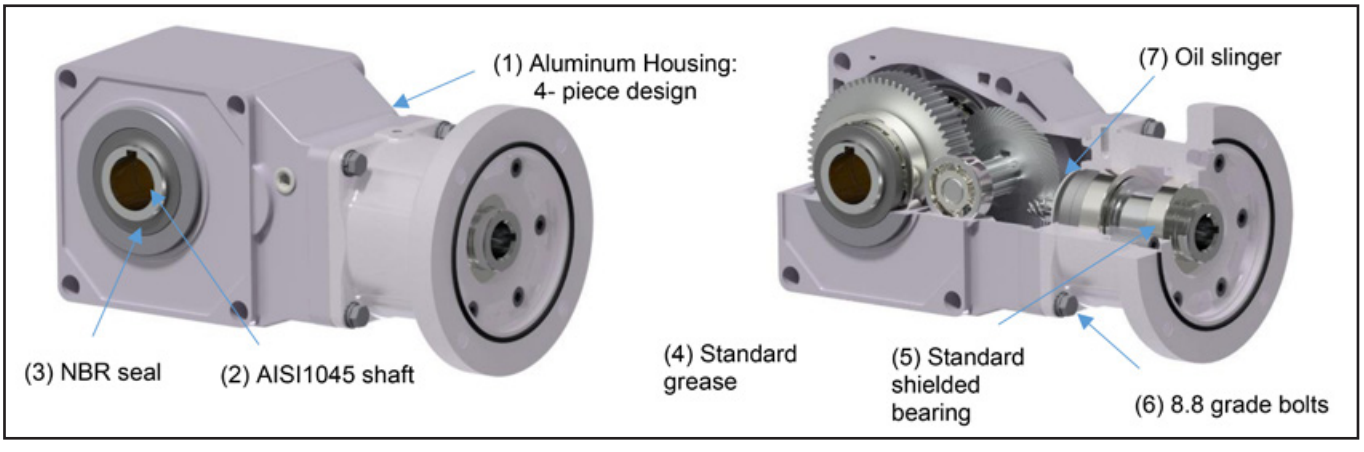


Figure 1 Existing gearbox to be redesigned for F&B applications.

tool is known for achieving high reliability in both, products and processes (Ref. 10). The main procedural steps of FMEA are defined as follows:

1. Clarify function of each system, component, or process elements.
2. Investigate root cause, failure modes and failure probability based on the function, interaction with other components, and environment.
3. Study the effects of problems, and prioritize casual factors.
4. Recommend actions.

Regarding QFD and FMEA, both tools require a systematic process to define 'what' and 'how' (cause and effect) relationship, and prioritize them. They tend to shift the cost, efforts and discovered problems away from the product launch timing (Fig. 2).They both assess technical details to identify further actions and recommend testing. Both demand cross-functional teamwork and contributions for successful implementation. The distinct difference in these two techniques is at what product development stage they are implemented. The FMEA approach is more production-oriented, and QFD is generally used in early stage (planning) of the product development cycle.

Ginn, D.M. et.al. discusses a methodology of integrating QFD and FMEA tools at conceptual, planning, design and processing stages of the product development (Ref. 11). The paper adopts this methodology and elaborates the simultaneous use of both tools at each stage.

As shown (Fig. 3), FMEA and QFD are interlinked at each

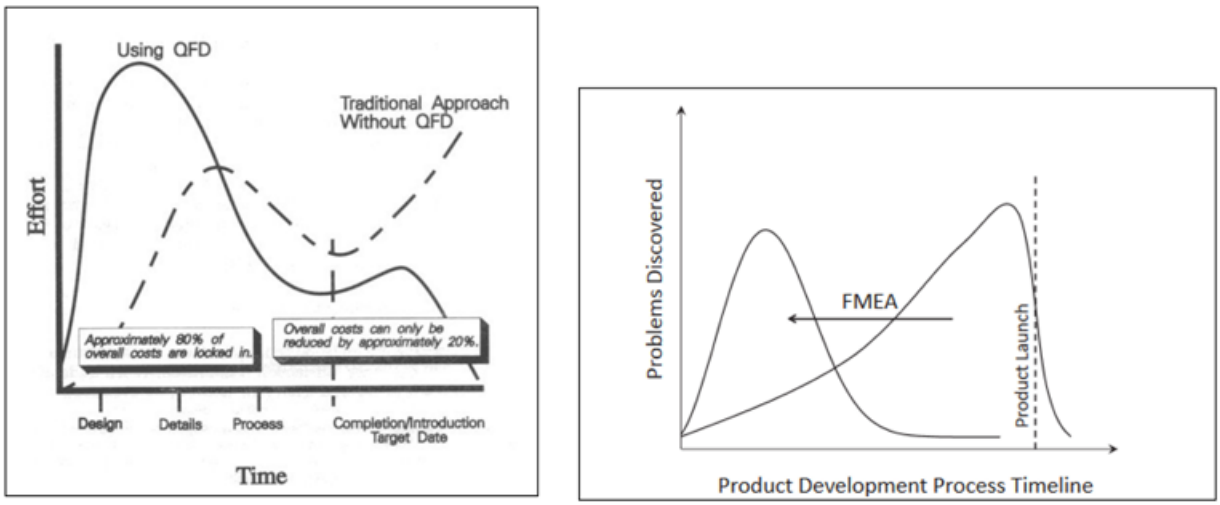


Figure 2 QFD & FMEA tend to shift development efforts and discovered problems towards earlier stages (away from product launch) (Refs. 7, 10).

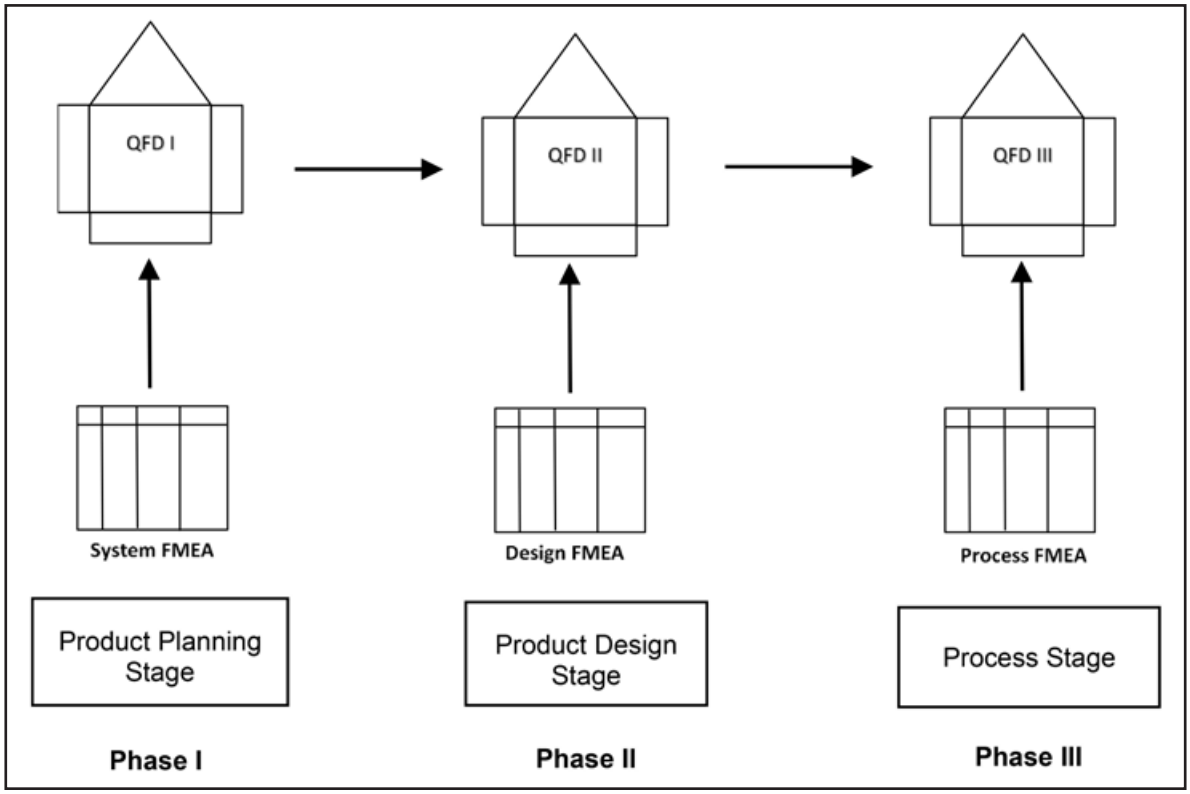


Figure 3 Integration of FMEA and QFD at each product development phase.

Table 1 QFD I - Product Planning

	Column #	1	2	3	4	5	6	7	9
	Direction of improvement Minimize (▼), Maximize (▲) or Target (x)	x	▼	▼	▲	▲	x	x	x
Weight/ Importance	Technical requirement ("Hows") / Application requirement ("Whats")	Housing material: Stainless steel OR Composite	Optimized lubricant (Grease) quantity	Thermal rating greater than Mechanical rating	Torque/ Weight ratio	No outer cavities on housing	Bolt holes at Bottom	Bolt holes at casing Face	Externally visible components - NSF complied
10	Corrosion Resistance/ NSF Compliance	9	3			9			9
9	Light Weight (for shaft mount)	9	1		9				
7	Multiple mounting options					3	9	9	
7	Cleaning friendly housing contour	1				9	1	1	
9	Acceptable housing surface temperature	9	9	9		1			
8	Adequate surface roughness for cleaning	3				1			
5	Torque capacity up to 2000 in-lbs	3		3	9				
9	Market level cost	9							
9	IP69K standard Certified	3				3			

stage of the product development cycle. QFD evaluates and determines the options and features to be incorporated into the product, and FMEA checks for the failure modes. Accepted features from FMEA process are considered for the next stage.

Table 2 Physical property difference between existing and new casing material

Property	Unit	Existing casing material: Die Cast Aluminum (ADC12)	Proposed Casing Material	
			Cast stainless steel (CF8)	Composite (Custom made)
Density	Kg/m^3	2760	7750	~1600
Mod. of Elasticity	$MPa \times 10^3$	71	193	11
Yield strength		165	205	-
Ultimate strength		331	485	~200
Thermal conductivity	W/m-°K	92	20.94	~4

Product Development — Phase I

The important 'requirement' related to food safety regulations is food contact materials, i.e. — the surfaces which directly or incidentally come in contact with the food. These surfaces should be smooth, non-porous, durable, and free from corrosion, pits or food particle accumulation. Food contact materials classification basically applies to the external surface(s) of the gearbox. External surface area exposed to the outer environment comprises of casing, shaft, hardware and seals. Washdown requirements defined with IP69K (Ingress Protection standard to rate the resistance to dust and high-pressure wash) are derived from industry practices. Torque range and mounting options (foot and shaft mount) are finalized from market research and competition offerings.

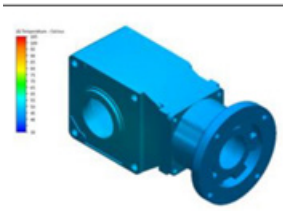
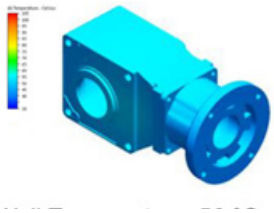
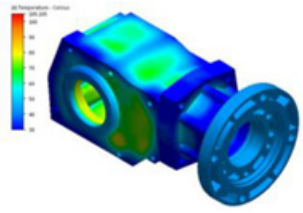
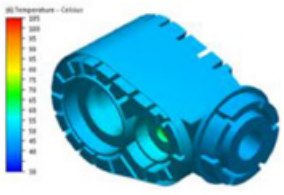
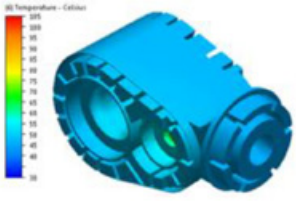
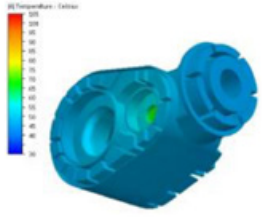
The existing gearbox meets the torque range requirement, but shows deficiencies in offering mounting options, and aforementioned properties required for food contact materials.

In product planning QFD (Table 1), different ideas and

Table 4 System FMEA

ITEM	Function	Potential Failure Mode	Effect of Failure	Severity	Potential Cause(s) of Failure
Gearbox must provide features required for food equipment, in compliance with food safety regulations	Provide corrosion resistance	Corrosion Crevice corrosion	Fatigue; Health hazard	9	Casing surface corrosion due to chemical washdown
	Sanitary equipment design (Ease of cleaning)	Accumulation of food particles	bacteria growth in cavities; Health hazard	10	Existence of surface cavities
	Keep gear lubricant contained from food	Lubricant leakage	Food contamination	10	Seal leakage
	Provide appropriate speed and torque	Cannot operate the application	Economical loss	10	Internal component (viz. gear, bearing, shaft) seized or failed
	Mounting options	Does not meet F&B application requirements for mounting	Not appropriate for installation	7	Mounting versatility not available
	Connect to equipment shaft	Does not meet F&B application requirements for mounting	Not appropriate for installation	5	Shaft connection options not available

Table 3 Comparison of CFD analyses for casing surface and lubricant temperatures

Thermal analysis (at ambient 20°C)	**Existing AL material**	**CF8 Stainless steel** (Analysis performed on existing design)	**Composite** (Analysis performed on preliminary design)
Casing surface temperature	 Wall Temperature: 48°C	 Wall Temperature: 56°C	 Wall Temperature: 64°C
Lubricant temperature	 Wall Temperature: 50°C	 Wall Temperature: 62°C	 Wall Temperature: 94°C

suggestions, influencing directly or indirectly the defined requirements, are brainstormed. They are weighed based on their influence, either 9 (strong relation), or 3 (moderate relation), or 1 (weak relation). These relations are decided by a cross-functional team, which is formed by the members of multiple departments. Stainless steel and composite are two casing material options shortlisted and proposed to replace existing aluminum alloy ADC12 (die cast aluminum). In comparison with ADC12, the proposed materials may offer better corrosion resistance, but they lag in providing equivalent thermal conductivity (Ref. 12). In the composite material option, both thermal conductivity and material strength are in question. Material strength cannot be easily analyzed (analytically or numerically) because of an anisotropic nature of the composite material.

At this early stage of the development, predicting behaviors of both materials under functional conditions, and picking the best suitable material for the next development phases would significantly impact valuable resources: development time and cost. Changing the material in later stages would reset the entire development cycle. Physical properties of the proposed materials and the existing casing are compared in Table 2.

Both material options are evaluated based on System FMEA recommendations and compared (Table 4). Though the composite material would provide better chemical resistance, it has scored less on providing appropriate structural strength and thermal conductivity, when checked with Finite Element Analysis (FEA). Table 3 shows the results of numerical analyses of thermal characteristics for different casing materials, using computational fluid dynamics (CFD).

Stainless steel is found more suitable to be utilized as a 'food contact material' in the gearbox system. For casting parts, such as housing, CF8 cast steel grade is selected. For

Occurrence	**Current design control**		**Detection**	**RPN**	**Recommended Actions**
	(Prevention)	**(Detection)**			
9	Aluminum casing (ADC12) with antimicrobial coating	Discoloration, Paint peeling, Cracking	4	324	Evaluate stainless steel and composite materials for corrosion resistance, as well as to substitute existing Aluminum (compare strength, temperature).
8	None	Any outer cavity susceptible to bacterial growth	10	800	A. Redesign casing with 1. surface roughness of 125 micron 2. Consistent outer surface, absence of gaps B. Design mounting accessories without cavities. C. Hardware selection with no cavities.
6	Appropriate seal installation	Visual inspection	8	480	1. Select Food grade lubricant with NSF H1 rating 2. Select more robust seal for washdown application 3. Food grade gasket
2	Gearbox selection based on application (demand) torque and speed	Application stops running	2	40	No issues found with existing design. No action required.
5	Only shaft mount arrangement available	Customer survey	2	70	Develop flange and torque arm mounting options
5	Keyed hollow bore, Shrink disc connections available	Customer survey	2	50	Develop solid output shaft option

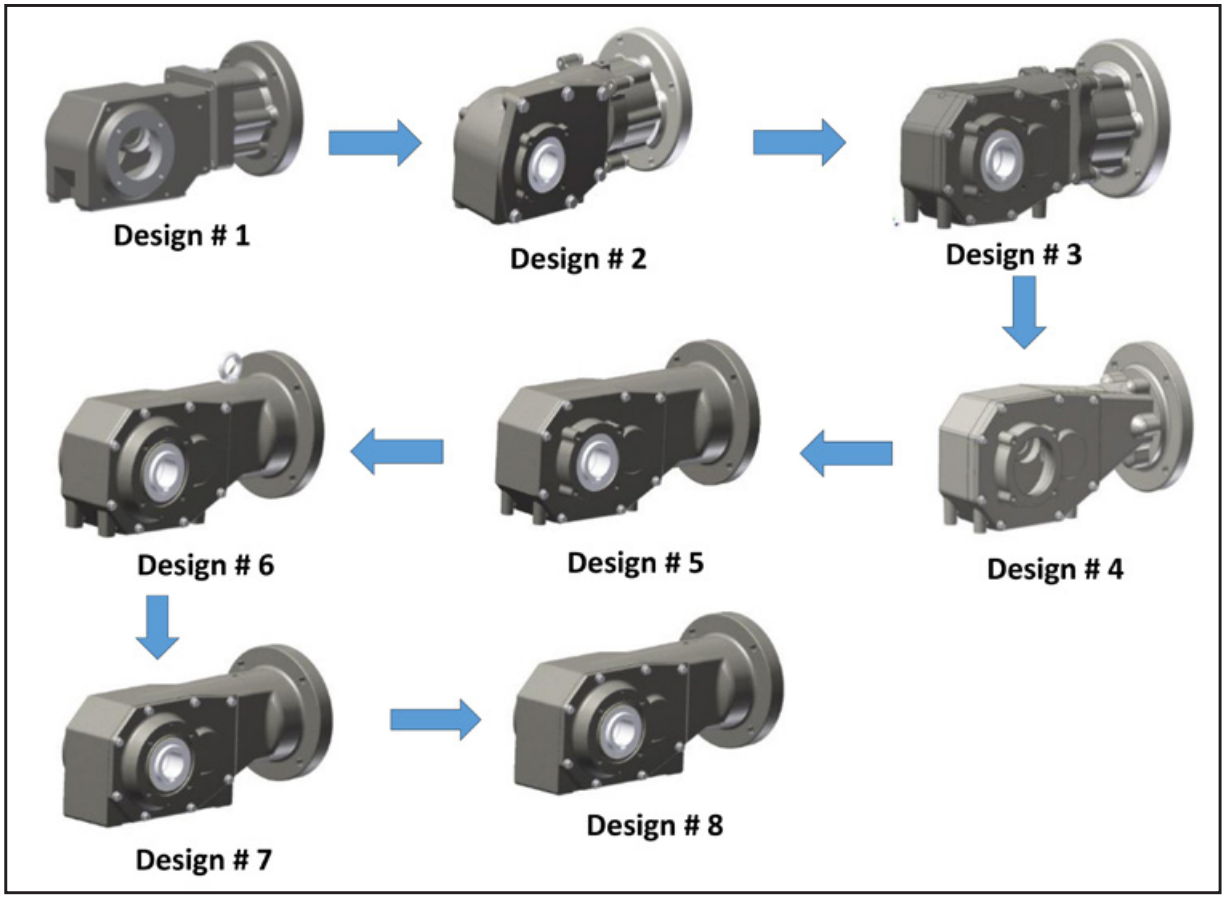


Figure 4 CAD models- From # 1, which is similar to the existing four-piece design, the casing evolved into a three-piece design on the 8th iteration.

Table 5 QFD II – Design

	Column #	1	2	3	4	5	6	7	8	9	10
	Direction of improvement Minimize (▼), Maximize (▲) or Target (x)	x	x	▲	x	x	x	x	x	x	▲
Weight/ Importance	Technical requirement ("Hows") / Application requirement ("Whats")	Investment Casting Process	Structure strengthening with ribs	Round-like shape/ contour	Corrosion resistant output shaft	Washdown resistant output Seal	Accessory- Floating Torque arm	Accessory- Flange	3- Part casing design	Food Grade Grease ZZ bearing	Additional SS parts
10	Housing material: Stainless steel	9	9	3		1	1	1	9		
8	Optimized lubricant (Grease) quantity		3	3		1			3	1	
7	Thermal rating greater than Mechanical rating										
7	Torque/ Weight ratio		9				1				
9	No outer cavities on housing	1		9					9		
6	Bolt holes at Bottom						9				
7	Bolt holes at casing Face							9			
9	Externally visible components - NSF complied				9					9	9
	Target or Limit Value	5 to 12 mm thk, 100 - 125 RMS roughness	2.5 SF over gear torque + dead weight	0.56 Kg	AISI 304	Cassette seal					

Table 6 Result of Design QFD

#	Part	Changes to existing gearbox assembly	
		New features/ parts	Existing features/ parts
1	Housing	Cast steel (CF8) housing parts (four piece)	Aluminum (ADC 12) housing parts (three piece)
2	Output connection	AISI 304 manufactured output shaft	AISI 1045 manufactured output shaft
3		Nickel plated shrink disc offering as an option	Standard shrink disc
4	Output seal	Cassette Seals: Food grade and washdown compatible	Standard double lip NBR seals
5	Lubricant	Food grade grease	Standard grease
6	Bearing	Food grade shielded bearings	Standard shielded bearings
7	Nameplate	Laser etched nameplate	Steel nameplate riveted on Housing
8	Plugs	Nylon (plastic) plugs: to plug unused housing holes	n/a
9	Hardware	Stainless steel bolts (hardware)	8.8 grade steel bolts
*	Accessory parts	Stainless steel floating torque arm	Do not exist
		Stainless steel output flange	

output shaft and hardware, wrought steel AISI 304 is chosen.

CF8-grade cast steel is selected because of its corrosion resistance property, availability and customers' acceptance. Stainless steel casting is considered 'corrosion resistant' when used in aqueous environments below 1,200°F. Low carbon content (below 0.2%) and higher chromium content (above 16%) used in chemical composition enhances corrosion resistance. The austenitic (CF) grade of this casting family is generally preferred for chemical, pharmaceutical, and food industries. CF grade is resistant to most of organic acids, compounds used in aforementioned industries. Corrosion resistance properties mainly come from a passive surface film that protects from the surrounding environment. This film is formulated and stabilized by maintaining the minimum amount of chromium content in the casting's chemical composition.

Stainless steel does not alter the taste, color or odor of the food when in contact with it for a prolonged period of time. This includes the use of stainless steel for food preparation, processing, transportation and storage. Stainless steel's resistance to several alkaline cleaning agents is proven. Several experiments show that the release of chromium and nickel under the influence of acids is very low or negligible (Ref. 13).

Other components exposed to the outer environment are also listed to be replaced. For instance, the seal can have better water and chemical resistance. The output shaft and mounting accessories could be modified to meet the same purpose.

With the existing design as a reference, different patterns, shapes and variations are created and reviewed. The most apt design for F&B application is chosen based on its emphasis on smooth contours, no external cavities or pockets, optimized weight, optimized internal volume, optimized machining area, and mounting arrangement considerations (Fig. 4).

Product Development Phase II

Part level QFD is performed after finalizing system level options with Product Planning QFD and System FMEA. 'Hows' from QFD I become 'whats' in QFD II to determine part characteristics (Table 5). In the redesign process, the list of items shown in Table 6 would be incorporated in the gearbox assembly.

Housing parts are developed such that the heat dissipation

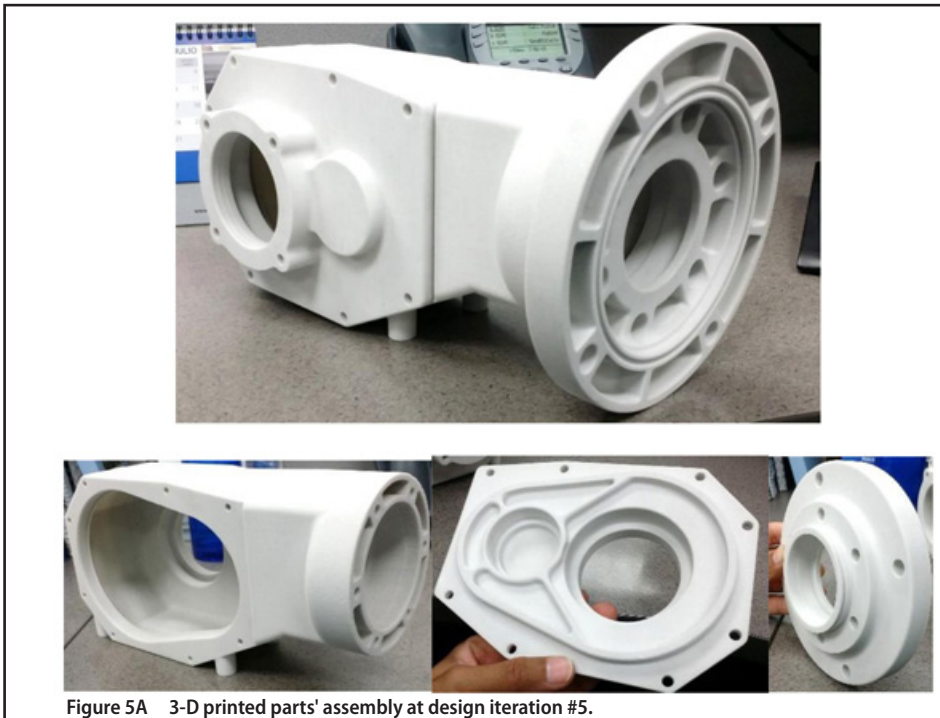


Figure 5A 3-D printed parts' assembly at design iteration #5.

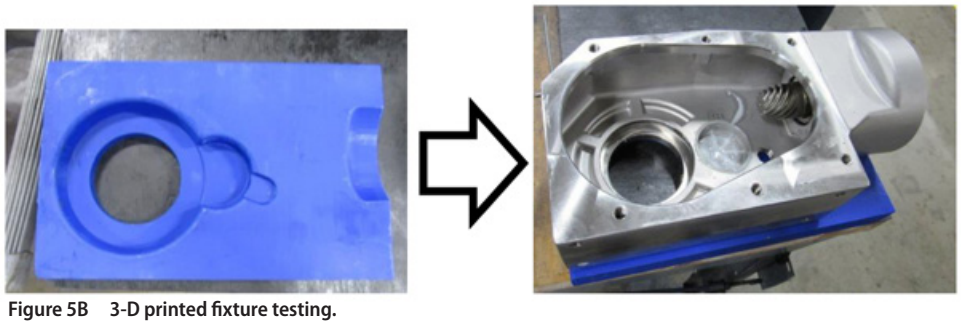


Figure 5B 3-D printed fixture testing.

Figure 5 Examples of the utilization of 3-D printed parts.

and weight increase issues would be addressed. Design FMEA is used to identify part level failure modes (Table 7). Effective system output produced by System FMEA will be used as an input for the design FMEA, which in turn becomes input for the process/assembly FMEA (Ref. 14). Before developing actual housing prototype parts for testing purposes, a digital prototype (Computer Aided Design, or CAD model) is iterated and refined with the help of 3-D printing tools and FEA.

3-D Printing

The 3-D printer processes STL format files of the components created using CAD software. 3-D printing of the parts, after each major iteration, has made it possible to reduce errors associated with the geometry of the new parts (Fig. 5A). CAD modeling validation and component assembly areas are particularly benefited by 3-D printing technology. For instance, in case of CAD modeling, a thorough inspection of 3-D printed part has revealed an extra length of a tapped hole located on the outer surface of the housing breaking into the internal cavity.

Table 7 Design FMEA for Cast stainless steel housing

ITEM	Function	Potential Failure Mode	Effect of Failure	Severity	Potential Cause(s) of Failure	
					Primary	Secondary
Housing parts (Casing, Cover, and Adapter)	Support Gear loading	Deformation under load	Lubricant leakage, Vibration, Bolt shearing	10	Demand Overload Motor Startup load	
					Insufficient static strength	Cast steel material property is inadequate
					Casing defect	Cast porosity
	Support reaction torque (torque arm connection, Flange connection)	Deformation under load	Lubricant leakage, Vibration, Bolt shearing	10	See 'Support Gear loading'	
	Support Bearing	Bearing looseness	Vibration and noise	7	Bearing spins in the bearing housing	Improper tolerance on bearing housing
						Inadequate Surface finish
	Heat Dissipation	Higher lubricant temperature	Shorten grease life (< 2000 hours) Hypoid pinion failure	9	Inadequate heat dissipation through Casing wall	Casing surface area
						Heat conduction of SS material
					Less airflow around Unit	Lack of forced convection
					Higher Ambient temperature	Less heat dissipation due to small temperature difference (ΔT)
			Higher internal pressure build-up		See potential causes of 'Shorten grease life'.	
		Freezing of lubricant (Grease)	Gearbox 'cold start' issue	10	Low ambient temperature	Lubricant's inadequate (higher) viscosity at low temperature
	Protect internal components from Environment	Seal failure	Lubricant leakage	10	Internal pressure	High lubricant temperature
					Temperature incompatibility	Seal material cannot withstand temperature
					High pressure washdown	
		O- ring (Cover) failure	Lubricant leakage	8	Internal pressure causes lubrication leakage	Improper fit in O-ring groove
	Provide alignment to the rotating parts	Component misalignment	Premature component wear out, Noise/ Vibration Fatigue	7	Out-of-tolerance casting machining	Deviation of tolerance from print
	Anchoring	Failure of mounting holes, part deformation	Equipment damage	10	Inadequate mounting hole pattern	High stresses generated in Assembly
	Provide required properties for F&B Application	Crevice corrosion Galvanic corrosion Pitting corrosion	Unfit for application	10	Inappropriate passivation on cast steel parts	
				8	Contact with 'not-recommended' chemicals	
		Stress corrosion	Premature (fatigue) failure	10	Prolong contact with Chlorides	
		Seal failure	Lubricant leakage		Loose oil seal OD fit	Inadequate surface friction
						Oil seal shrinkage due to chemical incompatibility
					Increase in internal pressure	High lubricant temperature
						High Grease to Air ratio inside the box

For gearbox assembly, 3-D-printed housing parts are used to identify assembly interference, and components' assembly sequence. Assembly testing and subsequent changes elaborated in Figure 12 are performed using 3-D printed parts. 3-D-printed assembly jigs and fixtures are developed and modified to test the process at each major iteration (Fig. 5B).

Finite Element Analysis

Finite Element Analysis (FEA) is an efficient way of carrying out part and assembly optimization on a variety of design options, helping to narrow down to the best fitted one. Structural, modal and thermal analyses are commonly performed utilizing this tool. However, the reliability of the results depends upon the assumptions made at the time of defining and building the analysis model. This tool undoubtedly helps to expedite through QFD and FMEA processes. The FMEA generated 'recommended actions' are validated through FEA before performing actual testing (see Table 7 as an example). Conclusions on each analysis can be drawn quickly to move along.

Tertiary	Occurrence	Designed Value		Detection	RPN	Recommended Action
		Measure	Criteria			
	5	Stiffness, Stress	Support Assembly inertia, and minimum 250% motor torque.	9	450	FEA validation
	6			9	540	
	5	Number of sand holes per area	Max. 2 sand holes on a machined surface	5	250	UT sampling
Design defect	4	Bearing-housing fit	Prototype parts' tolerance study	5	140	Vibration test
	4	Surface finish	125 micron (check manufacturer's recommendation)	6	168	Surface roughness testing
-	7	Surface area	Min. 2000 hour grease life	9	567	Life test
	7	N/A				N/A
Absence of motor fan	6		Motor fan mandatory in worst case	10	540	Thermal testing
	6	Ambient temperature	Maximum ambient temperature 40 °C	9	486	Thermal testing
	3	Lubricant viscosity	Viscosity < 9000 cSt at a given min. temperature	6	180	Viscosity calculation/ Testing
	5	Internal pressure	5 - 7 PSI pressure	8	400	Testing
	5	Seal material	Compatible to temperature range 20°F to 104°F	7	350	Testing
	5	Pressure wash	IP69K ingress protection	7	350	Test to qualify IP69K
Wrong O-ring selection	2	Internal pressure	5 - 7 PSI pressure	8	128	Air Pressure test
Machining vendor cannot meet the tolerance requirement.	7	Tolerance	within 50 micron	8	392	Review of PPAP process
	4	Material stiffness	Support Assembly inertia, and minimum 250% motor torque.	5	200	FEA validation
	3		Passivation per ASTM A967	2	60	Salt Spray test per ASTM B117 standard, as defined in NSF/ANSI 51
	7		Define 'compatible' chemicals for washdown	2	112	Mention in Operation and maintenance manual.
	6			2	120	
	5		Housing bore machining roughness	6	270	
	4		Define 'compatible' chemicals	8	288	
	2		200°F maximum	5	180	
	2			4	72	

Finite Element Method solves problems numerically by discretizing or meshing the structure. In Computer Aided Design (CAD) based finite element analysis (FEA), solid model geometries are usually imported directly in FEA environment and analyzed for critical stresses and deformations under specific loading conditions.

In system FMEA, at the conceptual design stage of the product development, composite and stainless steel (cast steel) materials are investigated for F&B application. Stainless steel is chosen to develop the housing for phase II. This material brings higher structural strength compared to existing aluminum material, along with less heat conductivity. In the redesigning process, the housing wall thickness is optimized to balance the heat dissipation and the structural strength. The FEA results are considered for the housing strength; however, the heat dissipation is validated from the actual testing. It is observed that the temperature related numerical results (from the CFD tool) depend upon multiple and complex assumptions, and not precise enough to be considered in the final decision making.

FEA is performed with two models. In the first one, bearing loads are determined by running dynamic (geometrically

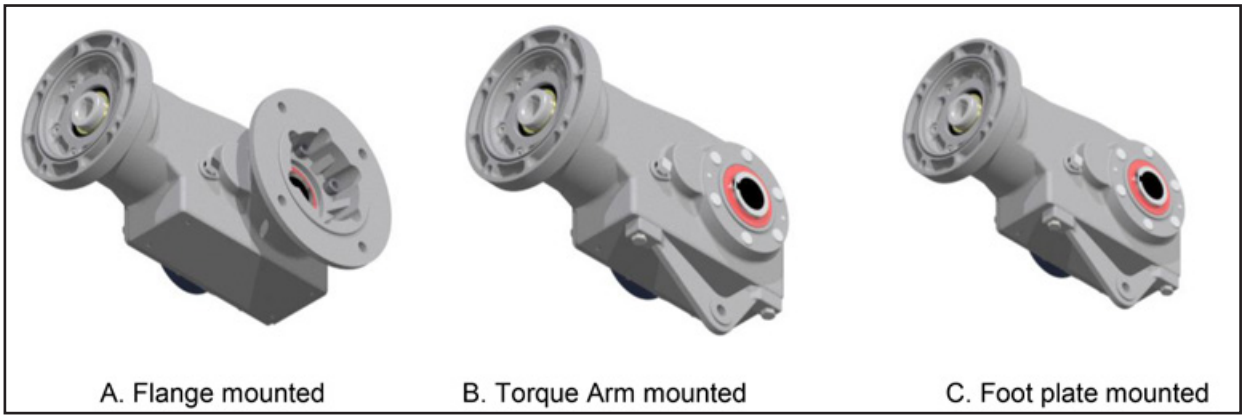


Figure 6 Development of gearbox mounting options.

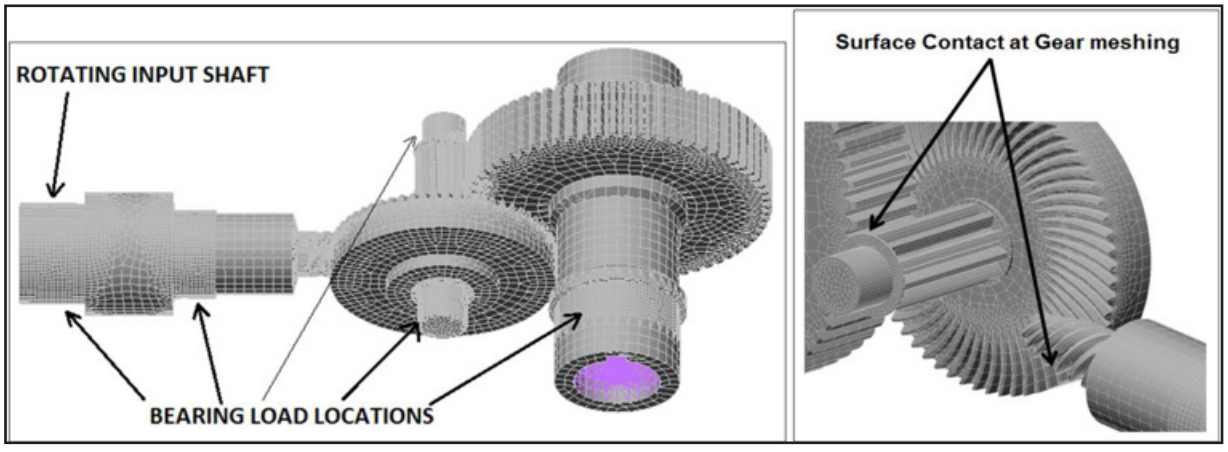


Figure 7 Meshing of internal parts' assembly, and gear meshing surface refinement.

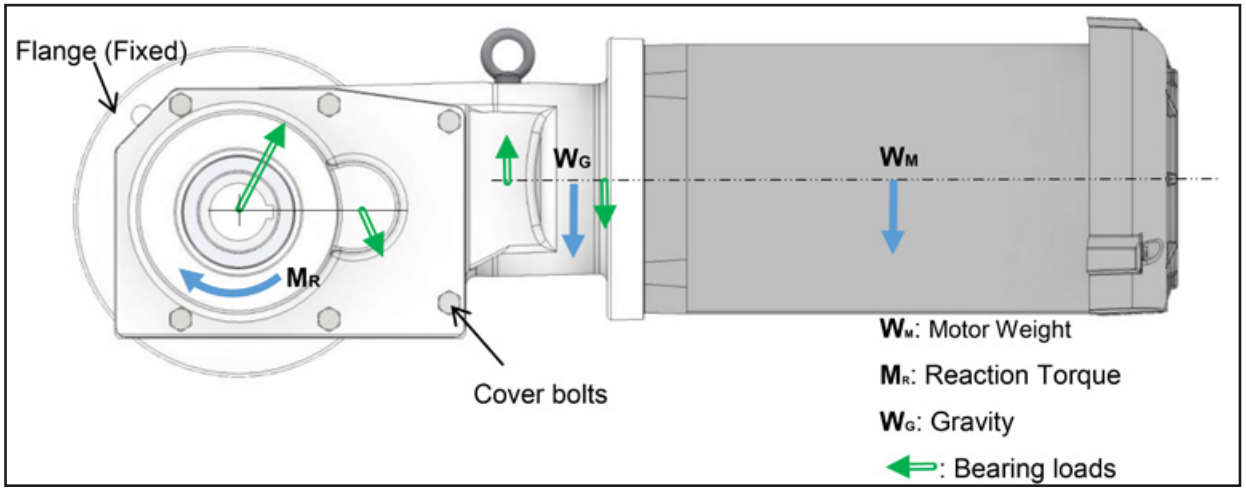


Figure 8 Loads acting on flange-mounted horizontal gearbox.

nonlinear) analysis. In the second model, the determined bearing loads are applied to stainless steel casing parts to find Von Mises stresses and deformations. The second model is simulated in a static analysis environment.

Table 8 Loads on the casing parts

	Load	Description	Acting at
1	Motor Weight	Largest motor (145TC frame size)	C.G. of motor
2	Bearing radial loads	Imported from dynamic FEA (model 1)	Casing bearing seats
3	Reaction Torque	Based on % of motor torque and gearbox reduction ratio	About axis of output shaft

Model 1: Determination of bearing loads. In this first part of the analysis, the load carrying internal components' assembly (comprised of shafts and gears) is imported to the FEA environment from 3D CAD format. This assembly excludes the casing parts, as shown in Figure 7. The goal is to calculate the loads imposed in the gearbox system by the motor running at full load condition.

Relative positions of all parts are exactly similar when assembled in the casing. The bearing load locations shown in Figure 7 are constrained radially to calculate the loads imposed by gearing movements. While setting up the model, each reduction stage is assigned with its respective rotational speeds, named as initial velocities. For example, initial velocity of high speed shaft (HSS) is 1,800 rpm; whereas the intermediate shaft runs at 180 rpm. In order to induce motion into the model, the HSS is forced to rotate at continuous speed of 1 revolution in 0.033 seconds (defined as 'prescribed displacement'). The simulation duration is set for 3 complete rotations of the HSS. The contacts (surface-to-surface) are defined between gears (hypoid pinion & gear, and intermediate shaft and spur gear) to transmit the motion from one stage to another. For precise gear engagement, the fine meshing is assigned at contact surfaces. To depict full load condition, full load torque is applied on the low speed shaft (LSS).

Model 2: FEA of stainless steel parts' assembly. In the second part of the simulation, bearing loads calculated in model 1 are applied to the bearing seats of the housing components which are held together by fasteners. The calculated bearing load is a vector quantity; therefore, all loads are assigned in specific directions.

Flange, or face mounted reducer is identified as a critical load case in which the maximum loading is shared by the housing components and the bolts (Fig. 6A). Figure 8 and Table 8 elaborate the load locations and magnitudes.

The following assumptions are considered while building this model set-up:

1. The bearing load is applied in parabolic distribution on the cylindrical surface of the bearing seats.
2. Coefficient of friction between all mating surfaces, including bolt threads is 0.2.
3. CF8 (cast steel) and wrought stainless steel are defined as isotropic materials.
4. The model simulates static analysis with utilization of bearing load calculated from dynamic simulation.
5. Bolts are preloaded before applying the loads from Table 8; the preloading values are determined based on the proof stress.

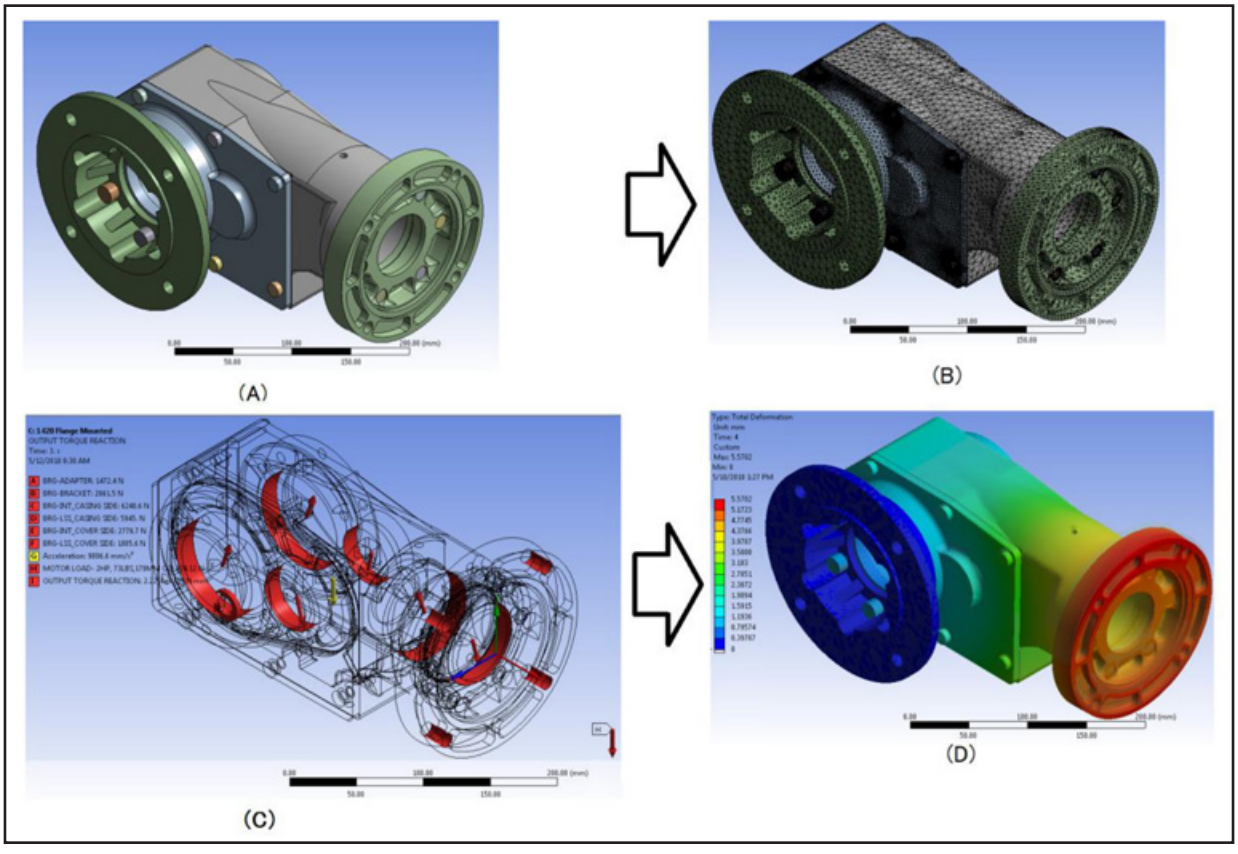


Figure 9 Finite Element Analysis Flow: (A) Geometry cleaning, (B) Meshing, (C) Loading, (D) Simulation.

6. For flange mount condition, only face bolt holes constrained in all degrees of freedom ('fixed').

Frictional contact between mating surfaces makes the model non-linear. The complete model is formulated with 1,188,563 nodes and 539,528 three-dimensional elements (SOLID186, SOLID187) (Ref. 15). The mesh density is optimized to alleviate its effect on the variation of result values within 5%.Figure 9 shows the FEA details and general sequence of the model building.

After running simulations, results are analyzed for higher stresses and displacements. The size of the cover bolts is selected such that the bolts would sustain the motor weight, the gearbox weight, and the bearing loads generated from at least 250% of motor torque. In other words, the mentioned loads would not overcome the clamping forces of the bolts.

Selection of other features. In reference to Table 6, output shaft material, output seal type, lubricant, shielded bearing lubricant, nameplate and plug are substituted. The output seal is substituted with cassette type seal which comprises of a two-piece metal stainless steel metal case (Fig. 10). This type of radial seal provides better resistance in washdown applications.

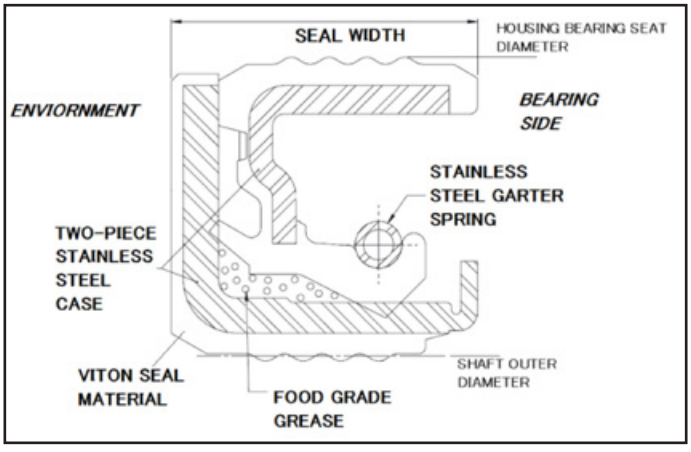


Figure 10 Cassette-type radial oil seal.

Table 9 Lubricant and maximum housing surface temperature comparisons

Temperatures	Unit 1 (Lowest ratio)		Unit 2 (Highest ratio)	
	Aluminum	Stainless	Aluminum	Stainless
Ambient	20	20	20	20
Housing surface (max. temperature area)	59.5	65.9	47.5	57

(in deg. Celsius)

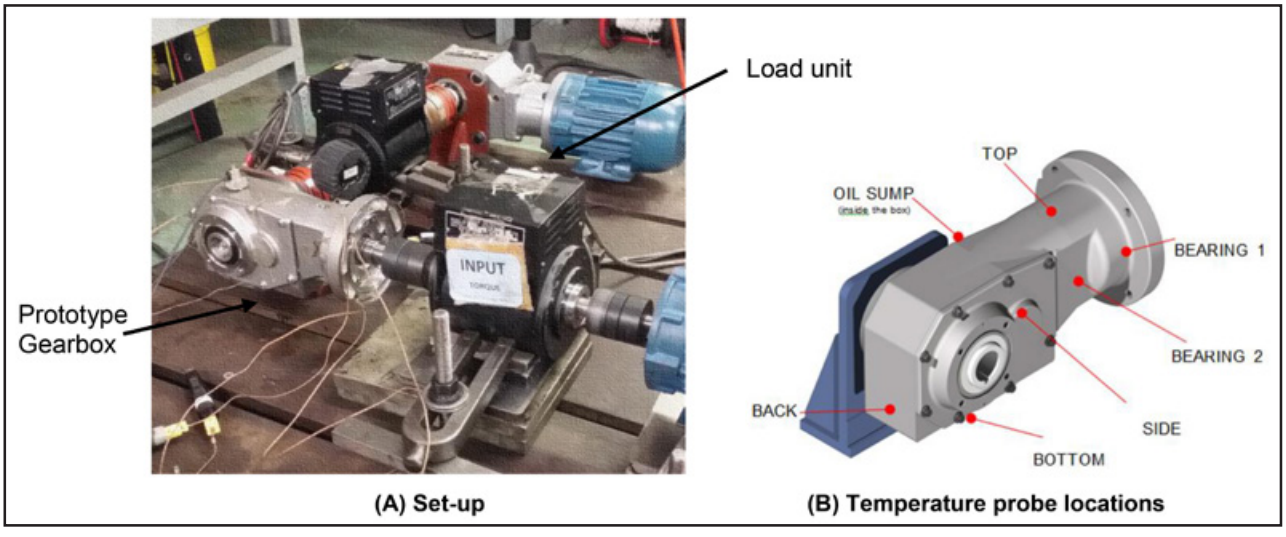


Figure 11 Prototype test setup.

Table 10 Process FMEA for Oil slinger assembly

Assembly Sequence #	Process Function	Potential Failure Mode	Effect of Failure	Severity
1	Install High speed shaft subassembly	none		
2	Heat oil slinger with Torch	none		
3	Slide the slinger on the subassembly from casing side opening	Cannot slide as it loses the heat before installation. Difficulty in installation.	**Process Effect:** Longer assembly TAKT time. Improper installation. **Product Effect:** Lubricant leakage	8
4	Install snap ring using pliers	Cannot access snap ring with pliers	**Process Effect:** Longer assembly TAKT time. Improper installation. **Product Effect:** loosening of oil slinger when product is in operation	9

As the lubricant effect gearbox lubricant changes from standard to the food grade-compliant, one has conducted physical testing to evaluate the lubricant's suitability for gears, bearings and overall temperature.

Physical Prototype Testing

Surface temperature validation of the gearbox housing has been determined as a primary purpose of performing physical prototype testing. Additionally, assembly validation, influence of cleaning and sanitizing chemical (used in washdown applications) and field testing are other items achieved from the prototype (Fig. 11). Product is finalized after second iteration of the physical prototype. Salt spray test and ingress protection tests are also followed.

Product Development Phase III

Digital and physical prototypes are iterated and finalized in the previous development phase. This phase focuses on qualifying the final prototype parts for production and assembly. Process FMEA is utilized to identify and act on the potential failures originated from the parts' manufacturing and product assembly.

As an example, the change from four-piece casing design to three-piece design is required to validate the existing assembly process. With FMEA (Table 10) and Figure 12, the paper illustrates the changes made in Oil slinger design and assembly for the ease of installation and assembly TAKT time improvement.

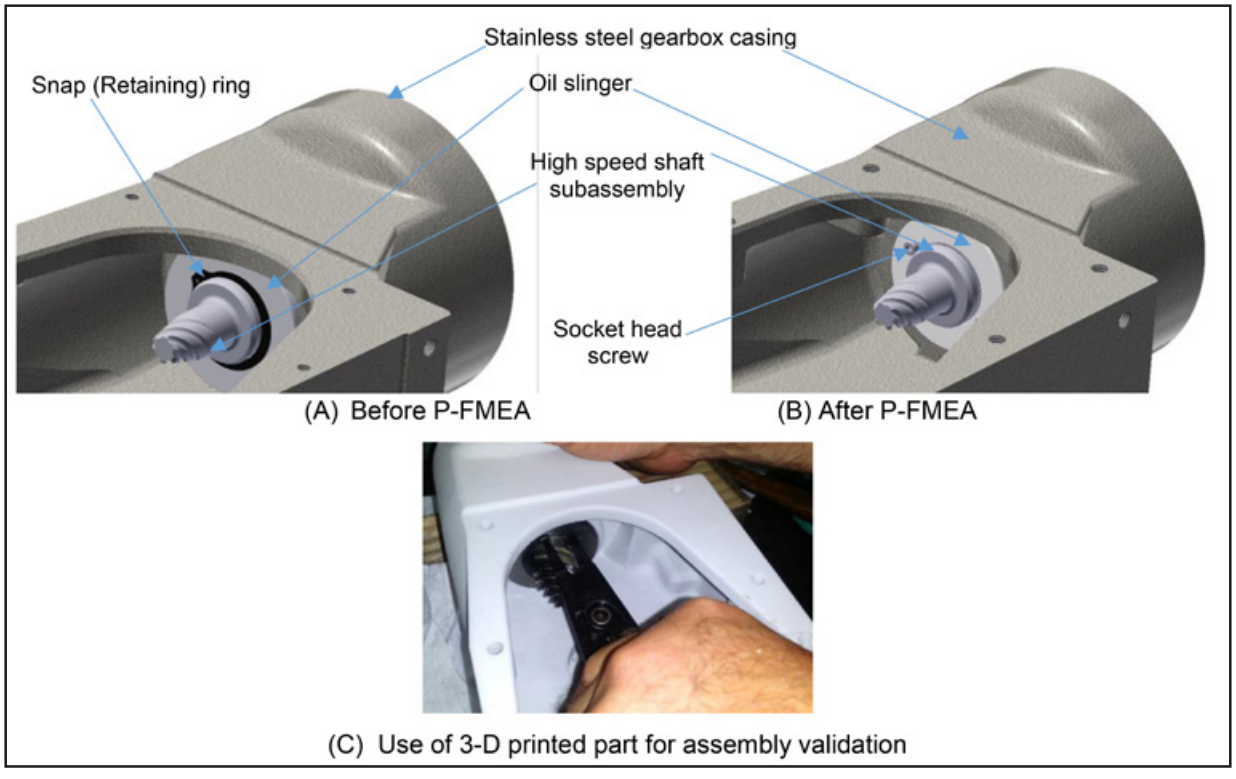


Figure 12 Change in oil slinger design after executing process FMEA.

Potential Cause(s) of Failure	Occurrence	Current design control		Detection	RPN	Recommended Actions
		(Prevention)	(Detection)			
It takes too long to access the subassembly, because of narrow gap in casing opening	7	none	Visual check TAKT time count	9	504	1. Change oil slinger design, introduce clearance fit to eliminate the need for heating process. 2. Introduce screw installation
Not enough casing opening to use pllers	8	none	Visual check TAKT time count	9	648	1. Eliminate snap ring from the assembly 2. Introduce screw installation 3. Change Casing design to create bigger casing opening

Conclusion

Product redesign of an existing gearbox is performed in an efficient product development environment in order to meet food and beverage industry requirements. Effective use of the integration of QFD and FMEA tools in a redesign process is demonstrated in the paper. These tools have facilitated decision making, technical prioritization and potential failure elimination processes.

Finite element analysis and 3-D printing tools are utilized to accelerate the product development process through different phases. These tools have helped to keep the physical prototypes and their testing as minimal as possible. Gearbox housing design is iterated and validated to meet structural, thermal, and cleaning/sanitization requirements. The design iterations are also checked for process and assembly before making physical prototypes. The laboratory tests, such as IP69K and salt spray test are carried out to confirm the ingress protection and surface consistency confirm corrosion resistance, respectively. **PTE**

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A Model for Predicting Churning Losses in Planetary Gears

Jean-Baptiste Boni, Christophe Changenet and Fabrice Ville

Introduction

Because of their compactness and axisymmetric arrangement, planetary gearboxes are widely used in automotive and aerospace applications. In the general context of the reduction of energy consumption and polluting emissions, gearbox efficiency has become a major issue. The power losses in planetary gears can be divided into two parts: i) the load-dependent power losses associated with the friction between the gear teeth and the frictional moment in rolling elements bearings; and ii) the load-independent (or no-load) power losses such as those generated by gears and planet-carrier windage, oil trapping and/or churning, seals and the viscous forces in rolling elements bearings. Numerous studies have been conducted on load-independent power losses for one pinion or a pinion-gear pair. Conversely, the studies, which deal with no-load dependent power losses in planetary gears, are sparse. They focus on global power losses produced by the planetary gear train but not on power losses distribution between the several sources previously stated.

It is important to underline that the sources of power losses can be very different from one mechanical transmission to another. One determining factor relies on the kind of gears which are considered. If one focuses on power losses occurring in cylindrical gear trains, numerous relationships can be found in literature. As an example, the work of Changenet on churning losses (Ref. 1) can be cited, whereas the work of Diab (Ref. 2) and Velex (Ref. 3) can be accounted for the study of friction losses.

As far as power losses occurring in planetary gears are concerned, the works conducted by Durand de Gevigney (Ref. 4), Kahraman (Ref. 5) and Talbot (Ref. 6) can be cited. However, all these studies concern oil jet lubricated planetary gear sets and it can be pointed out that no work deals with churning losses in planetary gears which are splash lubricated.

In order to investigate this source of dissipation, the authors have used a specific test rig. Tests were performed for different operating conditions: rotational speed, oil sump level and temperature. Some results have already been published by the authors in a previous paper (Ref. 8). The major conclusions are given here. An increase of the lubricant temperature was shown to produce a moderate decrease in churning loss, whereas it is strongly influenced by the rotational speed. Moreover, as the speed increases, the oil sump tends to disappear and the lubricant is distributed more toward the outer circumference of the housing. Then the oil sump level influence has to be interpreted according to this fluid distribution. The planetary gear set under consideration was designed in such a way that removing components is easy. Then experiments with no sun gear and/or by removing some planets have been performed during this study. These tests have demonstrated that churning losses of a planetary gear train can represented by a set of components consisting of viscous drag losses associated with gears (planets and sun gear) and the planet-carrier, and of oil trapping in inter-tooth spaces between planets and ring gear or planets and sun gear. The power losses caused by planet-carrier drag forces do not appear to be major contributors to the churning loss, whereas the number of planets is of primary importance.

Notations:

$P_{D,P}, P_{D,C}, P_{D,S}$	Drag losses due respectively to planets, planet-carrier and sun gear [W]
$P_{T,P-R}$, $P_{T,P-S}$	Pocketing losses due respectively to the contact between planets and ring gear and the contact between planets and sun gear [W]
ω_P or ω_C or ω_S	Rotational speed respectively of the planets, planet-carrier or sun gear [rad/s]
R_P or R_S	Pitch radius of the planets or the sun gear [m]
ρ	Oil density [kg/m^3]
Q_v	Flow of trapped oil [m^3/s]
v_p	Linear speed at pitch radius [m/s]
b_P or b_C	Width of the planets, planet-carrier [m]
m	Modulus of the gears [m]
n	Number of planets [-]
υ	Kinematic viscosity of the oil [m^2/s]
h_{tooth}	Tooth height [m]
h	Oil ring thickness [m]
R_{ring}^{root} or R_P^{root} or R_{sun}^{root}	Root radii of the ring, the planets and the sun gears [m]
R_C^{est} or R_C^{int} or R_C	External, internal or average radii of the planet-carrier [m]

In keeping with this first study, this paper aims to establish some analytical relationships to estimate churning losses in splash lubricated planetary gears.

Experimental Investigations

Test rig. A precise description of the test rig shown in Figures 1 and 2 is available in (Ref. 8); only the main features are exposed in this paper. The geometrical characteristics of the epicyclic gear train under consideration are listed (Table 1).

As explained (Ref.7), an electric motor is used to drive the planetary gear through a belt. The gear set is composed of a planet-carrier carrying 3 planets that are mounted on needle bearings.

Figure 1 Photo of the test rig.

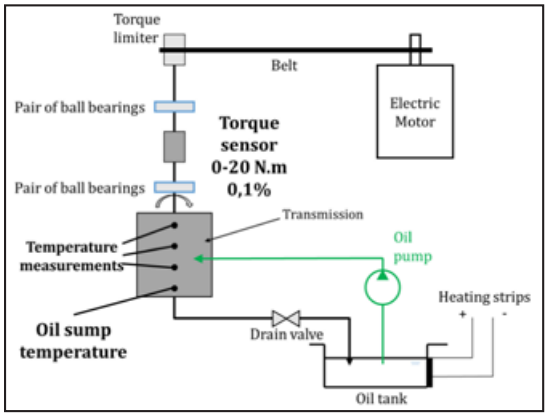

Figure 2 Scheme presenting the test rig.

The input speed is applied on the planet-carrier, whereas the sun gear is connected to the output shaft. In order to measure the power losses generated by this system, a torque sensor is used. Several type-K thermocouples are also used to monitor different temperatures (outer ring of roller bearings, ring gear and oil sump for instance). For this study the maximum input speed reached is 2,000 rpm.

For the oil sump, two kinds of lubricants have been used. Their physical characteristics are shown (Table 2).

Table 2 Physical properties of the oils used in the study

Oil number #	Density (kg/m^3)	Kinematic viscosity at 40°C (cSt)	Kinematic viscosity at 100°C (cSt)
1	837 at 30°C	41	7.4
2	900 at 15°C	200	18

Test protocol. Each test for any configuration is repeated twice in order to check the repeatability of the experiment and the consistency of the measure. For each measurement, the resisting torque is measured once the oil sump temperature is stabilized.

Due to its versatility (Ref.7) several configurations can be investigated with this test rig. As an example, some tests can be conducted by removing one or more planets and by using stationary cylinders (i.e. non-rotating mechanical components) instead of these gears. The different configurations are listed (Table 3).

Table 3 List of tests

No. of the test	Configuration	Speed range (rpm)	Viscosity values for oil 1 (cSt)	Viscosity values for oil 2 (cSt)
1	Planet-carrier with 3 cylinders, no sun gear	[200–2000]	7.4 - 13 - 24.9 - 88.2	111
2	Planet-carrier with 1 planet and 2 cylinders, no sun gear	[200–2000]	7.4 - 13 - 24.9 - 88.2	111
3	Planet-carrier with 3 planets, no sun gear	[200–1500]	7.4 - 13 - 24.9 - 88.2	111
4	Planet-carrier with 3 planets and sun gear	[200–1250]	7.4 - 13 - 24.9 - 88.2	111

As described (Ref. 7), the torque needed to run the planetary gear set is measured with oil sump in the casing for each operating condition and then again in the absence of any lubricant; thus, churning power losses are deduced by subtraction.

Table 1 Planetary gear set geometrical features

		Sun gear	Planets	Ring gear	Planet- carrier
Number of teeth	[-]	54	27	108	-
Modulus	[mm]	1.4			Average radius: 70
Face width	[mm]	37	30	32	68
Pressure angle	[°]	20			-
Helical angle	[°]	0			-
Number of planets	[-]	3			-

The four kinds of tests which are listed (Table 3) are performed in order to establish an analytical model to quantify the power losses generated by each component in the planetary gear set: the planet-carrier, the planets and the sun gear.

Summary of previous results (Ref.7). As it has been mentioned in the introductory section, the authors have already performed some experimental investigations to study churning losses in a planetary gear train. Because of centrifugal effects, they have shown that oil is ejected at the planet-carrier periphery and an oil ring is created (Fig. 3).

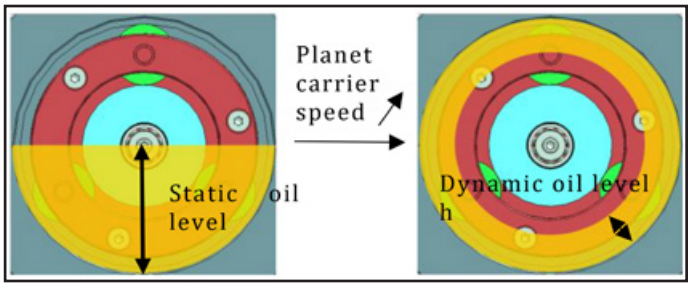

Figure 3 Scheme of the formation of the oil ring with its thickness noted h.

As far as churning losses are concerned, their evolution can be interpreted as a function of this oil ring thickness. Figure 4 presents a typical result for a rotational speed equal to 800 rpm and with oil #1 at 30°C. Three different parts can be underlined from Figure 4:

1. Only the lower part of the planets is submerged in the oil. The churning losses are associated with those due to oil pocketing and drag of the planets.
2. The oil ring reaches the planet-carrier. To the two previous sources of power losses, the drag forces acting on the planet-carrier must be added.
3. The last zone corresponds to an oil ring which reaches the upper part of the planets and the sun gear. These components generate new sources of dissipation.

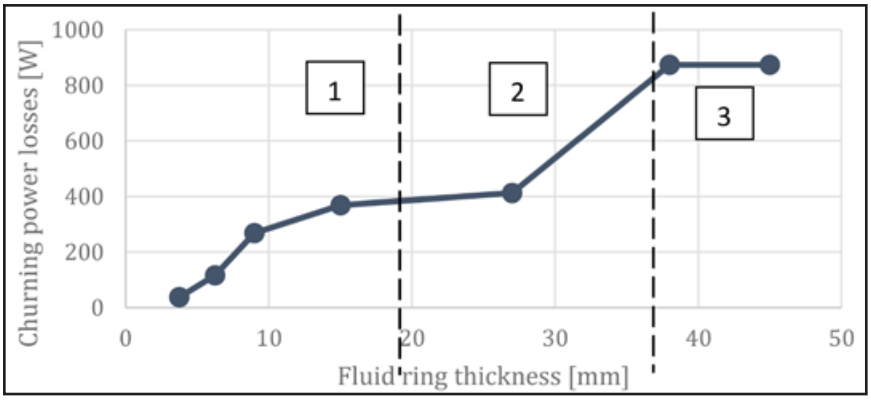

Figure 4 Churning power losses regarding the oil ring thickness.

It can be considered that the assumption of the oil ring is an acceptable approach to analyze churning losses. As a conclusion, this study aims to use this hypothesis in order to establish an analytical model for quantifying the churning power losses in a planetary gear set. As presented in (Ref.7), the churning power losses (P_{ch}) can be expressed as follows by considering the three above-mentioned parts:
In part 1:

$$P_{ch} = n(P_{D,P} + P_{T,P-R}) \quad (1)$$

Where n is the number of planets, $P_{D,P}$ represents drag power losses of planets and $P_{T,P-R}$ corresponds to the ones generated by oil trapping in inter-tooth spaces between planets and ring gear.
In part 2,

$$P_{ch} = n(P_{D,P} + P_{T,P-R}) + P_{D,C} \quad (2)$$

Where $P_{D,C}$ represents drag power losses generated by the planet-carrier.
In part 3,

$$P_{ch} = n(P_{D,P} + P_{T,P-R}) + P_{D,C} + P_{D,S} + n(P_{T,P-S}) \quad (3)$$

Where $P_{D,S}$ represents drag power losses of sun gear and $P_{T,P-S}$ corresponds to the ones generated by oil trapping between planets and sun gear.

In conclusion, several sources of power losses need to be calculated in order to predict the overall churning losses. In this study, the drag loss due to the sun gear has not been developed because of the non-sufficient immersion level to reach the sun gear.

Analytical Expressions of Churning Power Losses

Oil pocketing. In order to predict the power losses due to oil pocketing between gears, the formula of Mauz is used (Ref.8):

$$P_{T,P-R} = \omega R_P . 4.12 . \rho Q_v^{0.75} v_p^{1.25} b^{0.25} m^{0.25} (v)^{0.25} \left(\frac{h_{tooth}}{h_0}\right)^{0.5} \quad (4)$$

With $h_0 = 2.3 \times$ m.

Equation 4 is given to estimate $P_{T,P-R}$, but it can be also used to quantify $P_{T,P-S}$.

As far as oil trapping between ring gear and planets is concerned, the oil flow is estimated as follows:

$$Q_v = v_p . b . \min(h; R_{ring}^{root} - R_C^{ext}) \quad (5)$$

As far as oil trapping between planets and sun gear is concerned, the oil flow is quantified as follows:

$$Q_v = v_p . b . \min(h - R_C^{int}; R_{sun}^{root} - R_C^{ext}) \quad (6)$$

The above formulae can be used to subtract the oil pocketing power losses to the overall churning losses. From this approach, it is possible to isolate the power losses generated by drag effects. The function "*min*" is used to describe the fact that the oil ring does not always reach the planet-carrier (Eq. 5)or the sun gear (Eq. 6), depending on its thickness.

Drag power losses. To determine this source of dissipation, the work from Changenet (Ref.1) is used and the power losses can be expressed as follows:

$$P_{D,P \text{ or } C} = \frac{1}{2} \rho \omega^3 S_m R^3 C_m \quad (7)$$

In this formula:

- ω is the rotational speed of the considered rotating element: for the planet and for the planet carrier [rad/s]
- R is the pitch radius of the considered rotating element: for the planet-carrier, for the planets and for the sun-gear [m]
- C_m is the drag coefficient [-]
- S_m is the wet surface [m²]

The use of Equation 7 underlines that for each source of dissipation, the wet surface S_m and the drag co-efficient must be calculated differently.

Planet-carrier. To begin with, the wet surface is calculated as follows:

$$S_{m,C} = \underbrace{\overset{3\,holes\,for\,planets}{\overbrace{0.7}} \times 2\pi . R_C^{ext} . b_c}_{cylindrical\,part} + \underbrace{2 \times 2\pi \left(R_C^{ext2} - (R_{ring}^{root} - h)^2\right)}_{two\,flanks} \quad (8)$$

As a first approximation, the planet-carrier is assimilated to a rotating disk and its drag coefficient can be deduced from the works of Goldstein (Ref. 9):

$$C_{m,C} = \alpha \times R_e^{-0.16} \quad (9)$$

Where α is a coefficient and *Re* is the Reynolds number that is calculated by:

$$Re = \frac{2\,R_C^{ext2}\omega_C}{\nu} \quad (10)$$

As the geometrical shape of the planet-carrier is more complex than the one of a disk, the configuration associated with test No. 1 (Table 3) is used to isolate the drag of the planet-carrier. The value of the coefficient α was deduced from these tests: α = 0.046.

Planets. To develop the model for estimating the planet drag torque, the measurements performed during tests No. 2 and 3 (Table 3) are used. This source of dissipation can be isolated from the overall measured power losses by subtracting the oil pocketing losses and the planet-carrier drag losses.

To use Equation 7, the wet surface is calculated by using Equations 11–12. The parameters used in these equations are defined (Fig. 5).

$$S_{m,P} = R_P^2 (2\theta - \sin 2\theta) + 2R_P b\theta + \frac{2Z\theta h_{tooth} b}{\pi \cos \alpha} \quad (11)$$

$$\theta = \frac{\theta_1 + 2\theta_2}{2} \quad (12)$$

$$\theta_1 = \begin{cases} 2\cos^{-1}\left(\frac{R_P - h}{R_P}\right) & \text{if } h \le R_{ring}^{root} - R_C^{ext} \\ 2\cos^{-1}\left(\frac{h_c}{2R_P}\right) & \text{else} \end{cases}$$

$$\theta_2 = \begin{cases} 0 & \text{if } h \le R_{ring}^{root} - (R_{PS}^{ext} - h_c) \\ \sin^{-1}\left(\frac{H}{R_P\left(1 - \frac{h_c}{h_c + 2(H)}\right)}\right) - \tan^{-1}\left(\frac{h_c}{2R_P}\right) & \text{else} \end{cases}$$

With:

$$H = R_C^{ext} - h_c - (R_{ring}^{root} - h) \quad (13)$$

Dimensional analysis (Ref. 10) has been used to determine an expression of the drag coefficient:

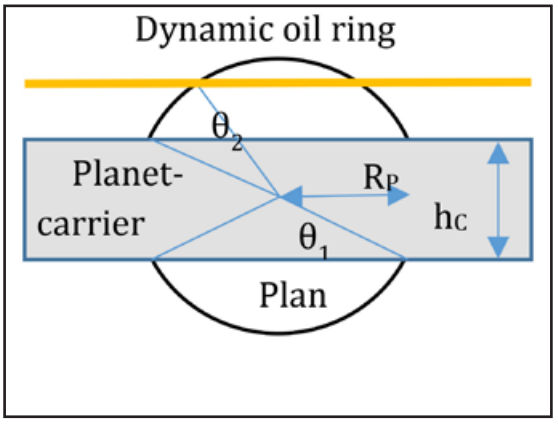

Figure 5 Scheme for the calculation of the planet's wet surface.

$$C_{m,P} = 3.88 \times Re^{-0.1} \times Fr^{-0.63} \quad (14)$$

$$Re = \frac{2R_{sat}^{\ 2}\omega_P}{\nu}$$

$$Fr = \sqrt{\frac{\omega_P^{\ 2} R_P}{g}}$$

Re is the Reynolds number that characterizes the oil flow around the planets and *Fr* is the Froude number. They account for the ratio of inertial forces to viscous forces within the oil and for the ratio of the flow inertia to the gravity.

Comparison between measurements and calculated results. A first set of comparisons is given (Fig. 6). Churning power losses are plotted as a function of the oil ring thickness. These results are given when oil #1 is used and for an input rotational speed equal to 800 rpm.

A satisfactory agreement is observed for all immersion levels. Further comparisons are then made at a given oil ring thickness, i.e.: 24 mm. Figure 7 presents the churning losses evolution as a function of planet-carrier rotational speed. Here again, a satisfactory agreement is shown between calculated values and the measured ones.

Finally, Figure 8 presents the churning losses evolution as a function of the lubricant kinematic viscosity when oil #1 is used.

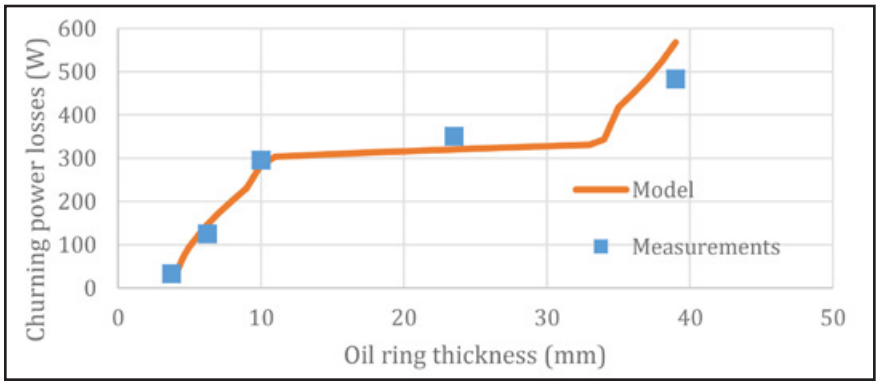

Figure 6 Testing of the previous two models regarding oil dynamic level (at 800 rpm and 88cSt).

As it has been underlined in previous studies (Refs. 1,9), this figure demonstrates that the influence of oil viscosity on churning losses is not very significant.

Conclusion

This study aimed to develop a model for calculating churning power losses for a splash lubricated epicyclic gear train. The proposed model relies on the hypothesis of a dynamic oil level as assimilated to a ring (Ref. 7). The approach is also based on previous studies on churning power losses for cylindrical gears (Refs. 1,11). Some analytical formulations are given to quantify the different sources of dissipation in churning losses, i.e.: oil pocketing and drag torque acting on rotating components. Some comparisons with experimental results obtained on a specific test rig show that this model can be satisfactory.

Future work will consist of investigating the influence of these power losses on the thermal behavior of such planetary gear trains.

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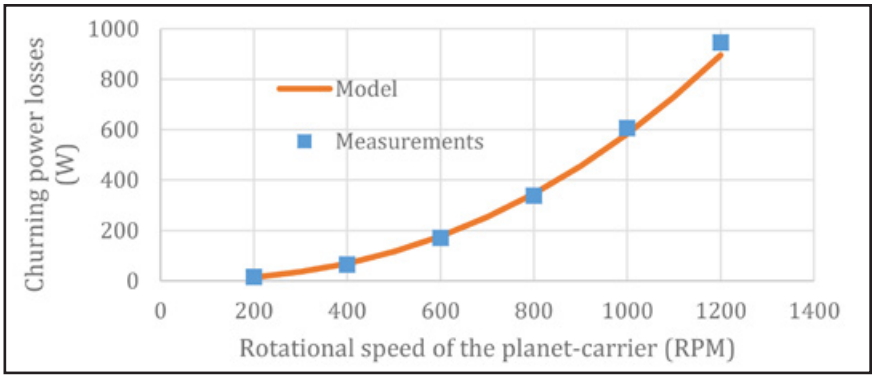

Figure 7 Testing of the previous two models regarding input speed (at 88cSt and h = 24 mm).

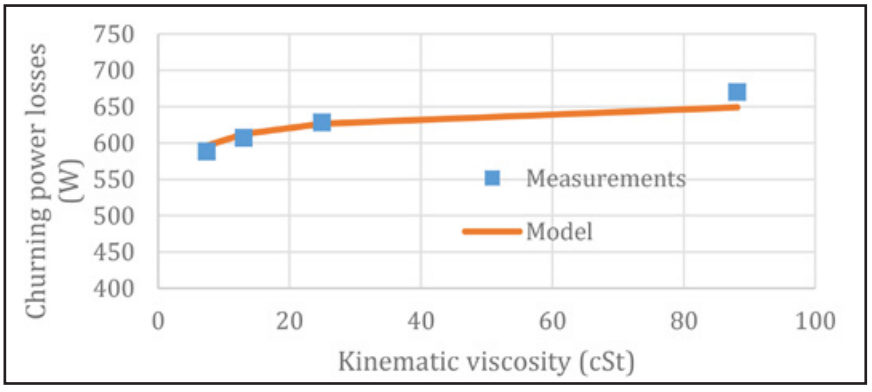

Figure 8 Testing of the previous two models regarding oil viscosity (at 1,000 rpm and h = 24 mm).

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Mitsubishi Electric

INVESTS IN AKRIBIS SYSTEMS

Mitsubishi Electric Corporation has taken an equity stake in Akribis Systems Pte Ltd (Akribis), a Singapore-based manufacturer of linear servo motors and linear stages, to strengthen its industrial automation solutions for the global market. Mitsubishi Electric, by integrating its servo systems and other industrial automation products with Akribis' product lineup, aims to meet increasing needs for high specification, high precision manufacturing

Due to the miniaturization and high functionality of smartphones and the accelerated adoption of electric vehicles, linear servo motors and linear stages are increasingly in demand. Used in equipment for manufacturing semiconductors, flat-panel displays, lithium-ion batteries, etc. they achieve increased productivity and precision. This aligns with Mitsubishi Electric's servo systems which have been widely adopted in various production facilities around the world due to the company's conclusive industrial automation product lineup.

Mitsubishi Electric, through its investment in Akribis, which has a high share of the global market for linear servo motors and linear stages, aims to accelerate its advancement of e-F@ctory and strengthen its total industrial automation solutions by combining its own servo systems and other industrial automation products with Akribis' wide product lineup and flexible customization abilities. *(eu3a.mitsubishielectric.com/fa)*

Bosch Rexroth

APPOINTS DR. HEINER LANG TO EXECUTIVE BOARD

Dr. Heiner Lang will join the executive board of Bosch Rexroth AG, Lohr a. Main, Germany. Once on the board, he will take over responsibility for engineering, which currently lies with Rolf Najork, chairman of the executive board of Bosch Rexroth AG and member of the board of management of Robert Bosch GmbH, responsible for the industrial technology business sector.

In his new role, Lang will also be responsible for the three Bosch Rexroth business units which constitute the factory automation division (automation and electrification solutions, assembly technology, linear motion technology). In addition, he will retain his role as general president of the automation and electrification solutions business unit.

By expanding the executive board, Bosch Rexroth is responding to the increasing importance of the factory automation business area as well as focusing on topics of the future, in terms of software-based, automated and connected solutions. "Bolstering our cross-divisional capacity for innovation is truly on Bosch Rexroth's agenda, and we are making that clear right now by strengthening the board with the appointment of Heiner Lang," emphasized Najork.

Along with his other responsibilities, having Lang appointed to the executive board will strengthen Bosch Rexroth's position in making the Factory of the Future a true reality.

Lang became general president of the automation and electrification solutions business unit at Bosch Rexroth in July 2017. This business unit boasts a wide range of drive and control technologies for factory automation and provides Industry 4.0 solutions for the Factory of the Future. Before this new role, Lang started his career at Bosch Rexroth as the head of technology for the industrial applications business unit in January 2017. Prior to that, he was president of Europe and Asia at MAG IAS GmbH. Lang studied mechanical engineering and obtained a Ph.D. from the University of Karlsruhe. (*www.boschrexroth-us.com*)

Bonfiglioli & Schaeffler

COLLABORATE ON WIND TURBINE GEAR DRIVES

A compact Industry 4.0 solution package for wind turbine azimuth drives is the result of a long-term development partnership between Bonfiglioli and Schaeffler. Schaeffler Torque Sense and SmartCheck sensors record torque, speed, vibration and temperature information. These data are transmitted through a gateway, combined and processed

using algorithms, developed by Bonfiglioli and based on the more than 60 years know-how in gear motors and dedicated specifically for the application. Subsequently, the data will be made available for the users on the Bonfiglioli Cloud platform. The Bonfiglioli Dashboard provides a clear overview

of the collected information for the operator. Maintenance measures can be carried out in a load-oriented manner and the unplanned downtimes of the system can be minimized, and operating costs can even be more than halved.

On the Bonfiglioli dashboard, the operator can carry out a continuous control of the state of the geared motor based on the data situation; even an estimation of the remaining service life of the drive takes place. Abnormal behavior of the azimuth drive is reported as naturally as critical conditions. On this basis, the maintenance intervals can be optimized to the actual needs and necessary repairs can be made at favorable times. At the same time, the control of the drives can be optimized, whereby overloading can be avoided. Valuable result is the drastic reduction of unplanned downtime or vice versa, the significant increase in the profitability of a plant. (*www.bonfiglioli.com*)

Continental

HOSE PLANT CELEBRATES 40TH ANNIVERSARY

Continental's Norfolk, Nebraska hose plant, is celebrating its 40th anniversary this year.

"We are proud to share in this 40th anniversary celebration of a very valuable and productive facility," said Jim Hill, ContiTech CEO for the North America Region. "This plant has made hydraulic and industrial hose for applications all over the world, and we are confident that it will continue that process into the future."

The plant was built and began business operations in 1979. Stan Patzel was the facility's first plant manager. "Stan is retired now and lives in the Lincoln area, but he and the early pioneers of our plant still remain in touch with us," said Dan Granatowicz, current plant manager. Today, the 282,000 sq. ft. plant rests on 100 acres about 115 miles northwest of Omaha and 120 miles north of Lincoln, the state capital which is the home of another Continental plant.

"Our facility has been a strong contributor to the Continental family of hose," said Granatowicz. "This is due in great part to an exceptional workforce and we look forward to at least another 40 years of successful operations."

The facility produces more than 70 million feet of hose a year and has produced more than 2.5 billion feet of hose in its 40-year existence. The Norfolk plant manufactures hydraulic and industrial hose for a variety of industrial applications including a wide variety of fuel dispensing, freon charging, mine spray and general purpose hose.

"The Norfolk plant is part of an organization that enables us to strategically position ourselves to provide dynamic growth for all of the hose markets in which we compete in the North America region," said Hill. "We will continue to grow our customer network and provide the seamless distribution of our products with our focus on North America." (*www.continental-industry.com*)

Come And Get It!
Learn, Touch and Taste at Process Expo
October 8–11, McCormick Place, Chicago, IL

Pardon our quibble, but in these crazy times of one new weight-loss and health-conscious diet after another, perhaps "Process Expo" (*www.myprocessexpo.com*; *fpsa.org*) may not be the best possible name for a trade show about food and how it ends up on your table. Given the evidence that ingesting "processed food" in large quantities is not good for us, maybe simply Food Expo would be a better choice.

Moving on, "Process Expo — the Global Food Equipment and Technology Show — represents the pinnacle of food technology, bringing together the world's most successful food and beverage processors, packaging professionals, equipment manufacturers, and leaders in the field of academia."

And there is no denying it — this show looks like a very comprehensive learning experience — and loads of fun.

The show is conceived, owned and organized by the Food Processing Suppliers Association (FPSA) — a global trade association serving suppliers in the food and beverage industries. Walking this show has to be one of the more enjoyable trade show experiences out there. In real time, exhibitors are cooking up a storm — right in their own booths.

The FPSA recently released the demonstration schedule for the five live (food) production lines that will be served up at this year's Process Expo. The FPSA states that no other show offers this unique experience to see technology in action — from creation to the final packaged product.

At this show you will see in-the-moment examples of how machinery blends seamlessly into your operations and envision how to solve your production challenges.

Live Demonstrations Schedule

Foodstuffs used for the live demonstrations include (date and time):

1. Sliced Pepperoni. This complete line moves from raw ingredients through the smokehouse and then slicing and packaging for the consumer.

Tuesday, October 8–Thursday, October 10	**11:00 am 1:00 pm 3:00 pm**
Friday, October 11	**11:00 am**

2. Ground Beef Patties. This automated line starts with cuts of beef and ends with the convenient packaged product you see in the supermarket.

Tuesday, October 8–Thursday, October 10	**11:00 am 1:00 pm 3:00 pm**
Friday, October 11	**11:00 am**

3. Frozen Pizza. This complete line moves from the creation of the crust through the depositing of sauces and toppings and the packaging of the finished product.

Tuesday, October 8–Thursday, October 10	**11:15 am 1:30 pm 3:30 pm**
Friday, October 11	**11:00 am**

4. Sliced Cheese. From the separator and HTST, all the way through to post-packaging inspection, the line will produce a variety pack of cheese (sponsored by Dairy Farmers of America).

Tuesday, October 8–Thursday, October 10	**10:00 am 12:00 pm 2:00 pm**
Friday, October 11	**10:00 am**

5. Pet Food Kibble. See how your pets' dry kibble is produced and packaged in one of the fastest growing segments of the food industry today.

Tuesday, October 8–Thursday, October 10	**10:15 am 12:30 pm 2:30 pm**
Friday, October 11	**10:00 am**

Process Expo Summed Up in Three Words: Process — Pack — Profit

According to the FPSA, Process Expo is "the nation's largest trade show dedicated to bringing the latest technology and integrated solutions to all segments of the food and beverage processing and packaging industry. Indeed: it is a food show, a beverage show, and a mechanical engineering and motion control show. Processors can gain a competitive advantage and increase their profits with the innovative technology being demonstrated on the show floor, where food processing and packaging experts present their machines and products. Both veterans and those new to food-and-beverage processing and packaging get training on food safety, trends, leadership, and more.

Who attends Process Expo?

As the show online site puts it: Whether you bake it, bottle it, grill it, slice it, package it, sanitize it, pasteurize it, or treat it — you'll profit from time spent at Process Expo learning of practical, proven advances for your plant and company — directly from experts who know your business.

Food-and-beverage processors and packaging professionals from small-to-large companies across the globe attend Process Expo. Attendees come from a wide spectrum of food production and manufacturing responsibilities, including CEOs; owners; corporate management; sales and marketing; production; operations; sanitation; maintenance; research and development; quality assurance; engineering; chefs; contract manufacturers; and just about anyone else involved in helping get product to the marketplace.

Attendees also represent a cross-section of vertical markets in addition to manufacturers thought to be outside the food industry that can actually benefit from the machines, products, and safety issues covered at Process Expo. These vertical markets include sectors such as: Bakery, Grains, Nuts, Seeds, and Snacks; Meat, Poultry, and Seafood; Beverage, Coffee Blends, and Juices, and more (see show site for complete details).

And, *cannabis* — yes, cannabis — manufacturers as well as professionals who work in food processing for convenience stores and commissaries will find value and insights from the suppliers and other attendees. (No mention whether a cannabis brownies demonstration is on the menu.)

Where the Action is — on the Trade Show Floor

More than 500 food processing and packaging exhibitors will display machines, products, and services specific to your needs as a food and beverage processor or packaging professional. See new technology in action, visit with current suppliers, find new partners to work with, and strategize for the year ahead.

Training and Education

What's more, the Process Expo "University" sessions will keep you abreast of the latest food industry trends, data, and regulations; a special food safety program is also available to help you learn best practices. For instance, HACCP (Hazard Analysis Critical Control Point) certification training is available. Also, a two-day Dairy Processing 101 course and a pet food certification course have been added to the 2019 program.

Networking. At Process Expo, some 15,000 attendees exchange insights and get to know colleagues from all the food and beverage sectors during events throughout the show. These include receptions, private meetings, one-on-one time with suppliers and exchanges in the education sessions.

Industry Sectors Represented

What industry sectors are at the show? Simply *all of them*.

One of the advantages of attending Process Expo is the decidedly horizontal make-up of the exhibit hall. Here you will get exposure by meeting with attendees and suppliers who have ideas and technology that span the entire food and beverage processing and packaging industry.

Co-packers (or contract manufacturing companies) can find partners in processing as well as new manufacturing and packaging equipment and products for their plants.

Learn about the benefits of each market sector and how Process Expo can benefit you and your company. You never know what a supplier in one area could offer that could be implemented in your own plant. At this show you'll see it all and may see demonstrations first hand of solutions you've never thought of before.

Educational Presentations Schedule

Tuesday, October 8, 10:00 am–10:30 am

From Field to Fork — What is Your Data Telling You?
Theater II — Booth 4568
Speaker: Michael Simms, Columbus

Rate of Return for Hygienic Design with Liquid Desiccant Dehumidification Systems (LDDS)
Theater I — Booth 1677
Speaker: Pat Leach, Alfa Laval

Where is Your Automation Goldilocks Zone?
Food Safety Summit Theater — Booth 468
Speaker: Matt Hartman, Blentech Corporation

11:00 am–11:30 am

Industry 4.0 and Smart Data Analytics: Increase the Potential of All Production Plants with Data
Theater I — Booth 1677
Speaker: Jagjit Singh, ProLeiT Corporation

Latest Trends in High Pressure Processing (HPP) Including Pet Food
Theater II — Booth 4568
Speaker: Kevin Kennedy, Avure Technologies

State and Local Inspections and Investigations: From Relationships to the CSI of Food Safety
Food Safety Summit Theater — Booth 468
Speaker: Steven Mandernach, Association of Food & Drug Officials

12:00 pm–12:30 pm

Wastewater in a Circular Economy: Impacts and Opportunities
Food Safety Summit Theater — Booth 468
Speaker: Christopher Dooley, DMP Corporation

12:00 pm–12:45 pm

Cannabinoids as Functional Ingredients
Theater I — Booth 1677
Speaker: Justin Singer, Stillwater Foods

Marketing and Rebranding for the Small and Mid-Sized Meat Processor
Theater II — Booth 4568
Speaker: Tia Harrison, The Butcher's Guild

1:00 pm–1:30 pm

How Valve Automation Improves Productivity — from Product to Process Time Savings
Theater II — Booth 4568
Speaker: Jim LeClair, Alfa Laval

Premiumization in Pet Care: An Evolving Industry Trend
Profitable Food Production: How to Unlock the Potential of Your Plant with Technology and Automation
Theater I — Booth 1677
Speaker: Jim Wilson, Matrix Control Systems and Dave Detweiler SafetyChain Software

1:00 pm–1:45 pm

How to Break into Legal Cannabis Edibles and Beverages Product Development
Food Safety Summit Theater — Booth 468
Speaker: Mike Hennesy, Wana Brands

2:00 pm–2:30 pm

Contracting with an Experienced Design-Build Firm Early in an Automation Project Will Improve Your Bottom Line
Theater I — Booth 1677
Speaker: Mark Livesay and Andrew Nelson, ESI Group

2:00 pm–2:45 pm

The Future of USDA, FSIS Appendix A & B for Lethality and Stabilization
Theater II — Booth 4568
Speaker: Dr. Jeff Sindelar, University of Wisconsin

2:00 pm–3:00 pm

Food Safety Tips for Produce Processors
Food Safety Summit Theater — Booth 468
Speaker: Will Daniels, President, Produce Division at IEH Laboratories and Consulting Group

3:00 pm–3:30 pm

Put the Heat from Your Air Compressor System to Work for You
Food Safety Summit Theater — Booth 468
Speaker: Wayne Perry, Kaeser Compressors

3:00 pm–3:45 pm

The Need for New Leaders in the Food and Beverage Industry
Theater II — Booth 4568
Speaker: Jennifer van de Ligt, Director of Integrated Food Systems Leadership Program, University of Minnesota

3:00 pm–4:00 pm

Challenges in Improving Cleanability and Hygienic Design in Today's Food Packaging Equipment
Theater I — Booth 1677
Speaker: TBD

Other Industry Learning Opportunities:

Dairy Processing 101
Monday, October 7–Tuesday, October 8

This year Process Expo will feature a dairy workshop — Dairy Processing 101. Process Expo has teamed up with EAS Consulting Group, LLC (EAS), which specializes in Food and Drug Administration (FDA) regulatory matters, to offer a comprehensive two-day course that will cover critical industry topics.

The course is being held on Monday, October 7 from 8:00 am–4:00 pm and Tuesday, October 8 from 8:00 am–3:00 pm, giving attendees the opportunity to visit the Process Expo show floor. The cost to attend is $550 and when you sign up, you'll receive access to the show floor and all Process Expo U sessions for free.

Attendees will:

- Learn an overview of the US dairy industry.
- Understand the impact of dairy farm practices on the quality and composition of raw milk.
- Take home a working knowledge of how raw milk and dairy product prices are established.
- Acquire an appreciation of government requirements for dairy plants including FSMA'S PCHF regulation.
- Gain exposure to milk chemistry and microbiology (including dairy cultures).
- Get an in-depth overview of dairy processing technologies related to milk beverages, cheese, yogurt, ice cream, and concentration including membrane processing and drying technology.
- Get hands-on practical knowledge of dairy laboratory testing systems and capabilities.

Food Safety Training Courses (all courses will be held from Monday, October 7, to Wednesday, October 9, from 9:00 am–3:00 pm, giving attendees time to visit the Process Expo show floor.)

The food safety preventive controls regulations were issued by the U.S. Food and Drug Administration (FDA) requiring facilities that manufacture, process, pack, or hold food for humans and animals put measures in place to help prevent foodborne illness by implementing preventive controls for hazards. The FDA training helps the industry, particularly small- and medium-sized companies, to comply with the new preventive controls rules.

The cost to attend each of these courses is $650. These rates are significantly less for the same programs offered elsewhere as they are subsidized by Process Expo. Plus, when you sign up, you'll receive access to the show floor and all Process Expo U sessions for free.

The three courses being offered at Process Expo include:

1. HACCP Training

Hazard analysis and critical control points (HACCP) is a systematic preventive approach to food safety from biological, chemical and physical hazards in production processes that can cause the finished product to be unsafe and designs measures to reduce these risks to a safe level. This two-day course is recognized by GFSI and meets the GFSI requirements. Course topics include:

Professionals representing all industry segments — bakery, beverage, dairy, meat, pet food, and prepared foods — should take advantage of this opportunity. This course is a certified course based on Global Codex and meeting GFSI Certification requirement with certificates issued for those passing the course attendance/participation requirements.

2. Foreign Supplier Verification Programs (FSVP) Course

This 2-and-a-half-day course will provide participants with the knowledge to implement the requirements of the "Foreign Supplier Verification Programs (FSVP) for Importers of Food for Humans and Animals" regulation of the U.S. Food and Drug Administration (FDA). This regulation is one of a number of regulations and guidance that implement the provisions of the 2011 Food Safety Modernization Act (FSMA), which focuses on safe food practices. The Foreign Supplier Verification course meets FSMA compliance and FSPCA certificates will be issued upon successful completion of the course.

3. New in 2019: FSMA Preventive Controls for Animal Food Course

Process Expo is offering the 2-and-one-half-day Preventive Controls course for all pet food and treat processors. Developed by the Food Safety Preventive Controls Alliance (FSPCA), the Preventive Controls for Animal Food Course is being made available in response to the Food and Drug Administration's final rule issued for Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Food for Animals. **PTE**

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October 7–10—Gear Dynamics and Gear Noise Short Course Ohio State University, Columbus, Ohio. The purpose of this unique short course is to provide a better understanding of the mechanisms of gear noise generation, methods by which gear noise is measured and predicted and techniques employed in gear noise and vibration reduction. Over the past 37 years more than 1,950 engineers and technicians from over 360 companies have attended the Gear Noise Short Course. A popular feature of this course is the interspersing of demonstrations with lectures. The extensive measurement and computer software capabilities of the Gear and Power Transmission Research Laboratory allow instructors to do this in a simple and non-commercial manner. The Case History Workshop (Day 3) allows course instructors and participants to interact and to discuss gear noise and dynamics case histories presented by course attendees. Throughout the course, laboratory and computer software demonstrations are used to illustrate gear noise measurement and analysis techniques. The facilities of the Gear and Power Transmission Research Laboratory and the Acoustics and Dynamics Laboratory are used for these demonstrations. For more information, visit *www.nvhgear.org*.

October 15–17—Motion + Power Technology Expo TCF Center (formerly the Cobo Center), Detroit, Michigan. The Motion + Power Technology Expo (formerly Gear Expo) connects the top manufacturers, suppliers, buyers, and experts in the mechanical, electrical, and fluid power industries. Over three action-packed days in Detroit, end-users can shop the latest technology, products and services, and compare benefits side-by-side. Prominent exhibitors will conduct demos and host information-rich seminars as well as offer-up technical expertise. The education courses at the Motion + Power Technology Expo offer exclusive access to a wide-ranging series of technical seminars taught by industry leaders and insiders. From novice to expert, there are courses for all career-levels. Each course is conveniently situated just steps from the Expo floor—so you can combine classroom learning with hands-on experience with the equipment. Admission to the exhibit hall is included with your seminar registration. For more information, visit *www.motionpowerexpo.com*.

October 22–24—SouthTec 2019 TD Convention Center, Greenville, S.C. South-Tec draws manufacturing suppliers, distributors and equipment builders from across North America and around the world—bringing them together in Greenville, South Carolina. With hundreds of exhibiting companies, attendees can find all the latest technologies and services—plus the experts who build them—ready to demonstrate solutions that can help them grow their business. Visitors can make side-by-side comparisons, discover integrated equipment, hear about industry trends and forecasts, and leverage their purchasing power. For more information, visit *www.southteconline.com*.

October 30–31—Advanced Engineering 2019 Birmingham, United Kingdom. Advanced Engineering continues to build even further upon its position as the UK's largest annual gathering of OEMs and engineering supply chain professionals. Advanced Engineering provides a platform for knowledge transfer and business discussions across: R & D, design, test, measurement & inspection, raw materials & processing, manufacturing, production and automation. The 2019 edition features co-located shows such as Aero Engineering, Composites Engineering, Automotive Engineering, Performance Metals, Connected Manufacturing and Medical Device Engineering. Lab Innovations is the UK's only show dedicated to the entire laboratory industry. 150+ exhibitors will showcase laboratory equipment, laboratory technology, analytical equipment, life science supplies and much more to thousands of laboratory managers, laboratory technicians and procurement managers. For more information, visit https*://www.easyfairs.com/advanced-engineering-2019/advanced-engineering-2019/*.

November 6–8—AGMA Gear Failure Analysis (Fall) St. Louis, Missouri. Explore gear failure analysis in this hands-on seminar where students not only see slides of failed gears but can hold and examine those same field samples close up. Experience the use of a microscope and take your own contact pattern from field samples. Gear engineers, users, researchers, maintenance technicians, lubricant experts, and managers should consider attending. Instructors include Rod Budny (RBB Engineering) and Andy Milburn (Milburn Engineering, Inc.). For more information, visit *www.agma.org*.

November 19–21—Power-Gen International 2019 New Orleans, Louisiana. Power-Gen International provides comprehensive coverage of the trends, technologies and issues facing the generation sector. Displaying a wide variety of products and services, Power-Gen International represents a horizontal look at the industry with key emphasis on new solutions and innovations for the future. Topics include plant performance, cyber security, energy storage, flexible generation and more. Learn more at *www.power-gen.com*.

November 19–22—Formnext 2019 Frankfurt, Germany. Formnext is more than an exhibition and conference. It's an entire platform for companies from the world of additive manufacturing. Here, a veritable who's-who from the realms of design and product development, industrial tooling, production solutions, quality management, and measurement technology comes together with leading providers in basic materials and component construction. It will also explore clever ways in which AM can be integrated into process chains in industrial production. In addition, top international speakers and other experts will be on hand to engage conference attendees in in-depth discussions at the highest technical level. For more information, visit *https://formnext.mesago.com/events/en.html*.

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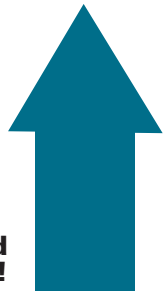

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Picking and Placing with Flexible Fingers

Joseph L. Hazelton, Contributing Editor

They're like real fingers, able to pick up hard stuff, a spark plug or a metal pipe connector, and pick up soft stuff without breaking or smushing it: an egg, a loaf of bread, a donut.

Oftentimes, they pick up these things using one program that's changed by resetting two variables: amount the fingers open and strength of their grip.

And imagine, this pick-and-place system started a few years ago as a research project at Harvard University, Cambridge, MA. Since then, it's been improved for use in industry. Today, the fingers are used in industries like manufacturing, e-commerce and retail, and food and beverage; and they're made by Soft Robotics Inc., Bedford, MA.

To understand how the fingers work, imagine a balloon, the kind you twist into animal shapes. Filled with air and held in your hands, the balloon is a long, thin tube, with one end in your left hand and one end in your right.

Now, imagine the balloon isn't made of latex. Imagine it's made of two materials, one for the balloon's top half, one for its bottom half. And imagine the top half is made of softer, more flexible material than the bottom half.

So, when this balloon fills with air, it won't inflate uniformly. The softer material will inflate more than the harder one, so much more it'll make the harder material curl.

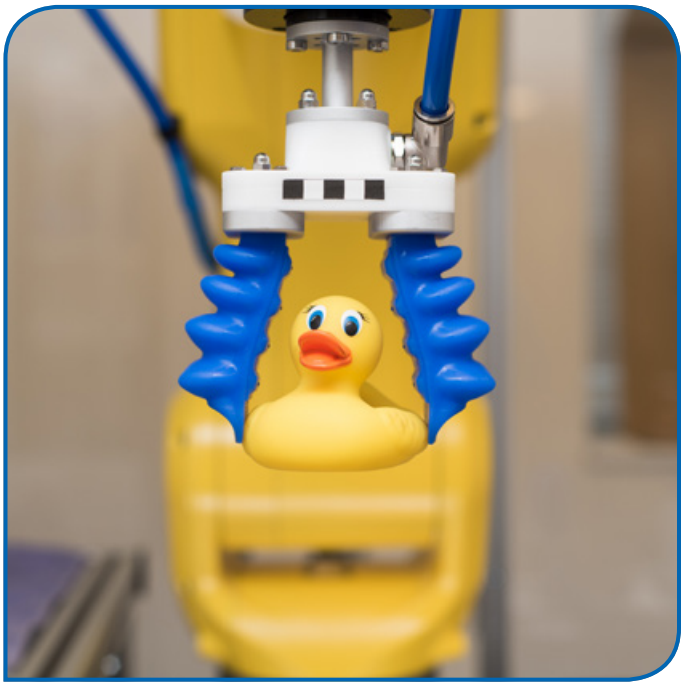
So that the bottom curls as much as a finger, the top needs excess material. To imagine the excess, look at your own finger, at the knuckles. They have excess skin. When your finger is straight, the excess folds, making small ridges. Bend your finger, and the excess unfolds.

Now, look at the blue fingers in the photo above. Each finger has excess material, the accordion-style folds. So, when a finger fills with air, the accordion half expands fast, its folds smooth out, and the other half curls. Just like a finger.

Besides flexible fingers, there's also an adjustable "palm." It's a metal hub and plastic spacers. There are actually two kinds of hubs, a circular one and a parallel one.

Of course, with a circular hub, the fingers are in a circle. That makes it easier to pick up some things: a strawberry or a donut. With a parallel hub, the fingers are in two parallel rows. Each finger has an opposite across the hub. So, a hub with six fingers has two rows of three fingers each. That way, the fingers can hold longer things, like an IV bag or a coffee bag. With the plastic spacers, the palm can be resized as needed.

Now, to move the fingers, there's an electropneumatic control system. It attaches to a robot arm and is attached to a company's air tank on its shop floor.



Actuated by air, these blue fingers bend like real fingers and can pick up things different in size, shape, weight, and firmness. Two fingers can pick up a rubber ducky; six can pick up a 13-pound bag of laundry detergent. (Photo courtesy of Soft Robotics Inc.)

This system is controlled by desktop software. On a computer screen, the program has two slider bars, one to control how much the fingers spread apart, the other to control the fingers' grip strength. Both settings make up a grip profile, and the system can store up to eight of them.

Oftentimes, though, the system doesn't need different profiles to work. One profile may be enough for many things different in size, shape, weight, and firmness.

"The system is so adaptable, we don't use the profiles that much," says Carl Vause, CEO of Soft Robotics. "For the majority of applications, we use a single grip profile."

But, when picking up different things, a protein bar and a loaf of bread, how does the system stop? How does it know its grip is secure and it doesn't have to squeeze any harder?

It knows because of a natural phenomenon, which Vause explains.

Filling with air, the fingers bend, wrapping around their object. At some point, the force they're exerting will match the force exerted by the object: equilibrium. Air pressure will stop accumulating, the pressure achieved will hold steady, and the robot arm will lift and move the object.

"We rely on that phenomenon to grip things without sensors," Vause says, "and do it across these wide ranges of objects without damaging them." **PTE**

Stressed out?

Juggling too many motion control projects while trying to keep up with new technology can be overwhelming! It's time to contact an automation specialist at SEW-EURODRIVE for help.

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