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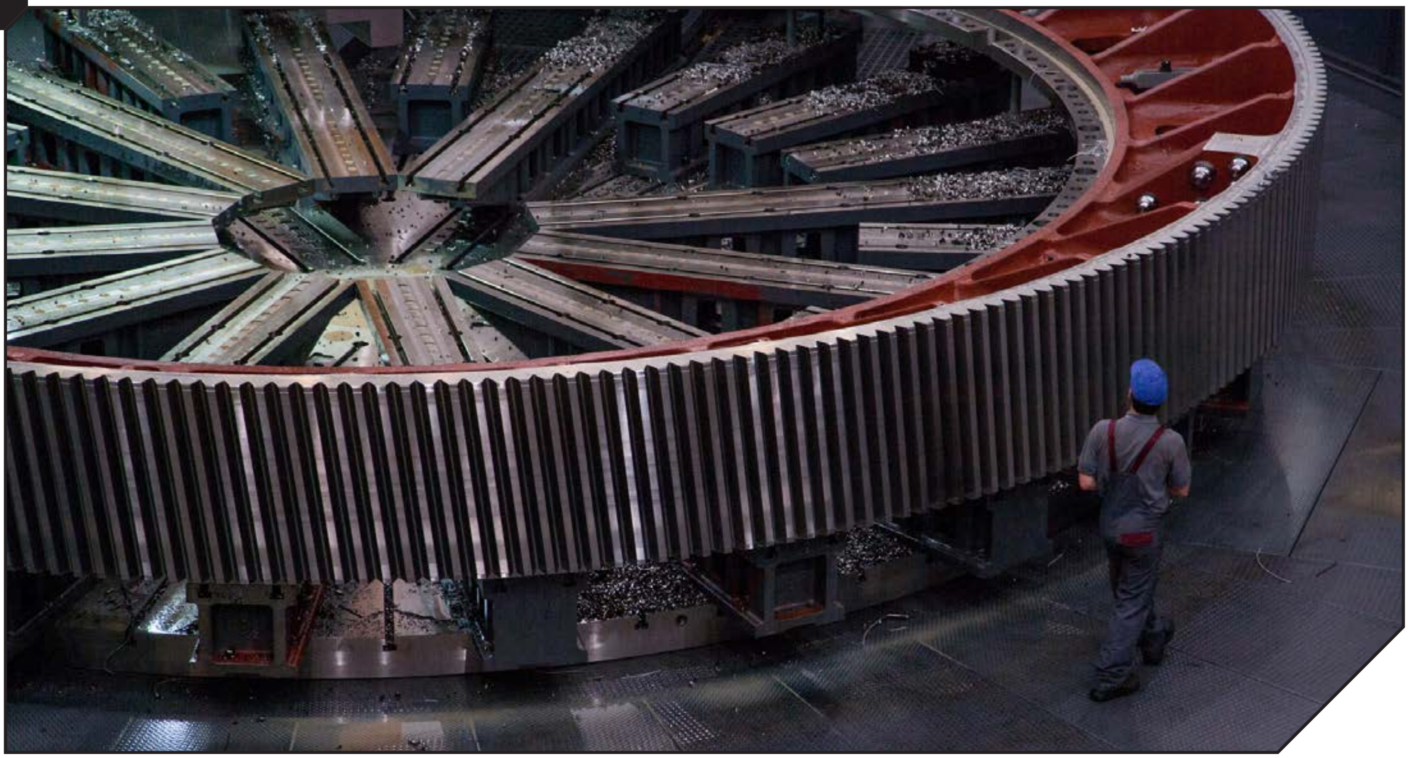

features

technical

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departments

THE GEAR INDUSTRY'S INFORMATION SOURCE

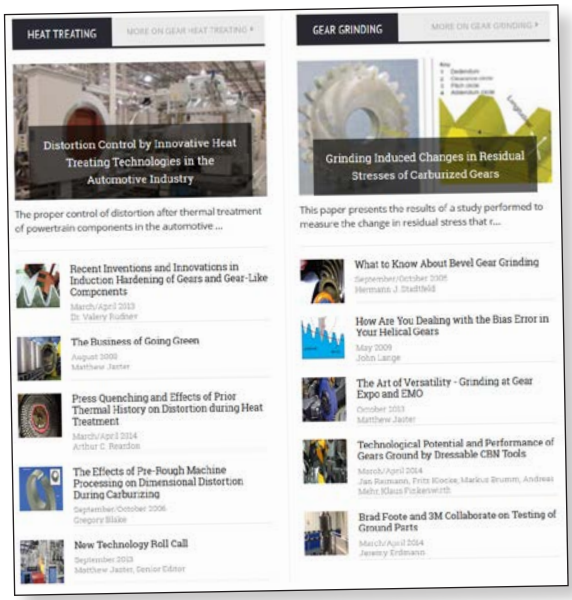
www.geartechnology.com

GT Featured Topics

The ***Gear Technology*** home page ***(www.geartechnology.com)*** features an in-depth collection of more than 32 years of technical content. Articles are indexed by subject, so all you have to do is type what you're looking for in the search bar.

This Month's Highlighted Topics:

- **Heat Treating**
- **Gear Grinding**


HEAT TREATING | MORE ON GEAR HEAT TREATING »

Distortion Control by Innovative Heat Treating Technologies in the Automotive Industry

The proper control of distortion after thermal treatment of powertrain components in the automotive ...

Recent Inventions and Innovations in Induction Hardening of Gears and Gear-Like Components
March/April 2013
Dr. Valery Rudnev

The Business of Going Green
August 2000
Matthew Jaster

Press Quenching and Effects of Prior Thermal History on Distortion during Heat Treatment
March/April 2014
Arthur C. Reardon

The Effects of Pre-Rough Machine Processing on Dimensional Distortion During Carburizing
September/October 2006
Gregory Blake

New Technology Roll Call
September 2013
Matthew Jaster, Senior Editor

GEAR GRINDING | MORE ON GEAR GRINDING »

Grinding Induced Changes in Residual Stresses of Carburized Gears

This paper presents the results of a study performed to measure the change in residual stress that r...

What to Know About Bevel Gear Grinding
September/October 2006
Hermann J. Stadtfeld

How Are You Dealing with the Bias Error in Your Helical Gears
May 2009
John Lange

The Art of Versatility - Grinding at Gear Expo and EMO
October 2013
Matthew Jaster

Technological Potential and Performance of Gears Ground by Dressable CBN Tools
March/April 2014
Jan Reimann, Fritz Klocke, Markus Brumm, Andreas Mehr, Klaus Finkenwirth

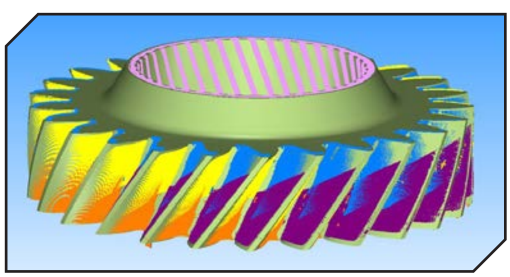
Brad Foote and 3M Collaborate on Testing of Ground Parts
March/April 2014
Jeremy Erdmann

Event Spotlight

Fundamentals of Gear Design is a continuing education program at the University of Wisconsin-Milwaukee. Attendees will develop an understanding of the history, basic gear tooth nomenclature, gear arrangements and more. The next class takes place March 15-17 and is taught by **Raymond Drago,** chief engineer for Drive Systems Technology, Inc. For more information, visit *www.geartechnology.com/news/6924/Fundamentals_of_Gear_Design/.*

Social Media

Have you browsed our LinkedIn page recently? We've added the latest gear news and product information from companies like Star SU, EMAG, GMTA and MS3D. Check out these and other gear manufacturing topics here: *www.linkedin.com/groups/3893880.*



Facebook is another resource that features updates on the ***Gear Technology*** Blog, additional Ask the Expert resources and a quick and convenient way to renew your GT magazine subscriptions.

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BPA WORLDWIDE℠ BUSINESS

Smart Ideas for 2016

Publisher & Editor-in-Chief
Michael Goldstein

For us, 2016 is the year of smart ideas. Not our smart ideas, but yours. We've spent a lot of effort collecting information from Gear Expo, our State of the Gear Industry annual survey and market research to find out more about what you want from us. We've also taken your suggestions and used them to make improvements, add new features and build on what we've been doing here for 32 years in our role as the Gear Industry's Information Source.

One of the most frequent requests we get is for more focus on back-to-basics type articles. Our industry — and manufacturing in general — is suffering from a loss of talent and expertise. Gear manufacturers need as much education and training as they can get their hands on, so we're doing our part. Much of what we've published over the past three decades has provided the foundation for the education of many of today's gear engineers. There's no reason why it can't continue to be that foundation for the next generation as well.

But they need to know how and where to find the information. You can go to our website and type "basics" in the search box to get access to these articles. But we've also taken it a step further. We've made a permanent spot for our Back to Basics articles right on the home page. We want you to have quick and easy access to this information, whether you are new to the gear industry or just need to brush up on the things you learned years ago. Look for the Back to Basics section on the right-hand side of the home page at *www.geartechnology.com*.

To make sure you find what you're looking for, we've spent the last several months going through our articles archive to tag each appropriate article with the right keywords. In addition to the basics articles, we've done the same for many of the other topics that you've told us are of most interest to you. So when you're looking for technical articles on "gear grinding" or "heat treating," you'll have access to the largest searchable database of content in our industry — more than 2,000 articles we've published over the past 32 years.

While on the website, take the time to re-subscribe, using the "subscribe" button on the upper left of the webpage. It just takes a few seconds, gives you the opportunity to send samples to some of your fellow employees and takes care of that necessity for two years.

Another new idea for 2016 can be found in this issue, on page 28. There you'll find the new Manufacturing sMart section.

In most magazines or newspapers, you can turn to the back and find the classified advertising section. Typically it's full of short-term advertisers: Help Wanted, Real Estate, For Sale, etc. In most magazines you'll find the more peripheral advertisers there — the ones whose interest in the publication's market isn't as strong, or the ones who don't have the budget to purchase a larger display advertisement.

Gear Technology used to have a classified section, too. But the advertisers there were never peripheral. In fact, many of them are leading suppliers, and they offer products and services that are extremely important to the gear industry. In many cases, they provide a technology or a niche product you can't find anywhere else.

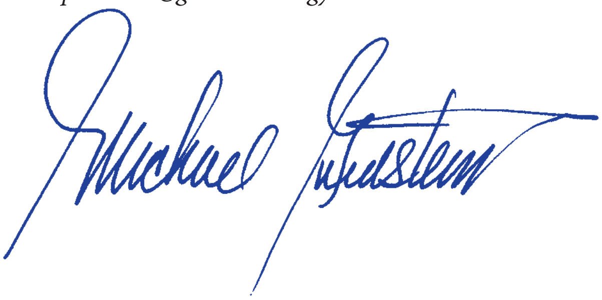
Until now, these important products and services have been relegated to the back pages of our magazine. It always made sense to us, because that's where magazines put the classified section.

But our classified section never really *was* a classified section.

So we've renamed it the Manufacturing sMart section and moved it to the heart of the magazine. We believe the section's new name better reflects the types of products and services you'll find there. But don't worry. Those important advertisers that used to be in the classifieds are still with us, as are several new advertisers who've joined them. Whether you're perusing the new section or the advertisements in the rest of the magazine, we're confident that you'll find some smart ideas of your own to begin 2016.

But all the smart ideas in the world won't help you unless you have the right people to execute them. Here at *Gear Technology*, we take great pride in the fact that our editorial staff's experience in our industry isn't measured in weeks or months, or even a couple of years. It's measured in decades. Having editors with extensive experience in manufacturing and technology gives us a great advantage when it comes to bringing you the most relevant information on gear manufacturing. In fact, we're pleased to announce the return of Senior Editor Matt Jaster to our staff after a one-year hiatus. Matt, an eight-year gear industry veteran, rejoins Senior Editor Jack McGuinn (10 years in the gear industry), Managing Editor Randy Stott (22 years), and myself (51 years), to give us by far the most experienced staff of editors in our industry. If you have an article idea or news to share with the industry, please don't hesitate to contact any one of us.

Also, if you have any smart ideas you wish we would implement to help you do your job better, we're always looking for ways to improve, so we invite you to share them with us via e-mail at *publisher@geartechnology.com*.



Samputensili

INTRODUCES SG 160 SKY GRIND

Samputensili has recently launched the SG 160 Sky Grind designed to eliminate the need for cutting oils during the grinding of gears after heat treatment and features two spindles: one for skive hobbing and one for generating grinding.

When grinding, most of the heat is transferred into the workpiece. Reducing friction, discharging the heat and evacuating the chips are the primary technological tasks for oil-based lubricants. However, the equipment dedicated to the oil treatment absorb 75 percent of the total energy consumed by a grinding machine, require a massive amount of space and significantly contribute to the costs of investment and maintenance of grinding machines.

Enrico Landi, division director of Samputensili Machine Tools, explains: "The new SG 160 Sky Grind removes 90 percent of the stock allowance with the first pass using a skive hobbing tool, which has the advantage of not heating the workpiece excessively. Subsequently, with the second finishing pass, a grinding wheel removes the remaining stock without causing problems of overheating the workpiece, therefore resulting in a completely dry process.

"Moreover, its innovative structure with two spindles actuated by linear motors and the use of more channels simultaneously ensure a chip-to-chip time of less than two seconds.

"The final result is an amazingly productive machine, even faster than traditional dual table grinding machines, characterized by a very small footprint and a lower cost of investment for auxiliary equipment. More importantly, by totally eliminating the need for cutting oils, the machine is extremely environmental friendly, both towards ecosystems and towards our most valuable resource: the health of working people."

Landi concludes: "We are sure that customers will appreciate our revolutionary concept, a proof that investing in innovation leads to the creation of cutting-edge, sustainable technological solutions."

For more information:
Star SU
Phone: (847) 649-1450
www.star-su.com

Emuge-Franken Solid Carbide End Mills

LAUNCHED IN NORTH AMERICA

Emuge Corp. recently announced the introduction of an extensive line of high-performance solid carbide end mills for applications ranging from universal milling to aerospace and high hardness machining. This new line further broadens the depth of Emuge's rotary cutting tool portfolio in the United States and Canadian metalworking manufacturing marketplace. The end mills, branded Emuge-Franken, incorporate the latest in end mill technology, geometry and coatings and are designed to outperform conventional end mill offerings.

"Emuge is well known for its high quality/performance taps and thread mills, but many people are not aware that Emuge has also been manufacturing high-performance end mills since the company was founded," said Bob Hellinger, president of Emuge Corp. "We have decided to aggressively launch a comprehensive line of high-performance mills to broaden our North American tool portfolio and meet customers' increased demands for high-performance tools in today's demanding applications."

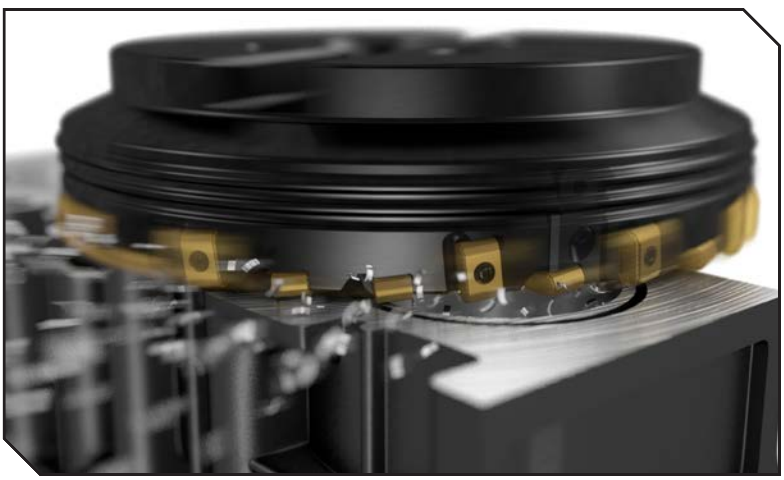
In addition to the end mills introduction, beginning in the first quarter of 2016, Emuge will be offering complete grinding/reconditioning services for end mill products as well as other cutting tools, at their West Boylston, MA facility.

Sandvik Coromant's CoroMIll 425

OFFERS EIGHT-EDGE FINISHING TOOL

Sandvik Coromant's CoroMill 425 offers an eight-edge finishing tool designed for face milling that greatly improves metal removal rate and tool life in the ISO K application area. Due to its innovative setting system, it is particularly user-friendly. This finishing tool was introduced for the face milling of cast materials. With its eight edges it is suitable for face milling components such as engine and cylinder blocks, axle housings, brake carriers and crankcases made of GCI, NCI and CGI materials. Due to its patented setting system, the tool features highly precise, reliable insert positioning that makes set-up very simple. On the CoroMill 425, the same inserts can be used as working or as wiper inserts. The wiper inserts are mounted in cassettes on the face of the tool. The insert version with a 25-degree entry angle and optimized chamfer is designed to reduce breakouts and burr formation on the workpiece. A choice of wear-resistant GC1010 PVD insert grade for dry milling and K20W grade for wet milling enables especially long tool life in CGI materials.

For more information:
Sandvik Coromant
Phone: (800) 726-3845
www.sandvik.coromant.com



The new Emuge US/Canadian solid carbide end mill launch includes the following tool lines:

Top-Cut VAR, a versatile, variable helix solid carbide inch end mill program featuring unique geometry and advanced ALCR PVD coating, for universal milling applications in virtually all materials. Top-Cut, metric end mills for universal milling applications with variable helix flutes and TiALN PVD coating ideal for both roughing and finishing operations.

Multi-Cut, carbide roughing end mills designed with a unique serrated cutting-edge chip-breaker technology for optimum chip evacuation and can achieve metal removal rates 5-10 times that of conventional end mills in a full range of materials.

TiNOX-Cut, a coolant-fed roughing end mill for demanding applications such as in exotic materials and Aerospace machining. Tools feature variable flute spacing and a serrated chip-breaker profile for aggressive material removal and a high heat-resistant multi-layer TiN/TiALN coating. Hard-Cut end mills specially developed for the machining of hardened materials up to 66 HRC.

For more information:
Emuge Corp.
Phone: (800) 323-3013
www.emuge.com

EMCO Maier

EXPANDS VERTICAL TURNING LINE

EMCO Maier is expanding its line of compact, heavy-duty inverted vertical turning machines for production with the Vertical VT400, designed with integrated automation for complete machining of cast or forged chucking parts to 400 mm (15.75") dia. The VT400 utilizes the machine spindle and chuck to load and unload parts.

The VT400 accomplishes turning as well as drilling and milling operations to complete parts with swing diameters to 450 mm (17.7"), lengths to 200 mm (8"), and part weights to 40 kg (88 lb). It combines compact design and fully automated operation to offer a cost-effective production solution for automotive, off-road, power generation and other critical industries.

With its vertical, water-cooled, high-torque, high-power 36 kW (48 hp), 4,000 rpm spindle, the VT400 makes turning, drilling and threading operations easy and keeps cycle times brief, even in tough material. The direct-driven axis travel is 37.8", 15.75", ± 3.5" in X, Z and optional Y. Main spindle torque is a strong 600 Nm (442 ft lb) with special hp and torque configurations available to take on very difficult applications.

Because the VT400 with its integrated pick-up system self-loads workpieces, it saves the user the costs and programming time related to external automation. This loading and unloading design allows for an extremely fast part to part times of 13 seconds with work pieces weighing up to 88 lbs.

The machine carries 12 driven VDI40 toolholders capable of 5,000 rpm and 40 Nm (29.5 ft lb) of torque. EMCO also offers different turret configurations such as VDI50, BMT65P. Special requests are always considered.

EMCO has used several standard and customized conveying solutions which will accommodate a range of queue quantities. These solutions bring the parts to and from a common loading and unloading location outside the machining area to the machine spindle for pick up.

A rigid machine structure results in substantial cutting performance in serial production and is ideally suited for fine- and hard machining. EMCO utilizes especially large cross roller guide ways in each axis guarantee excellent stability despite high loads. These ways are preloaded to eliminate backlash which allows the machine to continually hold extremely tight machining tolerances in unideal circumstances.

According to a company spokesman, “The VT400 offers the flexibility to supply its users with the ability to perform multiple machine operations with short set-up and retooling times. This reduces waiting times, resulting in a more productive machining environment. EMCO optimizes production processes and works to reduce chip-to-chip times, supporting complete part machining.”

The machine maximizes rigidity and stability with a steel-welded frame construction with a sand mixture for vibration-damping in the machine bed. The machine’s stable and rigid structure provides an optimum thermo- symmetrical construction of the headstock. A large saddle positioned over the guideways allows the machine to remove large amounts of material under heavy loads. The robust VT400 design has also proven to be an ideal machine for hard turning.

The new VT400 features the simple to operate and program Sinumerik 828D from Siemens with an option for Siemens ShopTurn conversational programming and the Fanuc 0i Control from Fanuc. The basic machine also includes a coolant device and a chip conveyor, which ensures rapid, effective chip removal.

For more information:
EMCO Maier
Phone: (248) 313-2700
www.emco-world.com

ARROW GEAR'S ADVANCED DESIGN ASSISTANCE

FOR GEARS THAT CARRY THE LOAD

In aerospace manufacturing, high-quality gears with complex shapes and exacting materials are the standard. Today, extremely high loads are placed on increasingly lighter gearboxes. For spiral bevel gears to perform properly under these extreme conditions, gear teeth geometry must be precisely machined to achieve optimum contact.

That's where our Advanced Design Assistance comes in. By combining cutting-edge software with state-of-the-art machines, we speed the critical process of tooth contact pattern development. At Arrow Gear, we continually invest in our technology, equipment and people to produce the tight tolerances and extremely complex part designs the industry demands.

See it in Your Results.
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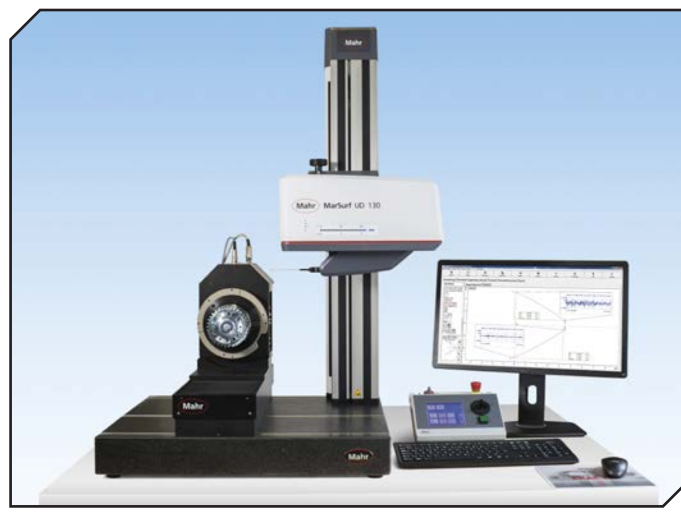
Mahr Federal System

GENERATES SINGLE PASS SURFACE AND CONTOUR MEASUREMENTS

Mahr Federal has introduced a new "entry level" surface finish and contour measuring system that can generate both surface and contour measurements in a single pass. The MarSurf UD 130 replaces the MarSurf UD 120 and offers improved features, including nanometer range measurements, high measuring and positioning speeds, a biomimetic probe design with improved rigidity and higher dynamics, and automatic probe arm recognition.

"We call the MarSurf UD 130 an entry level system because it is a more economical version of our high-end MarSurf LD 130," said Kevin Akin, product manager — form and surface metrology. "It's designed for applications in industries such as automotive or bearings that require high resolution, but which may not have the very high tolerance requirements of some optical or aerospace applications."



With measuring speeds up to 5 mm/second, the UD 130 is not quite as fast as its LD 130 cousin, but is still faster than any competitive model. Its traveling length is 130 mm, Z-axis measuring range up to 20 mm, and resolution of 2 Nm, Similarly, the UD 130 utilizes an interferometric probe system that provides better technical data than the inductive probe systems of competitive systems. Probe movement is registered by photo diodes and evaluated electronically. This innovative measuring method allows the system to achieve a very high resolution over a large range.

Probe arms are built using a bridge-truss design, which ensures maximum rigidity, reduced vibration and higher dynamics. Different probe tip geometries are available for different measuring tasks. Diamond tips with 2 µm and 5 µm radii can be used for roughness measurements, and ruby balls or carbide tips with 25 µm radii for contour measurements.

The magnetic mounting system allows probes to be changed by hand in seconds, and provides protection in the event of system collision. A ball stop assembly assures a repeatable probe mounting position, and an embedded electronic chip in the probe arm ensures reliable recognition. Plus, calibration data is saved, so probe changes do not require additional calibration.

The MarSurf UD 130 comes with Mahr's XCR 20 CNC software package for automatic measurement operation. Built on Mahr's modular MarWin platform, it provides extensive surface and contour measurement and evaluation capability, including functions such as line form evaluation, nominal/actual comparison, and the creation of auxiliary reference points. An intuitive, icon-based interface makes the software efficient and easy to use. Both the drive unit and measuring stand axes of the UD 130 can be controlled either by joystick or automated measuring programs. In combination with additional linear and rotary axes integrated with MarWin, fully automated part measurement is easily performed.

For more information:
Mahr Federal Inc.
Phone: (800) 343-2050
www.mahr.com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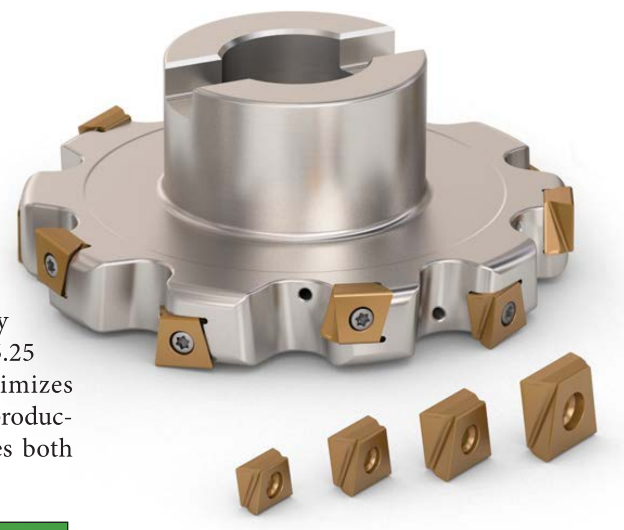
Seco Tools

INTRODUCES NEW INSERT SIZES



Seco has introduced two new insert sizes to its family of 335.25 disc milling cutters. With the additions of XNHQ inserts in 9 mm and 12 mm sizes, the cutter now offers a range of cutting widths from 0.531" to 1.26" (13 mm to 32 mm) for an even greater variety of applications.

The versatile 335.25 disc milling cutter performs slotting, back facing, helical and circular interpolation and plunging operations. Incorporating a unique cutter design and insert geometry with four cutting edges, the 335.25 reduces cutting forces and optimizes chip flow to ensure reliable and productive machining. The line features both fixed-pocket and adjustable-width versions to accommodate all production environments.

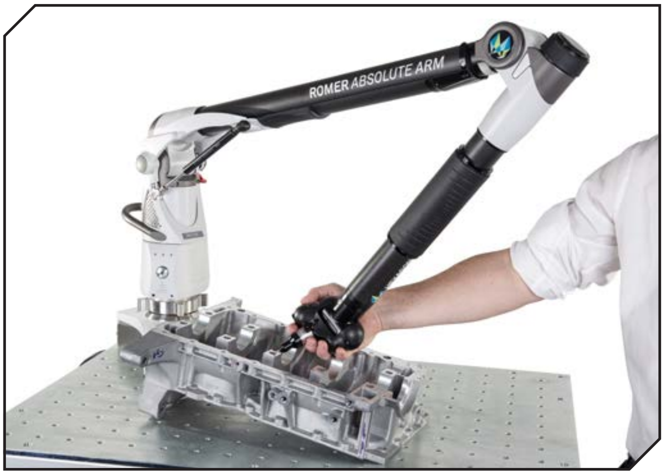
Available in diameters ranging from 4.00" to 12.00" (80 mm to 315 mm), the 335.25 line includes 0.75" and 1.00" (15 mm, 20 mm and 25 mm) cutting widths for the fixed-pocket version and from 0.531" to 1.26" (13 mm to 32 mm) cutting widths for the adjustable-pocket version. Inserts are offered in four sizes with corner radii from 0.016" to 0.236" (0.4 mm to 6.0 mm). Additionally, the range of insert grades available allows the 335.25 to be applied to all material types and each insert reduces costs by offering four cutting edges, two left hand and two right hand.

The adjustable disc milling cutter incorporates replaceable cassettes, making it easy to quickly adjust cutting width with precision. The cassettes feature a coating for extended durability, and two sizes of cassettes provide an optimized chip space and number of teeth to achieve a productive and reliable machining operation.

For more information:
Seco Tools, Inc.
Phone: (248) 528-5200
www.secotools.com

Hexagon Manufacturing Intelligence

OFFERS LATEST ROMER ABSOLUTE ARM



Hexagon Manufacturing Intelligence announced its new, top-of-the-line addition to the Romer Absolute Arm portable coordinate measuring machine (PCMM) product line. The most accurate Romer Absolute Arm to date, the 77 series is designed to provide absolute accuracy for high-end 3D measurement applications. The advanced PCMM achieves nearly a 20 percent improvement in scanning accuracy and a 15 percent improvement in touch-probe measurement accuracy over the popular 75 Series. The new Romer Absolute Arm is available in five sizes from 2.5 m to 4.5 m measuring volumes.

The 77 Series combines its high precision measurement advances with the proven technology of the Romer Absolute Arm, while retaining the arm's user-friendly nature. The Romer Absolute Arm can be switched on and used immediately without warm-up or referencing. Probe changes can also be made without recalibration to maximize flexibility on the job. Acoustic and haptic operator feedback facilitate usage in harsh shop-floor environments. The standard, versatile 3000 N magnetic base offers mounting options for all kinds of applications and part sizes. The Romer Absolute Arm 77 Series is now available to order worldwide via local Hexagon Manufacturing Intelligence commercial operations and agents with shipments starting in March 2016.

"The 77 Series takes the accuracy performance of the Romer Absolute Arm to a new level for dimensional control applications found in safety-critical industries as aerospace, defense, medical, and more," said Zvonimir Kotnik, business unit manager for portable products, Hexagon Manufacturing Intelligence. "Users will gain speed and precision with confidence utilizing this new PCMM line developed with Hexagon Manufacturing Intelligence's signature sensing, thinking, acting approach to product design. Alongside the 73 and 75 Series arms, the 77 Series gives us a three-level product range, so it is easier than ever for our customers to choose the right Romer Absolute Arm for their specific application requirements."

Like the 73 and 75 Series of Romer Absolute Arm, 77 Series arms are compatible with all Hexagon laser scanners, including the RS3 integrated scanner and the HP-L-20.8 and HP-L-8.9 external units. All Romer Absolute Arms are available in 6- and 7-axis configurations. The 6-axis models are ideal for touch-probe measurement, while the 7-axis design is well suited for high-speed laser scanning.

For more information:
Hexagon Manufacturing Intelligence
Phone: (401) 866-2000
www.hexagonMI.com

Rosler Surf Finisher

UTILIZES FULLY AUTOMATED PROCESSES

Rosler has unveiled its newest surface finishing technology with its new Surf Finisher machine, an automated surface finishing process which is ideal for deburring, surface grinding, smoothing and polishing of delicate, high-value components with complex geometries. The Surf Finisher offers several benefits, including fully automatic processing, short cycle times, high process stability, repeatability and finishing of precisely targeted surface areas.

The Surf Finisher was born out of a growing demand to improve the cost efficiency, stability and repeatability of surface finishing processes for highly valuable and complex components. Surf finishing allows fully automatic dry or wet processing of these components, which up until this point, could only be finished with costly manual or mechanical systems.

Surf finishing is the ideal technology for single component treatment in the aerospace, automotive and medical industries, or any other industry where precise deburring, surface grinding, smoothing and polishing are essential.

For more information:
Rosler Metal Finishing USA, LLC
Phone: (269) 441-3000
www.rosler.us

Absolute Machine

RELEASES TONGTAI CT-350 VMC

The new CT-350 five-axis vertical machining center from Tongtai features state-of-the-art performance in a small footprint. The CT-350 boasts high-end machine construction and performance at an affordable price. The structure of the CT-350 is a "C" frame-type machine and was designed around high level mold-type machining centers to ensure rigidity during cutting. The column of the CT-350 has a wide span making it torsion-resistant while cutting a 5-axis part. Rigidity is enhanced by using 45mm roller type guide ways and pre-tensioned, large-diameter ballscrews.

The CT-350's table size is 13.78" diameter and can handle a maximum load of 440 lbs. The integrated rotary table uses the roller gear cam in both the tilt and rotation axes. The roller gear cam design provides zero backlash, high rigidity, and fast rotation speeds. The stroke on this machine is 15.75" in X, 20.08", in Y and 20.08" in Z. The A-axis stroke is +30 degrees through -120 degrees, and the C-axis stroke is 360 degrees with rotation speeds of 40 rpm and 33 rpm, respectively. The CT-350 is truly high performance with rapid feed rates of 1,418"/minute in X and Y, and 1,182"/minute in Z. A 20HP direct-drive 15,000-rpm Big Plus 40 taper spindle with air/oil mist lubrication is standard in the CT-350, however an optional 20,000-rpm integral spindle is also available. For enhanced productivity, the standard 24-position arm type tool changer is equipped with a roller gear cam mechanism to reduce tool change time to only 2 seconds. Larger 30- and 40-tool ATCs are optional.

The CT350 is equipped with a FANUC OiM-F CNC control to perform 4+1-axis cutting. However, if 5-axis simultaneous cutting is necessary, a FANUC 31iM-B5, Siemens 840D or Heidenhain iTNC-640 can be installed. Tongtai has several different models of 5-axis machining centers. The HTT-1250 is a large horizontal machine for aerospace applications with 50" tilt/rotary table. The GT-800 and GT-630 are gantry-type high-speed, high feed rate machines with 31.5" and 25" tilt/rotary tables, respectively. The MDV-551-5AX is a small, double-column-type machine with high-speed rotation and a 20" tilt/rotary table. The new CT-350 is Tongtai's smaller 5-axis machining center with a small footprint for shops that need a 5-axis machine, but do not have the floor space for a larger machine tool.

For more information:
Absolute Machine Tools, Inc.
Phone: (800) 852-7825
www.absolutemachine.com

ITAMCO

CONNECTS FORKLIFTS TO INDUSTRIAL INTERNET OF THINGS

Forklifts, the workhorses of the plant floor, are more valuable than ever at ITAMCO. The company has connected their forklifts to the Industrial Internet of Things (IIoT) — the integration of machinery and equipment with networked sensors and software.

ITAMCO is a manufacturer of precision-machined components, specializing in gears — from mining gearing to production runs of CBN-ground transmission gears. In 2012, ITAMCO implemented an MTConnect-enabled machine-monitoring program. After key pieces of machinery were connected to MTConnect and to their Enterprise Resource Planning (ERP) system, ITAMCO developed a communication system for their forklifts.

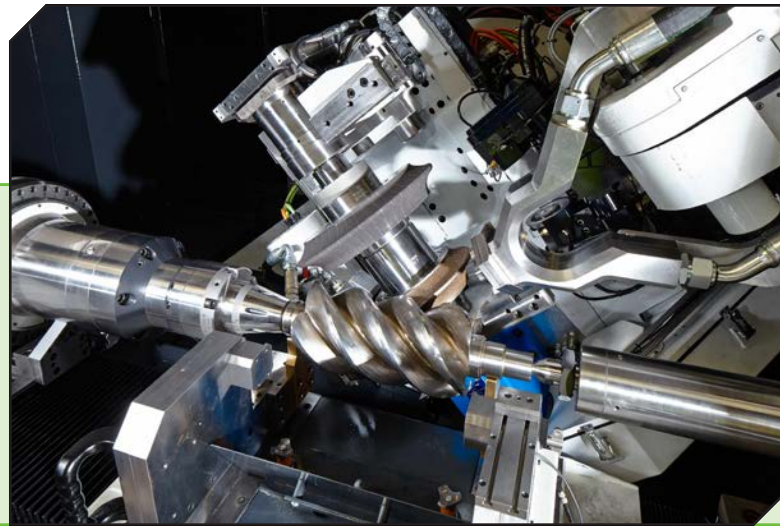
Now, as soon as a machine operator scans the barcode on a pallet, signifying the completion of the product cycle at his machine, a forklift operator and forklift are on their way to the machine. Each forklift is linked to ITAMCO's ERP system through its GPS and an application on a smart tablet mounted in the forklift. Forklift operators are notified via their smart devices — employees use iPods, iPads and smartphones — when they're needed. The communication system is so efficient it will summon the closest forklift to the machine. The forklift operator will also know how many pallets need to be moved and where they should be taken. If the product is being moved to another workstation, the workers in that area will be notified that the product is on its way.

"We developed the application because both of our facilities are rather large and forklift operators where always looking for forklifts to move their material but could never find one. Also, material would sit for hours at a machine, delaying the next operation. This application solved the problem by notifying a material handler as soon as the materials were ready to go to the next work area," said Joel Neidig, an engineer and lead technology developer at ITAMCO. The system has been well received by the ITAMCO employees. "It has definitely helped me schedule the movement of materials from one work center to another," said Arthur Doody, material handler at ITAMCO.

For more information:
ITAMCO
Phone: (574) 936-2112 (ext 1118)
www.itamco.com

PTG

OFFERS ULTRA-PRECISION MILLING AND GRINDING AT GRINDTEC 2016



PTG Deutschland GmbH, the German division of U.K.-based Precision Technologies Group, has chosen GrindTec 2016 – the International Trade Fair for Grinding Technology – to showcase its parent company's ultra-precise milling and grinding machines.

Visitors to Stand No. 2082 will be able to discover the full capabilities of PTG technologies such as the Zenith 400 helical profile grinder, the EX series rotor milling machines and the GTG2 gear-grinding center. All machines are built in the U.K. by Precision Technologies Group company, Holroyd Precision Limited.

"GrindTec 2016 is the perfect platform from which to present our ultra-precise milling and grinding machines to the widest possible audience," comments Johann Haugg, managing director of PTG Deutschland GmbH. "In addition to showing the immense capabilities of our technologies," he continues, "we will also be displaying a number of ultra-precise helical components."

The Zenith 400 represents the very pinnacle of PTG's helical profile grinding technologies and is the first machine of its kind to offer three grinding wheel options: aluminium oxide, ultra hard plated CBN and vitrified, dressable CBN. The Zenith 400 combines a 420 mm diameter grinding capability, with a maximum component weight of 700 kg. In addition to being a high precision, helical profile grinding machine, the Zenith 400 also offers high stock removal rates and aggressive semi finishing, with production rates and accuracies tailored to each customer's needs.

Holroyd EX series rotor milling machines have earned worldwide acclaim for their high speed, accuracy and unbeatable build quality. The standard range of EX series models can cut rotor or worm helix profiles in blanks up to 850 mm diameter. Where 850 mm is too small, Holroyd can build a 10EX machine that can perform the same functions on blanks exceeding one metre diameter. The flexibility of EX series milling machines means that they are equally efficient at producing complex components with helical screw profiles and gear parts such as worm shafts.

The GTG2 helical gear grinder sets new standards in the production of ultra-precise gears in diameters of up to 350 mm. Effectively a self-contained production cell within a single machine, the GTG2 offers: fast set-up to optimize production and minimize operating costs, fully automatic programmable cycles, a fully automatic grinding wheel balancing system, and the high power required for deep grinding operations.

For more information:
Precision Technologies Group (PTG)
Phone: +44(0) 1706-526-590
www.holroyd.com

Looming Large

What Will the Big Gear Market Offer in 2016 and Beyond?

Matthew Jaster, Senior Editor

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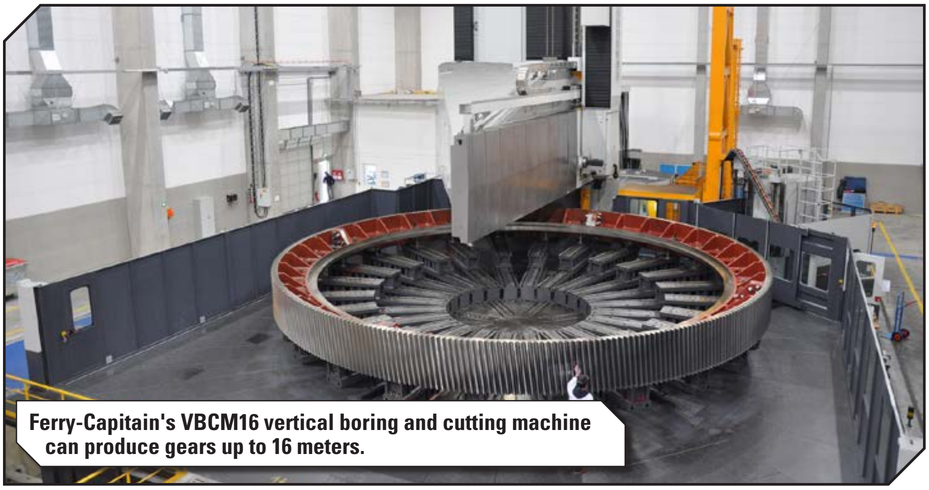
Let's talk about large gears. Not the size or scope or inspection process (we've covered all of these things here: *www.geartechnology.com/subjects/big+gears/*), but the forecast and market potential in areas that utilize these massive components. We'll examine key industry segments like energy and mining and tap IHS Economics for a forecast for 2016 and 2017 (spoiler alert: it's not great). Additionally, we'll discuss some of the critical factors influencing global big gear manufacturers Ferry-Capitain and Hofmann Engineering.

Ferry-Capitain Enhances Materials for Mining and Cement Applications

Ferry-Capitain Industries, LLC provides sales support and representation in North America for European manufacturers Ferry-Capitain and CMD. The company is able to offer packages (girth gears, drive pinions, couplings and speed reducers) for kilns, grinding mills and other custom applications. *Gear Technology* recently interviewed Christian Duquenne, vice president of sales and marketing at Ferry-Capitain, to discuss the current trends in the big gear market.



Ferry-Capitain's VBCM16 vertical boring and cutting machine can produce gears up to 16 meters.

GT: What will be the greatest challenges regarding large gear manufacturing in 2016?

FC: From a commercial perspective, an expected continued low level of new project work is likely to result in continued pricing pressure. Within this context, an emphasis on replacement project work is in order. From a technical perspective, the trend to increase installed power on grinding mills in the mining industry is expected to continue. Whereas a few years ago a 7,000 kW per pinion power requirement was considered "high," we are seeing more inquiries for per-pinion installed power in the range of 9,000-10,000 kW, some of which have materialized into orders. The key in meeting this particular challenge is the development of materials having the requisite mechanical properties that exceed those available just a few years ago, which can allow us to maintain a practical dimensional envelope—in terms of face width and web width—for the large gears.

GT: Will your company be investing in new equipment and new technologies in the next 12 months?

FC: We have made significant investments during the past several years in major gear machining equipment to improve capability and capacity. Since the commissioning in 2013 of our VBCM16 vertical boring and cutting machine that can produce gears with very high accuracy to 16 m (52.5 ft.) diameter, we have added complementary equipment for the turning and cutting of a smaller range of gear sizes. We are now turning our attention to upgrading some QC-related equipment for large gears, in particular the fixturing for performing roll checks, as this is a critical verification step to ensure that the tooth forms measured in the factory will translate to proper contact and power transmission in the field.

GT: What key industries will be the focal point for your organization moving forward?

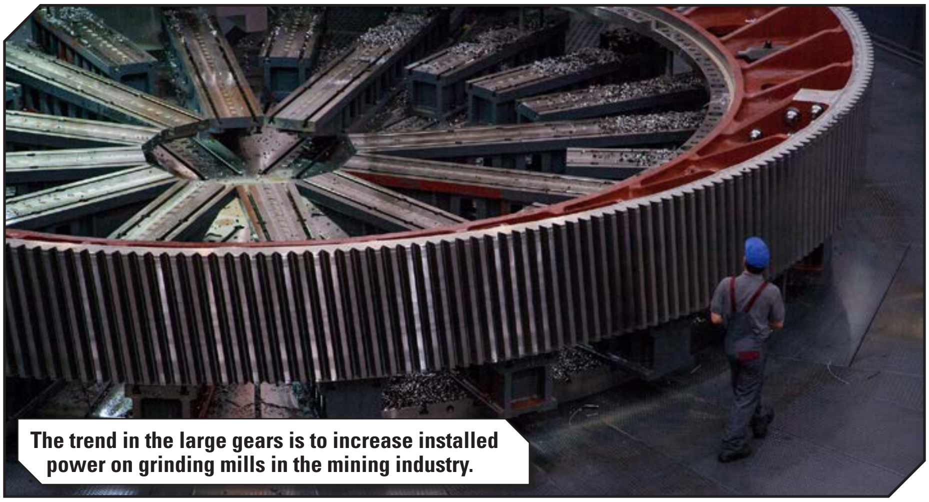
FC: The mining and cement industries have been, and will continue to be, the focal point for our open gearing production for many years. We have seen a few "specialty" applications requiring large diameter gears during the past several years, but these are relatively few in number.

GT: Any new opportunities in rebuilds?

FC: With a decrease of new project work in our target industries during the past few years, the percentage of replacement gearing has increased proportionally. What used to be about a 60 (new): 40 (replacement) split, is now almost reversed and closer to 40 (new): 60 (replacement), although at a lower level of overall activity. We expect this to be maintained through 2016 and possibly into 2017.

GT: How is your service and support team evolving in the large gear market?

FC: While the majority of the emphasis has been in providing installation and commissioning supervision services, we have become more involved in providing field



The trend in the large gears is to increase installed power on grinding mills in the mining industry.

measurement services for the replacement of older equipment for which the original design information may not be readily available. This type of work requires a different skill set than for installation supervision, and we are increasing our existing capabilities in this area.

GT: What bottlenecks are you seeing in the large gear market and how are these bottlenecks affecting your business?

FC: Whether this can be termed a bottleneck or not, there has been a lag in acceptance of new material grades and some inconsistency in gear rating standard specification by some customers. We are hopeful that the recently published *AGMA 6014-B15* (*Gear Power Rating for Cylindrical Shell and Trunnion Supported Equipment*), the latest revision to which Ferry-Capitain was a key contributor, will serve to alleviate some of these inconsistencies and will serve as the "standard" for many years to come. One other issue that may be considered a bottleneck is the time taken by some customers to execute orders for replacement gearing, sometimes waiting until their existing gearing has deteriorated to a critical state. The end result is expedited deliveries and typically higher cost to the end-user.

GT: What are the significant challenges regarding materials for large gear manufacturing?

FC: With a constant progression in installed mill power in the mining industry over the past decade, we have been able to follow this trend through the development of cast steel and ductile iron grades having improved material properties. With our proprietary FerryNod ductile iron material grades, we are able to guarantee a minimum hardness of 340 BHN (higher hardness = higher power). We can also guarantee the same minimum 340 BHN hardness for our cast alloy steel material, and may soon increase this to 350 BHN. As grinding mill power increases, not only does material hardness have to increase, but so does the gear tooth size, and thus the outer rim thickness (which is typically 5x module). By using cast gear blanks produced in our foundry facilities, the availability of high hardness rim material having a thickness in excess of 200 mm is not an issue for us.

For more information:
Ferry-Capitan Industries, LLC
Phone: (518) 452-8090
www.ferrycapitain-industries.com

What Economic Rebound?

The word "rebound" seems to pop up, disappear and then reappear without rhyme or reason. You've heard all the doom and gloom lately (China is shutting down, Latin America is bottoming out and the U.S. stock market had a very bad January) But what does it all mean? It means that a significant economic rebound in manufacturing isn't happening any time soon, according to Tom Runiewicz, senior principal economist at IHS Economics, US and World Industry Service.

"By my numbers, a lot of people in the industrial sector are starting to change their 2016 and 2017 forecasts," he said. "Overall, many analysts may end up downgrading their forecasts across the board. It's not a happy situation right now and when you look at areas like heavy industry (mining, agriculture and construction machinery); there are not a lot of reasons to be optimistic."

Runiewicz believes three factors are contributing to this. "A strong U.S. dollar, a collapsing energy market and an inventory build-up that needs to be corrected sooner rather than later," he said. "The United States has a real niche in the global market, especially when you're talking about big industrial equipment. Unfortunately, heavy industrial sectors are still getting hit really hard."

This economic uncertainty leaves manufacturers at a crossroad of sorts. Many won't be making significant machine investments until things start picking up. "You're going to see a lot of manufacturers simply trying to keep their heads above water if they're working in areas like mining, agriculture and construction machinery. U.S. manufacturers in these areas won't invest in new equipment and technologies until they see a stronger demand for new products from their customers," Runiewicz added. "It's also going to be a struggle to hold on to gear market shares right here in our own backyard as countries like Germany, Italy and China continue to send gears over to North America."

But like any market analysis, it's not all doom and gloom. Some specific segments are starting to gain a little bit of traction. "Areas like wind, cement, pharmaceuticals are picking up and automotive and aerospace are still doing quite well. There are opportunities if you're paying close attention to certain markets."

He expects energy and gas prices to start turning around this year "It's going to be slow going but we'll start seeing more activity in energy by the end of 2016."

But overall, we won't see anything remarkably close to an economic rebound in the foreseeable future. "Manufacturing grew slightly in 2014 (2.8 percent), a little less in 2015 (2.3 percent) and I'm forecasting only a 1.5 percent growth this year," Runiewicz added. "I still may drop that number to one percent before all is said and done."

For more information:
IHS Global
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Market Watch: Wind Energy

With the multi-year extension of the wind energy Production Tax Credit (PTC) and Investment Tax Credit (ITC), Congress recently secured stability for 73,000 American wind industry workers across all 50 states and private investors helping to grow American wind power, according to the AWEA.

"We're going to keep this American wind power success story going," said Tom Kiernan, CEO of the American Wind Energy Association (AWEA) in a recent press release. "With predictable policies now in place, we will continue advancing wind turbine technology, driving down our costs and passing the savings on to American families and businesses in all corners of the country. We look forward to building a future with more affordable, reliable, clean wind energy."

The rules will allow wind projects to qualify so long as they start construction before the end of the period. Industry leaders and others reacted to the news favorably, saying the multi-year extension supplies their companies with a level of predictability needed to keep U.S. factories open while adding new wind projects to the pipeline:

"Having PTCs for five years will allow us to make more supply commitments and build more projects, creating more jobs. It also allows us to work with the turbine vendors to lower the cost of our projects and minimize the economic impact of phasing down of the credits," said Mike Garland, CEO of Pattern Energy and chairman of the board for AWEA.

"The PTC has encouraged tremendous investment in wind energy, helping to reduce the cost of wind power while simultaneously creating a new American industry. This extension will bolster the continued growth of domestic wind energy and the jobs this growing industry supports, allowing our factories to plan for the future as we continue to deliver innovation that drives down the cost of wind power," said Jacob Andersen, CEO, Siemens Onshore Americas in a recent statement.

The performance-based PTC has helped to more than quadruple wind power in the U.S. since 2008 — up from 16,702 megawatts (MW) installed at the start of 2008 to 69,470 MW by the third quarter of 2015. This is enough power to supply over 18 million American homes. The PTC has helped spur innovation in wind turbine technology, causing wind's costs to fall 66 percent in just six years. The multi-year predictability will


The recent extension of the Production Tax Credit (PTC) gives wind industry companies the luxury to make more supply commitments.

help continue that trend and break the repeated boom-bust cycles the U.S. wind energy industry has weathered through two decades of uncertain tax policies.

For more information:
AWEA
Phone: (202) 383-2500
www.awea.org

Market Watch: Mining

Investor pressure in the mining sector is substantial and unlikely to ease in coming months as the focus remains on protecting returns and financial strength rather than gearing-up for higher commodity prices. The longer the mining sector remains stuck in stalemate, the greater the effect on the pipeline flow of both greenfield and brownfield projects and the greater the implications for market balances and metal prices in the coming years, this according to Bruce Always, base metals mining manager at GFMS team at Thomson Reuters.

In the company's annual GFMS Base Metals Review and Outlook (October 2015), one statistic jumped out over all others: The top ten miners have a combined market value just over $280 billion, which is roughly half of what it was 12 months earlier. What a difference one year makes. Rock bottom is an understatement. Currently, economists are beginning to look at potential turning points. In terms of recovery, 2016 appears to be a year where nickel is finally moving in the right direction and question marks will remain regarding aluminum, lead and zinc. All in all, it will be a few more years before anyone involved in mining or mining machinery has anything to get excited about.

For more information:
Thomson Reuters
Phone: (646) 223-4000
www.thomsonreuters.com


The top ten miners have a combined market value of $280 billion, roughly half of what it was 12 months ago, according to Thomson Reuters.

Hofmann Engineering Looks to Reduce Manufacturing Costs and Lead Times

Hofmann Engineering (HE) has provided specialist engineering in Australia since 1969. The company serves a broad spectrum of industries for steel gearing including cement, fertilizer, iron-ore, copper and any process where grinding mill comminution is employed. Hofmann acquired the Falk Australia facility in Newcastle. This 5,000 square meter facility manufactures components up to 14 meters. Holger Fritz, product manager mill gearing and Stephen Hooper, mill gearing engineer, recently discussed big gears with *Gear Technology*.

GT: What will be the greatest challenges regarding large gear manufacturing in 2016?

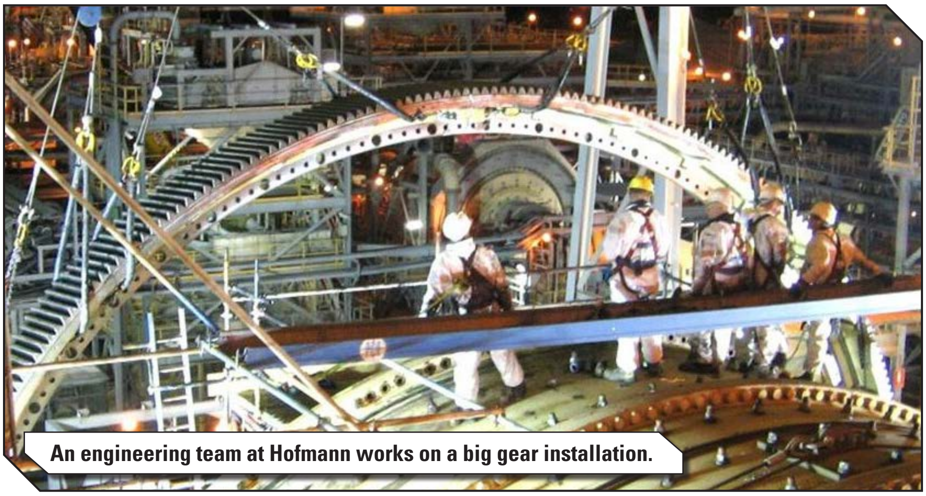
HE: 2016 is sure to be a very challenging year for large gears including retaining market share and remaining a viable business unit while new mining projects are few and far between.

GT: Will your company be investing in new equipment and new technologies in the next 12 months?

HE: The major difference in our investment strategy compared to the boom years is that, while there is an overcapacity for the manufacturing of large gears, we will look at innovations that reduce manufacturing cost and lead time. We recently designed, built and installed more flexible tooling for the large gear cutting machines that drastically reduces set up time and allows us to go from large diameter gears to much smaller gears with minimum effort. Hofmann Engineering will also continue to invest time and effort in cutting tools. Last year, we tested the most advanced cutting inserts with great results in terms of cycle time reduction for our roughing process. When cutting times are fairly long, as is the case with large diameter gears, any percentage reduction in cycle time results in a significant savings. Additionally, in the site service area, we have purchased a number of portable CMM measuring machines as well as invested in the latest scanning technology to accurately measure large components, in-situ, with minimum disruption to the operation.

GT: What key industries will be the focal point for your organization moving forward?

HE: Hofmann forged steel gearing has always done well in precious metals like gold, where high power and reliability are critical to the application and any unscheduled downtime results in the loss of thousands of ounces. One of the most interesting trends from 2014 and 2015 is the move in orders destined for the aftermarket. Mill gearing orders for 2012-2013 at Hofmann were about 33 percent new projects and 67 percent aftermarket. In 2014-2015, new project orders declined to nine percent and aftermarket orders climbed to 91 percent. This illustrates how important the aftermarket for open gearing has become


An engineering team at Hofmann works on a big gear installation.

since the end of the mining boom, and we believe 2016 is likely to remain the same.

GT: Any new opportunities in rebuilds?

HE: We have seen a few rebuilds come back to the factory, but this is only a small proportion of the total while the overwhelming majority of orders in 2015 were for new gears and pinions. Hofmann does offer an in-situ gear refurbishment that has been popular in 2015. This process involves creating a good contact pattern between a worn gear and a new precision ground pinion by slowly restoring the gear tooth without removing the gear from the mill.

GT: What bottlenecks are you seeing in the large gear market and how are these bottlenecks affecting your business?

HE: Cash, cash, cash. From the mine operators to the OEMs, everybody is trying to conserve cash, and the reasons are obvious. Commodities prices continue to slide, putting pressure on all aspects of mining and processing, particularly new projects.

GT: What are the significant challenges regarding materials for large gear manufacturing?

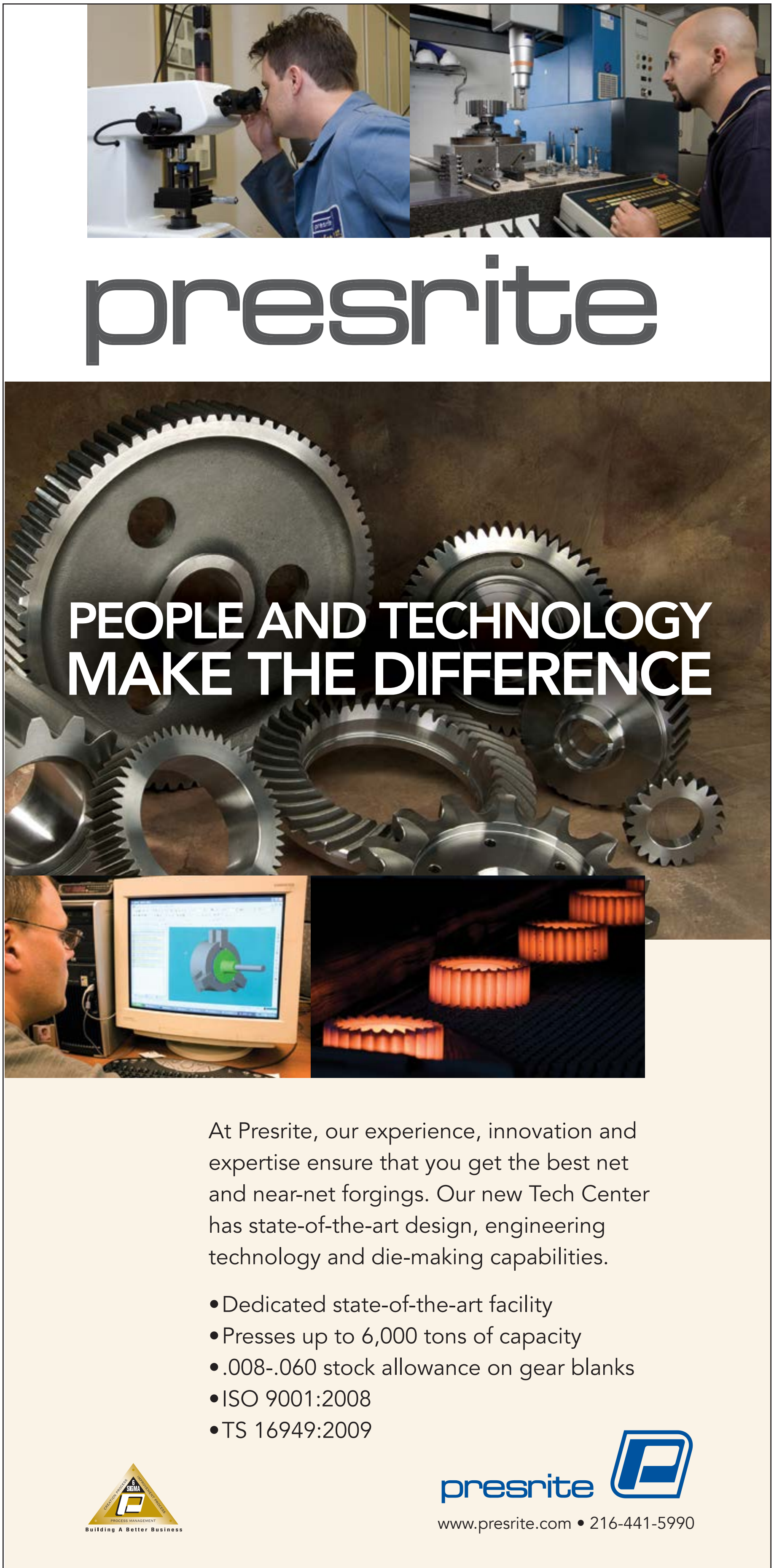
HE: There are several issues facing the materials that large gear manufacturers utilize. The trend for higher power mills will continue, and this will inevitably place higher demands on the gear material in terms of strength, hardness and toughness. On the other hand, in the aftermarket, the design of the gear sets cannot be altered, and if a mill operator has no desire to increase power, then offering higher hardness and strength is not necessarily an advantage, especially if it comes at a higher cost. A key factor here is selecting material that meets customer requirements, is available on short lead times and allows ease of manufacture so that the benefits can be passed on to our customers.

PCMM ON A MILL PINION

GT: How is your customer base changing in this volatile market today?

HE: The technical requirements of our customers have not changed significantly, but the price sensitivity has changed dramatically. Customers are demanding the lowest price to the highest quality levels in the best possible lead times and they are in a strong position to negotiate.

For more information:
Hofmann Engineering
Phone: +(61) 8 9279 5522
www.hofmannengineering.com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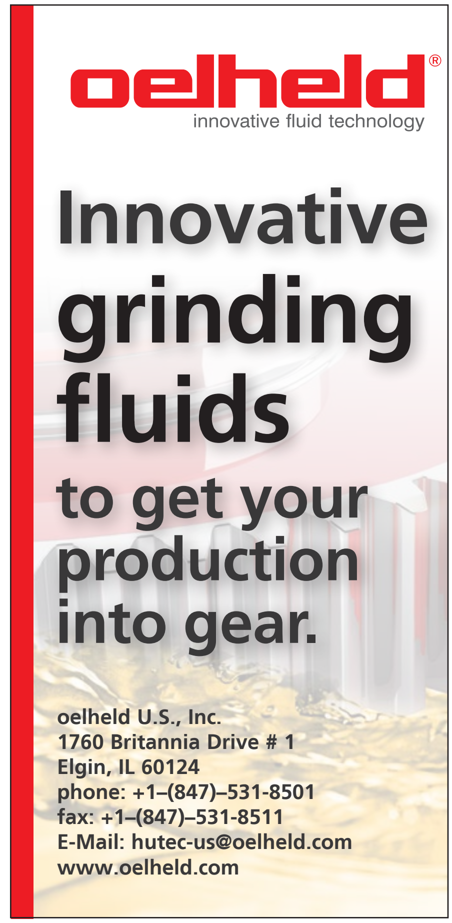
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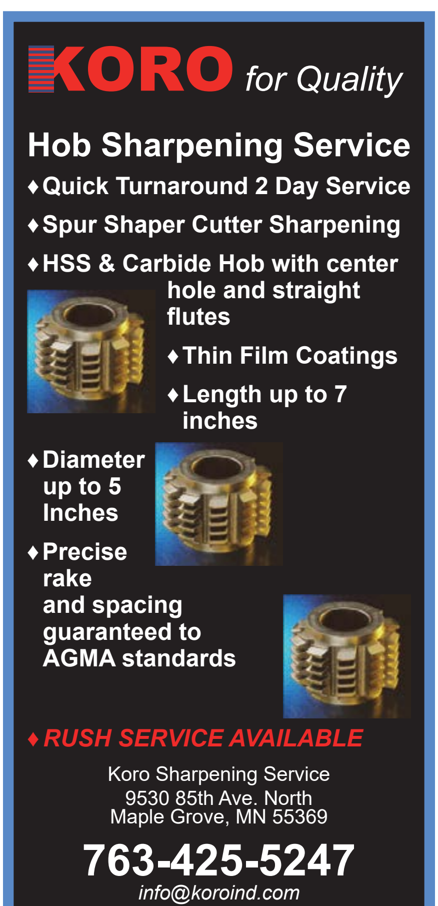
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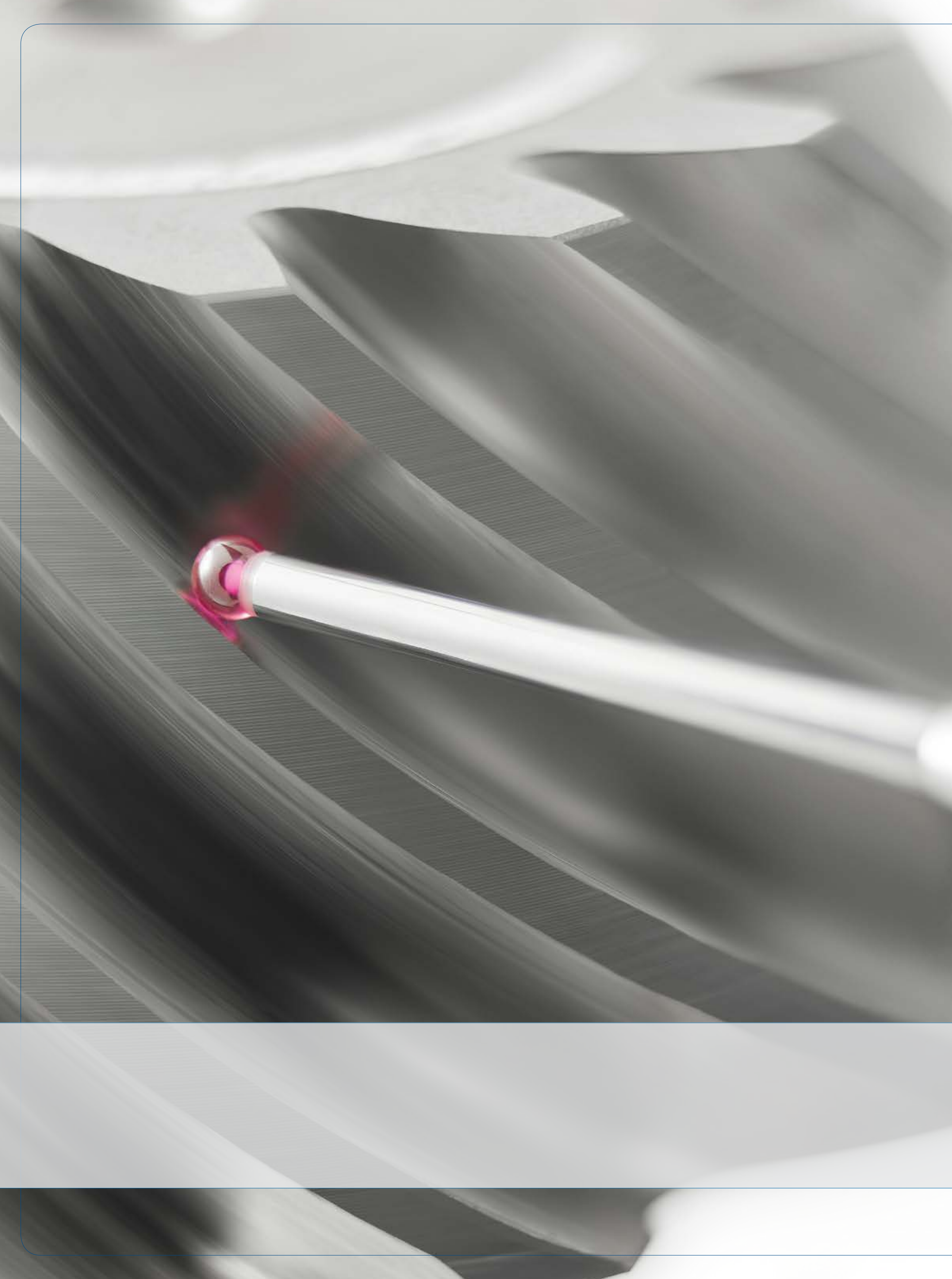

"Premature" Gear Failure

Email your question — along with your name, job title and company name (if you wish to remain anonymous, no problem) to: *jmcguinn@geartechnology.com*; or submit your question by visiting *geartechnology.com*.

QUESTION

I would appreciate if you could assist with a gear failure (occurring) after just seven weeks in service, post installation. This driving gear wheel has been installed in a medium-speed engine with backlash present at four different positions; with additional backlash checked on the mating surfaces. All backlash was found within (OEM)-recommended values. Please note included photos — it seems that the crack has started at the root fillet. Any comments would be appreciated.

Expert response provided by Chuck Schultz (PE).

No simple answers — despite the excellent photographs and concise description of the problem, there is just not enough information to "solve" this mystery. At the risk of being accused of "running the meter," there are many more questions to ask and tests to run before we could claim to know why this part failed after "only seven weeks." What follows is the procedure I use when confronted with a failure analysis request.

Understand the application. Based upon your request, we will assume seven weeks is much less than the expected life of a part in this service. I mention this because due to the statistical nature of allowable stresses, short design lives have more risk of premature failure. We need to know if this is a new installation or a replacement part. How have similar machines performed? Were there design or material changes on this particular part? Has the duty cycle changed? Has the operation changed? Something as simple as number of starts-per-shift can change a reliable machine into a maintenance hog.

It is very easy to jump to conclusions when doing a failure analysis. It is noted that the crack seems to have started at the root; ANSI/AGMA 1010 (Appearance of Gear Teeth -Terminology of Wear and Failure) is an excellent resource for failure analysts, and most of the tooth breakage photos

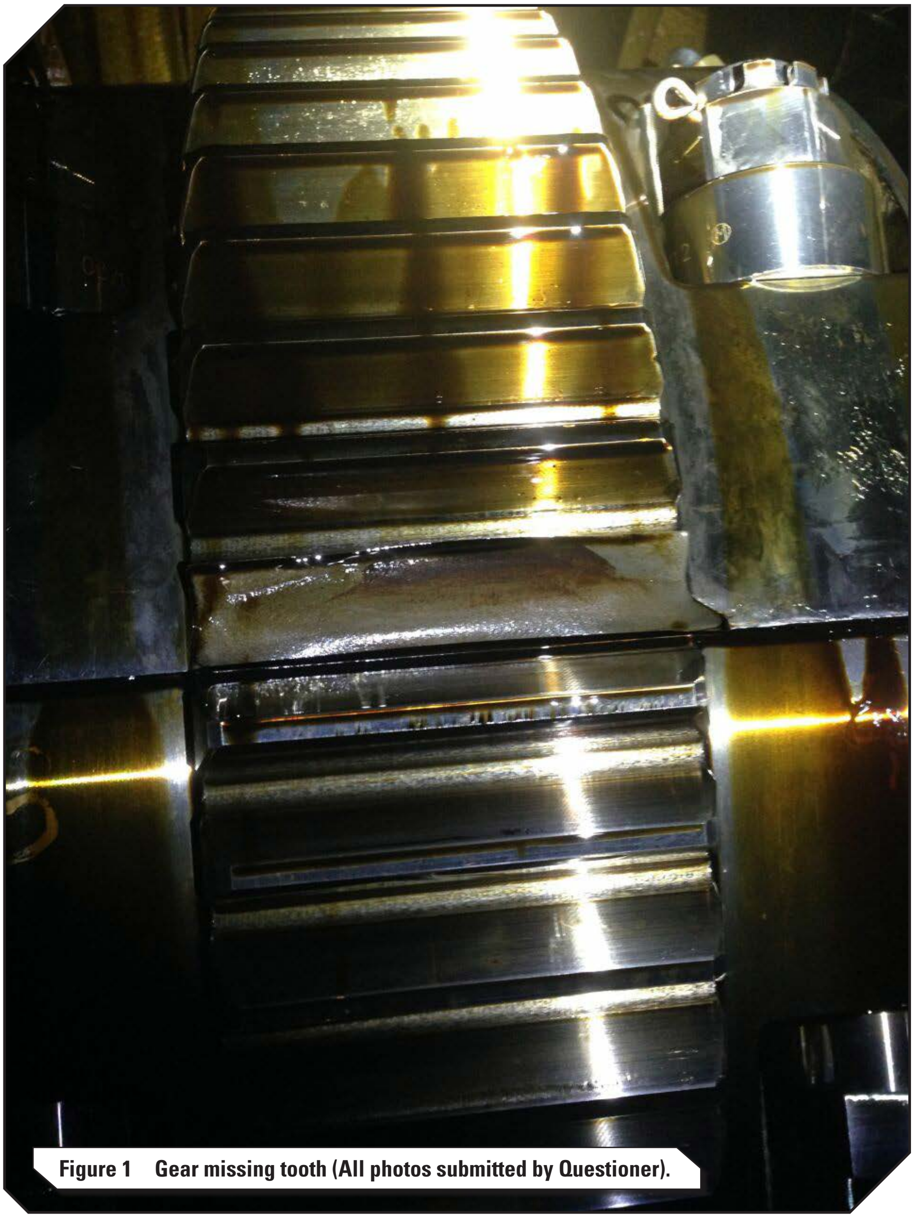

Figure 1 Gear missing tooth (All photos submitted by Questioner).

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failure
at www.geartechnology.com

show "activity" at the root. Each photo, however, has a different cause and suggested remedy. Applying the wrong remedy will just extend the failure and run up the cost.

Know the part's history. We once had a steel mill customer who was notorious for "re-cycling" used parts back into service. Used, as in "retrieved from the pile in back of the millwright's shop." I often tell people that if they could develop a way to accurately determine how much life was left in a part, they would be richer than King Midas. In the questioner's case we are told the part is new but there is still much to learn about what it was made of, what thermal processing it was subject to, and what quality control checks it had passed. Was it built to the right drawing? Was the material per the print? Was it checked for cracks along the way? Was it installed properly?

Verify the part's construction. Failed parts should be sectioned for tests at a qualified metallurgical laboratory. More than once the investigators have been shocked to discover the "wrong" material and heat treat were used to produce the component. "Wrong" could be a carburized part made on a through hardened base material, a through hardened part on a low- alloy material, or a strain hardened material that was thermally heat treated. Unfortunately, the world is awash in counterfeit parts that look just like the "real thing." Users do not know they have been bamboozled until a failure occurs and the met lab advises them that the base material doesn't match anything typically used for similar parts.

Some tests can be done in the field, without taking the machine further apart. The questioner reports checking backlash, yet nothing in the photos indicates poor assembly or misalignment. A quick check with crack detection compounds will reveal if the breakage is isolated to that particular tooth or if it had already spread to other teeth. While crack checking, examine the rest of the part closely for signs of poor heat treat, sloppy deburring, or damaged edges.

Talk to the operators and mechan-

Figure 2 View of removed tooth.

ics. Experienced operators can often sense when a machine is ready to fail. Inexperienced operators are unfamiliar with the warning signs and may bring on the disaster by ignoring long established procedures. Important clues can tumble out during casual conversation, things like wrecks elsewhere in the plant or new millwrights on the job.

Notice I said "talk" — not interrogate. An adversarial relationship doesn't help get to the truth. We once received a warranty claim gearbox with all the load flanks worn off, the bottom coated with filings, and the sump filled with brand new hydraulic fluid. Someone was worried about losing their job for not filling the box with gear oil before start-up and dumped in the handiest barrel of "oil" around. That failure was the first of that type in the installation, yet "nobody" knew anything about it. I am not saying this is the case in the questioner's failure, but skepticism is the appropriate attitude for every investigator.

Figure 3 Damage on removed tooth.

Review the facts. Once you have all the evidence in hand, go back again to ANSI/AGMA 1010 and review the photos, possible causes, and recommended remedies. Different causes can result in similar failures, but careful analysis of the evidence will usually result in a long-lasting solution.

Albert Einstein is famously quoted as saying "Things should be as simple as possible, but no simpler." It is tempting to rush to a conclusion based upon the appearance of a worn or broken tooth. Tempting — but expensive — in the long run. Unfortunately, three photos are not enough information to determine the cause of this failure.

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Thermal Behavior of a High-Speed Gear Unit

Christophe Changenet, Fabrice Ville and Philippe Velex

In this paper a thermal network model is developed to simulate the thermal behavior of a high-speed, one-stage gear unit which is jet-lubricated.

Introduction

In the general context of the reduction of energy consumption, there is an increased demand for more efficient gear units. It is possible to design geared transmissions which have a high efficiency: machinery 99 percent. But for high-speed turbo machineries (compressors, steam or gas turbines) the gearboxes may transmit power of several megawatts. In that case, one percent of dissipated power represents hundreds of kilowatts. This energy converted into heat is transferred through the elements and leads to a significant overall temperature rise of the mechanical components (Ref. 1), which can be harmful for the system integrity. Then reducing power losses has a dual objective: save some energy and reduce the overall heating of the gear set.

As for high-speed applications, oil jet lubrication appears as the most appropriate solution for lubrication and cooling gears. On the one hand, only a little amount of oil is sufficient for the formation of an oil film on tooth surfaces. On the other hand, a higher amount of oil flow rate is required for cooling gears. As has been demonstrated by numerous experiments, no-load power losses become prominent when considering high-speed gear transmissions (Ref. 2). Since these sources of dissipation increase with the lubricant flow rate (Ref. 3), the amount of lubricating fluid has to be carefully determined to ensure both sufficient heat transfer and high efficiency.

The aim of this study is to predict temperatures and power losses on industrial high-speed gear units, such as those used in power plants. A typical gearbox has been taken into account: an oil jet lubricated one-stage gear unit which is described in a first section. To simulate the heat transfer phenomena, the thermal network method has been used. The coupling between power losses and thermal calculations is explained in a second section. To validate the developed model, some comparisons between numerical and experimental results are given for different operating conditions. The influence of the oil flow rate on the thermal behavior of the gear unit is investigated in a last section.

Gear Unit Under Consideration

The system under consideration is a one-stage helical gear unit developed by Flender Graffenstaden. The whole set is enclosed in a housing made from cast iron. The gear data are given in Table 1.

The gear unit comprises two shafts which are supported by journal bearings. The unit is oil jet lubricated (kinematic viscosity of 32 Cst at 40° C and 5.4 Cst at 100° C/density of 870 kg/m^3 at 15° C). Different hydraulic circuits are used to lubricate the gears and the bearings. As far as the mating teeth are concerned, four injection nozzles are used along the tooth face width (Fig. 1).

All the tests performed during this study were conducted with no load applied. The rotational speed was imposed by an electric motor which also compensates for the losses in the gear unit. A torque sensor on the motor shaft was used to determine directly the mechanical power dissipated (accuracy of 0.1% of the measured value). Thermocouples were used for measuring temperatures at different locations: housing, inlet and outlet oil circuits, etc. Some temperature sensors were also placed on gears tooth in order to measure the bulk temperature of rotating parts. The data of these sensors were gathered by telemetry.

Table 1 Gear data

		Pinion	Wheel
Number of teeth	[-]	32	113
Module	[mm]	6 8	
Pitch diameter	[mm]	219.5	775
Tooth face width	[mm]	390	400
Pressure angle	[°]	20	
Helix angle	[°]	7.5	

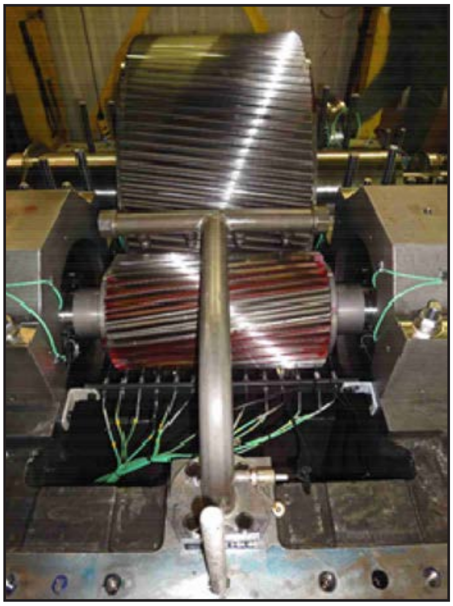

Figure 1 Lubrication of mating teeth.

Table 2 Elements of thermal network

Number	Element reference
1	Air
2	Gearbox housing
3	Injected oil
4	Mixture of air and lubricant
5	Oil trapped in the tooth interspaces
6, 7, 8, 9	Bearings
10	Primary shaft
11	Secondary shaft
12	Pinion
13	Wheel
14	Pinion's teeth
15	Wheel's teeth
16	Meshing of gear teeth

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Thermal Network

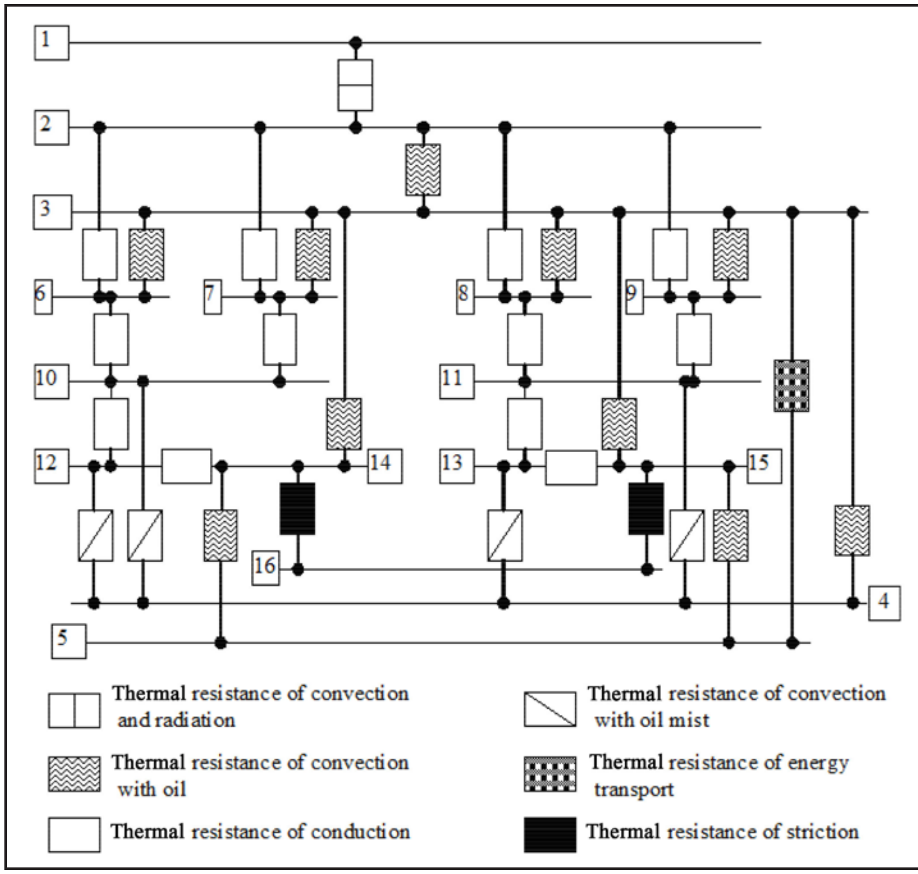

Figure 2 **Thermal network of oil jet-lubricated, one-stage gear unit.**

In order to simulate the thermal behavior of the tested gearbox, the thermal network method has been used. This method consists of dividing the geared unit into isothermal elements which are connected by thermal resistances. The one-stage jet lubricated gear unit under consideration has been divided into 16 elements, as detailed in Table 2.

The pinion and the gear wheel have been divided into two elements (nodes 12 and 14 for the pinion, nodes 13 and 15 for the gear wheel) in order to simulate the radial temperature gradient which may occur between the bulk temperature of a gear and the one of its teeth. Similarly, the lubricant has been separated in a number of nodes: the temperature of injection may be different to the one of the air/oil mist inside the casing, or the one of the oil that is trapped in the tooth interspaces. On the contrary, the gearbox housing has not been divided into several elements, since the objective was not to calculate the temperature distribution in the housing, but to determine a bulk temperature aimed at quantifying the heat exchanges with the air surrounding the gear unit.

The corresponding thermal network of the studied gear unit is described (Fig. 2) with the element labels as defined in Table 2. These elements are connected by thermal resistances depending on the kind of heat transfer, i.e. — conduction, free or forced convection and radiation. Following Changenet et al. (Ref. 4), the gearset is considered as an assembly of elements that have simple geometric shapes (as cylinders, flat plates, etc.) Thus, usual relationships of heat transfer can be used to quantify the associated thermal resistances. As an example — to evaluate the thermal resistance of convection and radiation between the housing and the surrounding air, Newton's and Stephan-Boltzmann's laws are respectively applied. In a similar manner the thermal resistance of conduction (for instance, between a gear and its shaft) is determined by applying Fourier's law. The oil jet flows used to lubricate the gearbox generate forced convection heat transfers: (a) along the casing walls, (b) with rotating parts and (c) by centrifugal fling-off on gear tooth faces. As a consequence, the thermal resistances of convection with oil (or air/oil mist) are determined according to the fluid flow considered. Finally, for a pinion and wheel in mesh under load, the gear tooth temperature consists of the addition of the bulk temperature and the flash temperature (Ref. 5); i.e., the Hertzian contact zone is very small in comparison with the characteristic dimensions of the gear tooth, and leads to a constriction of the thermal current from the surface to the body center. To account for this phenomenon, thermal resistances of striction are used in the thermal network (Ref. 4).

The heat generated by power losses in geared systems must be injected at certain nodes of the thermal network; five sources of dissipation have been taken into account in the gear set:

1. **Friction at the mating teeth of loaded pinion and wheel.** Tooth friction losses are calculated with relationships of Velex and Ville (Ref. 6). They are injected at node #16.
2. **Bearing power losses.** The resisting torque generated by a journal bearing can be estimated by using equations developed by Pierre and Fillon (Ref. 7). These power losses are injected into nodes #6 through #9.
3. **Windage effects.** The windage power loss generated by gears rotating in air/oil mist is evaluated according to Diab's formulas (Ref. 8). This source of dissipation is injected at node #4.
4. **Oil acceleration.** The oil jet flow that is used to lubricate gears is accelerated in the circumferential direction (Ref. 9). This phenomenon requires energy which is taken into account at node #3.
5. **Oil trapping.** The lubricant trapped in the tooth interspaces is successively compressed and expanded in these spaces, giving rise to power loss. Such power loss is quantified according to Butsch's relationships (Ref. 10) and injected into node #5.

The temperatures and heat flux distributions can be estimated by solving the equations generated by the thermal network (Ref. 4). The numerical solving procedure can be synthesized as follows: the different temperatures are initialized, power losses and thermal resistances are calculated, the bulk temperatures are determined and an iterative loop is made in order to revalue these parameters. Convergence is reached when the relative difference between two iterations is less than 0.1% for power loss and temperature.

Comparisons between Numerical and Experimental Results

The results presented in this section are written in a dimensionless form. For each node i of the network, the temperatures are expressed as:

$$\theta_i = (T_i - T_{air})/(T_{oil} - T_{air}) \tag{1}$$

Where T_{oil} and T_{air} are, respectively, the temperatures of the oil jet at the inlet and of the ambient air. As far as power losses are concerned, their dimensionless values are defined as follows:

$$P_i = Q_i/(M.c.\Delta T_{max}) \tag{2}$$

Where Q_i represents heat generated by node i, M the lubricant mass flow rate, c the oil-specific heat and ΔT_{max} the maximum temperature difference measured between the outlet and the inlet of the oil jet flow.

As mentioned, the tests presented in this section were performed with no applied load. Figure 3 presents power losses for different rotational speeds. In this figure the solid line (Num) represents the numerical results, whereas the marks (Exp.) account for the experimental findings. The results show that the prediction of power losses is satisfactory.

In Figure 4 the dimensionless temperature is plotted against the rotational speed for two different elements — a) the outlet oil circuit and b) the tooth of the gear wheel. This figure shows good agreement between the experimental and numerical results. One can notice that the bulk temperature of the tooth wheel is much higher than the one of the oil jet flow. This kind of result is logical for tests under load but seems surprising when no load is applied. The thermal network model can be used to analyze this result. For the studied operating conditions, the power losses due to oil trapping are very important; at 4,000 rpm this source of dissipation represents almost 33 percent of the total power lost. As a consequence, the oil trapping generates local temperature rises both for the gear wheel tooth and the pinion one.

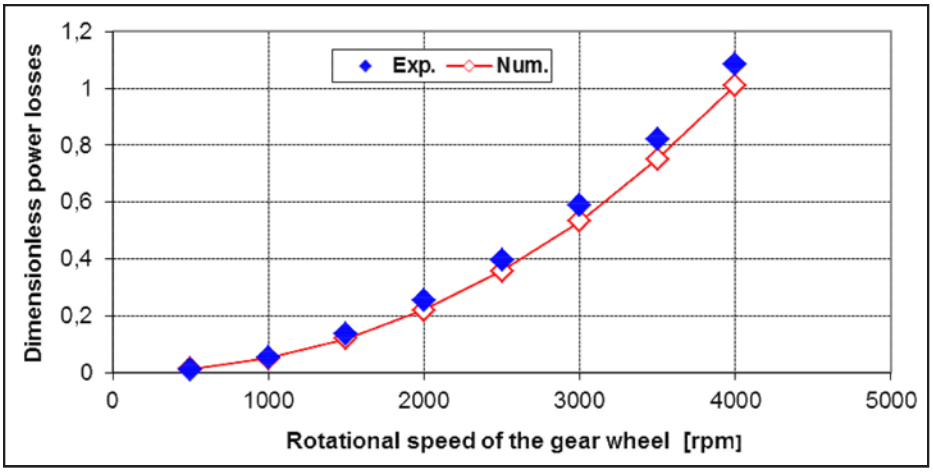

Figure 3 Dimensionless power losses vs. rotational speed.

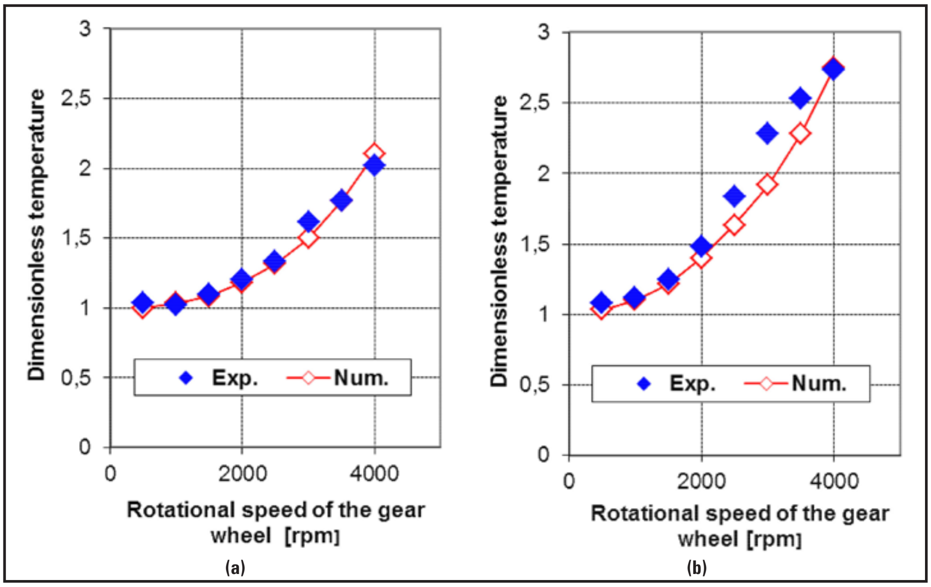

Figure 4 Comparison of measured and calculated temperatures for (a) oil jet at the outlet, and (b) tooth of the gear wheel.

Influence of Oil Flow Rate

The previous section has demonstrated that the thermal network model gives accurate results. So it can be used to simulate tests under load and to study the oil flow rate influence on the thermal behavior of the enclosed gear drive. For an input power equal to 30 MW and a rotational speed of the gear wheel equal to 4,000 rpm, the power loss distribution estimated through the thermal network is given in Figure 5. From these results it appears that power losses generated in the gear unit can be divided into four main sources of dissipation — tooth friction; bearings losses; windage effects; and oil trapping — which are almost equally distributed.

For high-power conditions an important part of the lubricant has to be used for cooling the gear teeth. Among the sources of dissipation highlighted in Figure 5, oil trapping and the torque required to accelerate the oil jet flow in the circumferential direction increase directly with the lubricant mass flow rate. On one hand, if too much oil entered the gear mesh, excessive losses may occur because of oil being trapped in the gear teeth and pumped out of the mesh. On the other, if not enough oil is injected the gear cooling can be insufficient.

The thermal network of the gear unit is then used to study the evolution of bulk temperatures versus the lubricant flow rate. As an example, Figure 6 presents the calculated temperature of the gear wheel. One can notice that above 300 l/min the gear wheel bulk temperature decreases slowly with oil flow rate. For this operating condition, the heat-transfer coefficient of convection between oil and gear wheel is high. Thus the associated thermal resistance is small and a change of its value no longer determines the thermal equilibrium of this element. It can be concluded from this evolution that there is no interest to significantly increase the

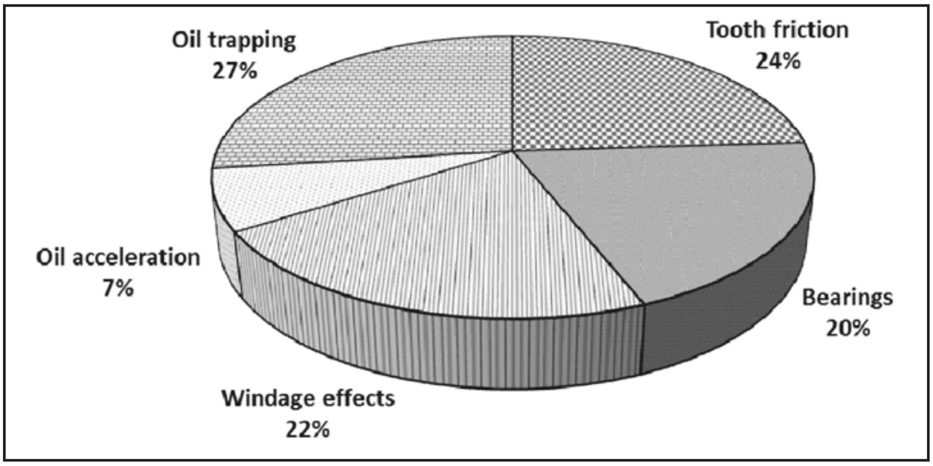

Figure 5 Power loss distribution.

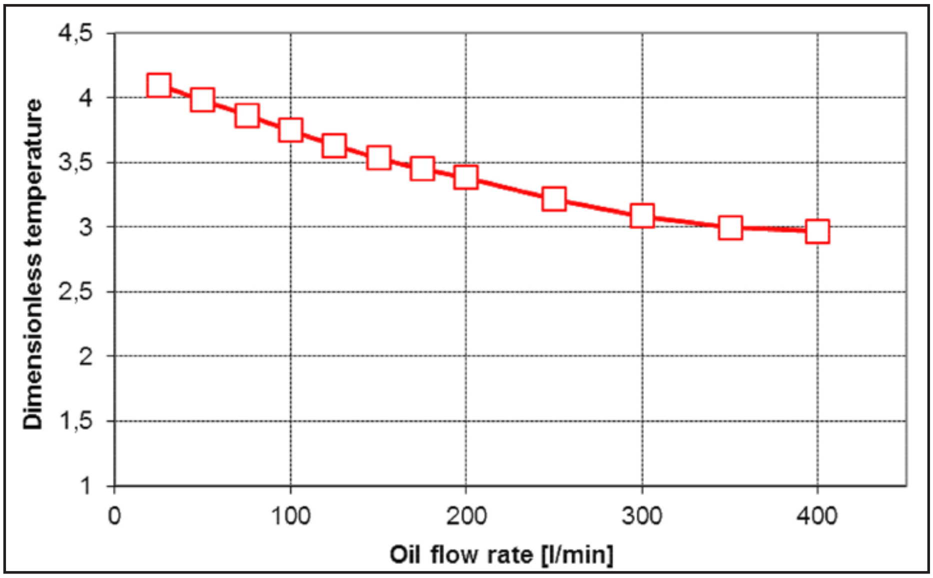

Figure 6 Evolution of gear wheel bulk temperature vs. oil flow rate.

lubricant mass flow rate. Moreover, this limitation will also induce a more efficient gear unit.

Conclusion

A model of a high-speed gear unit is presented that combines bulk temperature predictions and power loss calculations using a thermal network. A series of measurements was carried out on a specific test rig in order to validate this numerical model. Based on comparisons between experimental and numerical results, it is shown that the proposed model can accurately predict power losses generated in the gear unit and its steady state thermal behavior. As the model gives access to a detailed thermal mapping in the gearbox, it is used to study the evolution of rotating parts bulk temperature versus lubricant mass flow rate. It appears that above a given value, increasing the oil flow does not induce a significant decrease in gear bulk temperatures. Then an upper limit of the lubricant mass flow rate can be defined and used to design more efficient enclosed gear drives.

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Influences on Failure Modes and Load-Carrying Capacity of Grease-Lubricated Gears

Hansjörg Schultheiss, Johann-Paul Stemplinger, Thomas Tobie and Karsten Stahl

In order to properly select a grease for a particular application, a sound knowledge of the influence of different grease components and operating conditions on the lubrication supply mechanism and on different failure modes is of great benefit.

In this paper the experimental results of a number of research projects with greases ranging from NLGI 00 to NLGI 1 — using the FZG back-to-back gear test rig — are evaluated in context.

Introduction

For many years, greases have been used in the lubrication of ball bearings. For the lubrication of gears, however, oils still play the dominant role. In recent years, the advantages of grease over oil in certain gear applications have led to an increasing significance of grease in gear lubrication. Unlike oil lubrication, for which methods for the calculation of the gear load-carrying capacity have long since been established in standards, such as ISO 6336 or DIN 3990, calculation methods for the load-carrying capacity of grease do not yet exist. This is mainly due to the complex interaction of the influence parameters on the load-carrying capacity of grease-lubricated gears as well as the limited availability of accessible, experimental investigations. A large portion of the conducted experimental work on grease lubrication focuses on the application of grease in the lubrication of bearings. Therefore numerous studies have concentrated on lubricant film thickness investigations with grease. A good summary of these and further, similar work is given by Lugt (Ref. 10). Nonetheless, the number of experimental investigations on the load-carrying capacity of grease-lubricated gears is steadily increasing. For example, Fukunaga (Refs. 2, 1), and in more recent years, Krantz and Handschuh (Ref. 8), and also Krantz et al. (Ref. 9) performed experiments to investigate the effect of different operating conditions and grease parameters on the failure modes of grease-lubricated gears. In the past decade several research projects were conducted at FZG with the aim of expanding general knowledge of grease-lubricated gears. The experimental work therein focuses on the influences of different grease components and operating conditions on different gear failure modes such as scuffing, wear and pitting.

In this paper, selected experimental results from DGMK research projects 591(Ref. 3) 673 (Ref. 4), 670 (Ref. 14), 671 (Ref. 15) and 725 (Ref. 11), with greases ranging from NLGI 00 to NLGI 1, using the FZG back-to-back gear test rig and that have already largely been published on their own in papers and dissertations (see Refs. 12, 16, 5 and 13), are evaluated in context.

Lubrication Supply Mechanism for Grease-Lubricated Gears

The lubrication supply mechanism is of great importance, as it determines the amount of lubricant available in the gear mesh as well as heat dissipation from the gear mesh. These factors, in turn, determine the resulting gear failure mode and lifetime. For oil dip lubrication, under normal operating conditions oil is always available to the gear mesh if the sump fill-level is sufficient. The lubrication supply mechanism is, therefore, always the same and the lubricant film thickness increases with increasing rotational speed. For grease, however, the lubrication supply mechanism is more complex and depends on a number of factors. Fukunaga (Ref. 2) and Stemplinger (Ref. 15) each identify two main lubrication supply mechanisms for grease-lubricated gears, i.e. — "channeling" and "circulating/churning" (Figs. 1 and 2). Circulating refers to the lubrication supply mechanism where the grease in the sump in close proximity to the rotating gears circulates, regularly fills the tooth gaps to a certain degree and is thus available in the gear mesh. According to Stemplinger (Ref. 15), circulating, in comparison to channeling, ensures a better lubricant supply to the gears, better cooling,

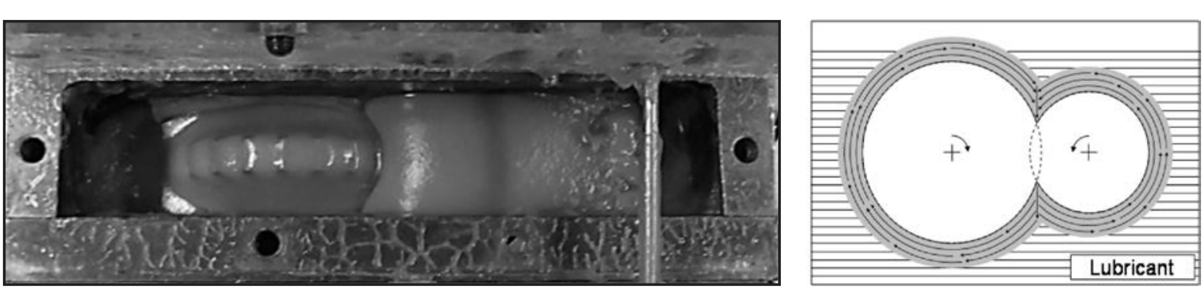

Figure 1 Lubrication supply mechanism "circulating" (Ref. 15).

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and thus lower bulk temperatures in the gears. Furthermore, more homogenous sump temperatures can be observed. Circulating mainly occurs at higher sump fill levels, lower NLGI grades, and lower rotational speeds.

Channeling, on the other hand, refers to a situation where the grease does not, or at least not to a significant degree, refill the tooth gaps of the rotating gears and thus very little, to no grease at all, is carried into the gear mesh. Often an accumulation of bleed oil can be observed, which may in fact be mainly responsible for the lubrication of the gears (Fig. 2). According to (Ref. 15), a lack of lubrication and cooling can be observed, which can lead to high bulk temperatures in the gears with a heterogeneous temperature distribution in the gearbox. In total, only a small amount of grease participates in gear lubrication and so comparatively low no-load losses can be observed. Channeling mainly occurs for low- to medium-fill levels, high NLGI grades and higher rotational speeds.

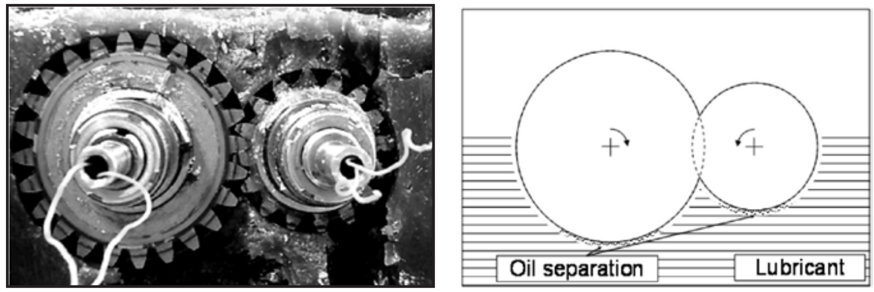


Figure 2 Lubrication supply mechanism "channeling" (Ref. 15).

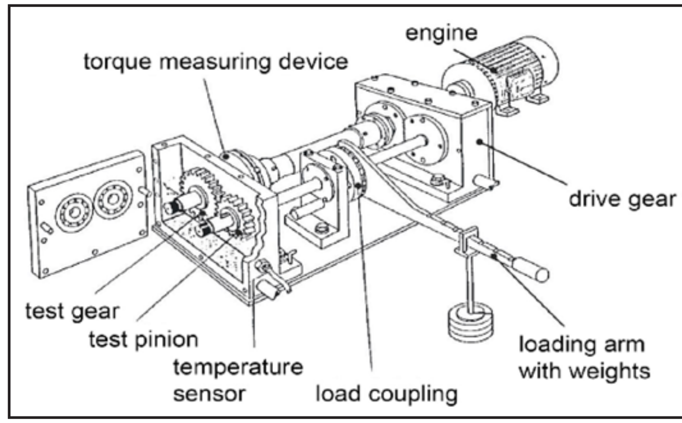


Figure 3 FZG back-to-back gear test rig.

Test Equipment

The experimental investigations of the gear performance under various test conditions were conducted on FZG back-to-back gear test rigs. The schematic setup of the FZG back-to-back gear test rig is shown (Fig. 3). Acc. to ISO 14635-1 (Ref. 6), the test rig utilizes a re-circulating power loop principle — also known as a "four-square configuration" — in order to provide a fixed torque (load) to a pair of test gears.

For the different investigations conducted, the gear types specified in the respective test regulation were used. Table 1 shows an overview of the data for the different test gear types used.

Table 1 Data of the test gears types A, C-PT, C-GF and 21/24

Dimension		Symbol	Type A	Type C-PT	Type C-GF	Type 21/24	Unit
Center distance		*a*	91.5	91.5	91.5	91.5	mm
Module		*m*	4.5	4.5	4.5	4.0	mm
Number of teeth	pinion	z_1	16	16	16	21	–
	wheel	z_2	24	24	24	24	–
Face width		*b*	20	14	14	15	mm
Helix angle		*β*	0	0	0	0	°
Pressure angle		*α*	20	20	20	20	°
Working pressure angle		α_w	22.44	22.44	22.44	22.44	°
Profile-shift coefficient	pinion	x_1	0.8532	0.182	0.182	0.22	–
	wheel	x_2	–0.5	0.172	0.172	0.177	–
Tip diameter	pinion	d_{a1}	88.70	82.46	82.46	92.70	mm
	wheel	d_{a2}	112.50	118.36	118.36	103.90	mm
Basic material	pinion	–	20MnCr5	16MnCr5	16MnCr5	16MnCr5	–
	wheel	–	20MnCr5	16MnCr5	16MnCr5	42CrMo4	–
Surface hardness	pinion	–	700–750	700–750	700–750	700–750	HV
	wheel	–	700–750	700–750	700–750	280–290	HV
Flank roughness	pinion	*Ra*	0.35±0.10	0.30±0.10	0.50±0.10	0.30±0.10	µm
	wheel	*Ra*	0.30±0.10	0.30±0.10	0.50±0.10	0.30±0.10	µm

Test Lubricants

Table 2 shows an overview of the lubricants used in the experimental investigations. All the tested lubricants were specially formulated for the investigations and are not commercially available. The EP additive package, however, is a fully formulated, commercially available product.

Influences on the Scuffing Load-Carrying Capacity of Grease-Lubricated Gears

The investigations on the scuffing load-carrying capacity were conducted in the project DGMK 591 (Ref. 3) in load stage tests, acc. to ISO 14635-1 with gears of type A. The pitch line velocity during the tests was $v_t = 8.3$ m/s ($n_1 = 2{,}250$ min-1), the starting sump for graphite as well as molybdenum disulphide (MoS_2) (Fig. 5). Under the given test conditions, MoS_2 performed better than graphite. An increase in the concentration of graphite did not further increase temperature in each load stage 50° C and the fill-level for all tests was at shaft center. For each lubricant, two runs were conducted. The results show that the base oil M680G-o exhibits a much higher scuffing load-carrying capacity than the grease M680Al00-o that is based on this oil (Fig. 4). Furthermore, with increasing base oil viscosity the scuffing load-carrying capacity of grease increases. Tests on the influence of a solid lubricant added to the grease showed an increase in the scuffing load-carrying capacity the scuffing load carrying capacity. Although the added solid lubricants were shown to increase scuffing load-carrying capacity, increased wear could be observed, especially with graphite. Furthermore, the thickener type was found to affect the scuffing load-carrying capacity. Although not shown in the diagrams, grease with a lithium soap thickener was shown to perform slightly better than grease with an aluminum-complex soap thickener.

Table 2 Test lubricants

Lubricant code	Base oil type	Nom. base oil viscosity v40 (cSt.)	NLGI grade	Tickener type	Thickener concentration (wt. %)	Solid lubricant	Additiv package
M680G-o	Mineral	680					
M680G	Mineral	680	–	–	–	–	EP
M70A100-o	Mineral	70	00	Al-X	4.4		
M70A100	Mineral	70	00	Al-X	4.3	–	EP
M680A100-o	Mineral	680	00	Al-X	3.3	–	–
M680A100	Mineral	680	00	Al-X	3.2		EP
M1200A100-o	Mineral	1200	00	Al-X	2.6	–	–
M1200A100	Mineral	1200	00	Al-X	2.5		EP
M70Li00	Mineral	70	00	Li	3.6	–	EP
M680Li00	Mineral	680	00	Li	4.7		EP
M1200Li00	Mineral	1200	00	Li	6.6		EP
P70Li00	PAO	70	00	Li	approx. 6.0	–	EP
P680Li00	PAO	680	00	Li	approx. 6.0		EP
P1200Li00	PAO	1200	00	Li	approx. 6.0	–	EP
M680ALOO-oC4.2%	Mineral	680	00	Al-X	2.6	4.2% C	
M680A100-C4.2%	Mineral	680	00	Al-X	2.5	4.2% C	EP
M680ALOO-oC11.1%	Mineral	680	00	Al-X	2.1	11.1% C	–
M680A100-C11.1%	Mineral	680	00	Al-X	2.0	11.1% C	EP
M680ALOO-oM	Mineral	680	00	Al-X	2.6	4,2% M	–
M680A100-M	Mineral	680	00	Al-X	2.5	4,2% M	EP
M680Li0	Mineral	680	0	Li	6.65	–	EP
M1000Li0	Mineral	1000	0	Li	6.8	–	EP
M1500Li0	Mineral	1500	0	Li	6.95		EP
M110Li1	Mineral	110	1	Li	8.1	–	EP

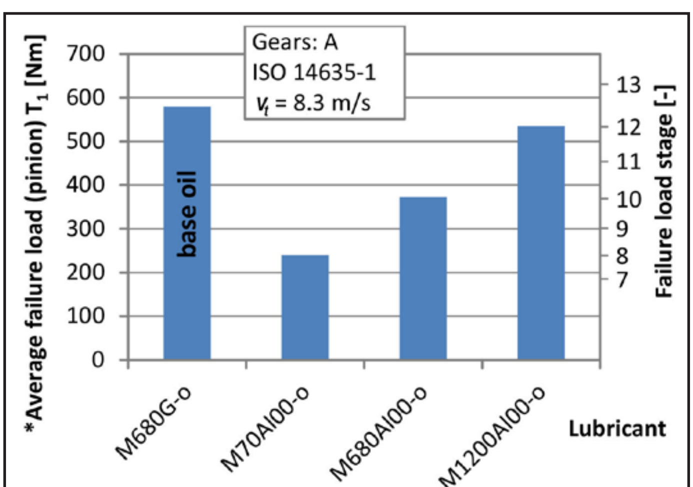
C = synthetic graphite solid lubricant
M= MoS_2 solid lubricant
EP = extreme pressure additive package
Al–X= aluminium complex soap thickener
Li = lithium soap thickener
EP = 4 wt. % EP additive package (RC9505)

Influences on the Wear Behavior of Grease-Lubricated Gears

In DGMK 725 (Ref. 11) the influence of various grease parameters on the slow speed wear behavior was investigated with gears of type C-GF. The pitch line velocity during the tests was $v_t = 0.05$ m/s ($n_1 = 13$ min^{-1}), the pinion torque $T_1 = 626.9$ Nm ($p_c = 2{,}385$ N/mm^2) and the fill-level for all tests was at shaft center. The total test duration of the three-stage test used was 120 h. In the first 40 h the sump temperature was kept at 60°C; in the second 40 h at 90°C; and in the third 40 h at 60°C. For each lubricant, two runs were conducted and the average wear sum calculated. Under the given test conditions the lubrication supply mechanism in all tests was observed to be circulating. The results show that for lithium soap grease with either mineral base oil or PAO-based oil, tendentially lower wear occurs with increasing base oil viscosity (Fig. 6). The PAO-based greases show slightly lower wear than their mineral oil-based counterparts. The addition of the solid lubricant graphite to the grease M680Al00 leads to an increase in wear (Fig. 7). The concentration of solid graphite, however, has little effect on the wear behavior. The solid lubricant molybdenum disulphide (MoS_2) also leads to an increase in wear in comparison to the reference grease with no solid lubricant (M680Al00), although the increase in wear is not as large as with the same concentration of graphite.

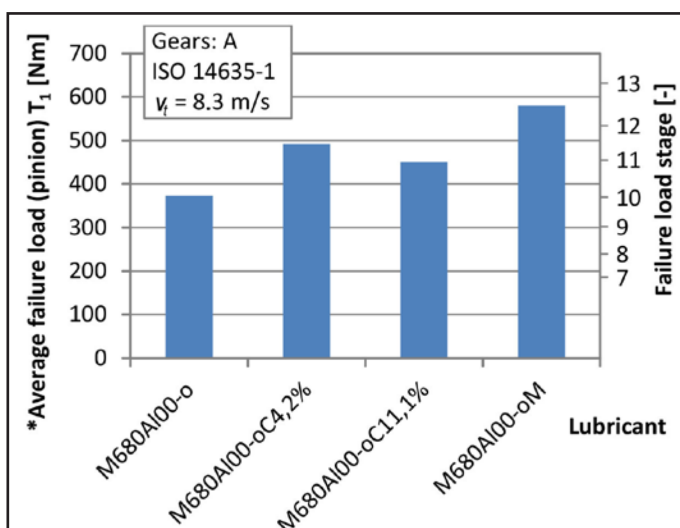
Figure 8 shows results of wear tests conducted (Refs. 3, 14). After a load stage test acc. to ISO 14635-3 (Ref. 7), a 100 h run at LS 10 ($p_c = 1{,}539$ N/mm^2) followed. Only the wear in the 100 h run was evaluated (Ref. 7).

The NLGI 00 grease and the base oil show comparable wear. Increasing the NLGI-grade to 0 shows a clear increase in wear. This indicates that with NLGI 00 grease the lubrication supply to the mesh is better than with NLGI 0 and thus is likely to be



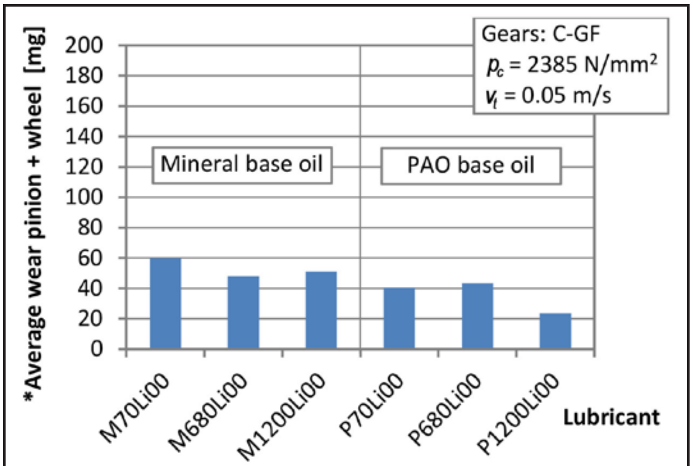
* Average failure load from two test runs

Figure 4 Influence of base oil viscosity on scuffing load carry capacity of NLGI 00 grease without EP additive package (Ref. 3).



* Average failure load from two test runs

Figure 5 Influence of the solid lubricant type and concentration on scuffing load-carrying capacity of NLGI 00 grease without EP additive package (Ref. 3).



* Average wear sum for pinion and wheel from two test runs (120 h each).

Figure 6 Influence of the base oil-type and viscosity on the slow-speed wear behavior of NLGI 00 grease with EP additive package (Ref. 11).

circulating, while with NLGI 0 channeling effects possibly occur which lead to an increase in wear. An increase in the base oil viscosity of the NLGI 0 grease tends to lead to a further increase in wear.

Influences on the Pitting Lifetime of Grease-Lubricated Gears

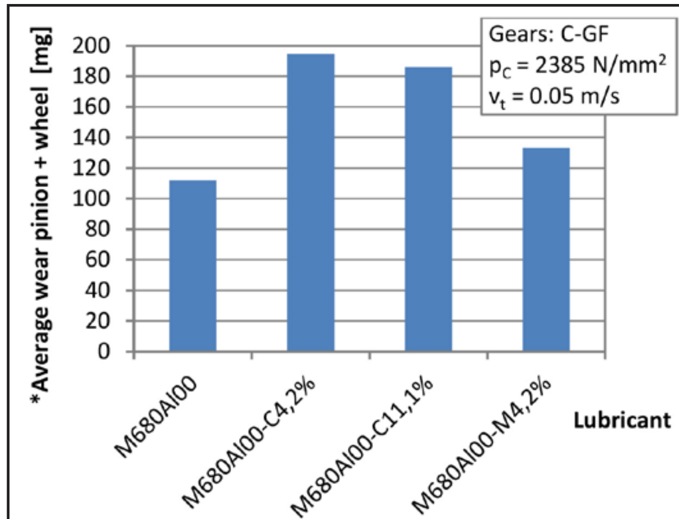
In the projects DGMK 591(Ref. 3), 673 (Ref. 4) and 670 (Ref. 14), tests were run under various conditions and with different gear types to investigate the influence of different grease components and operating conditions on the pitting lifetime of NLGI 00 and NLGI 0 greases. The fill-level for the tests was at shaft center; an overview of the test results is given in Figs. 9 – 11.

The results show that for grease, pitting lifetimes that are almost equal to those of the base oil can be achieved. This can be observed for M680Al00 and base oil M680G at 6.7 m/s (Fig. 9), as well as for M680Li00 and base oil M680G at 5.5 m/s pitch line velocity (Fig. 10). At the higher pitch line velocity (8.3 m/s), however, the pitting lifetime of M680Li00 is much lower than that of its base oil M680G (Fig. 10). This is due to the dominant lubrication supply mechanism. At lower speeds, circulating dominates, at the higher rotational speed dominates, at the higher rotational speed, however, channeling takes the upper hand. Figure 11 shows that for 6.7 m/s the pitting lifetime of the NLGI 0 grease M680Li0 is lower than for its base oil M680G. This shows that the NLGI-grade affects the lubrication supply mechanism — in this case probably leading to dominant channeling effects. It was also observed that increasing the base oil viscosity led to an increase in the pitting lifetime (Figs. 9 – Fig. 11).

Flank Load-Carrying Capacity of NLGI 1 Grease at Different Pitch Line Velocities and Fill-Levels

Figure 12 shows an excerpt of different investigations that were conducted in the research project DGMK 671 (Ref. 15). The diagram shows the different lubrication supply mechanisms for M110Li1 for two different fill-levels of 40 and 80% and the resulting failures. The sump temperature ϑ_S and the material loss of pinion Δm (*pi*) and wheel Δm (*wh*) are also shown.

In the 100h test, the investigated base oil for M110Li1 (not



* Average wear sum for pinion and wheel from two test runs (120 h each).

Figure 7 Influence of solid lubricant type and concentration on the slow speed wear behavior of NLGI 00 grease with EP additive package (Ref. 11).

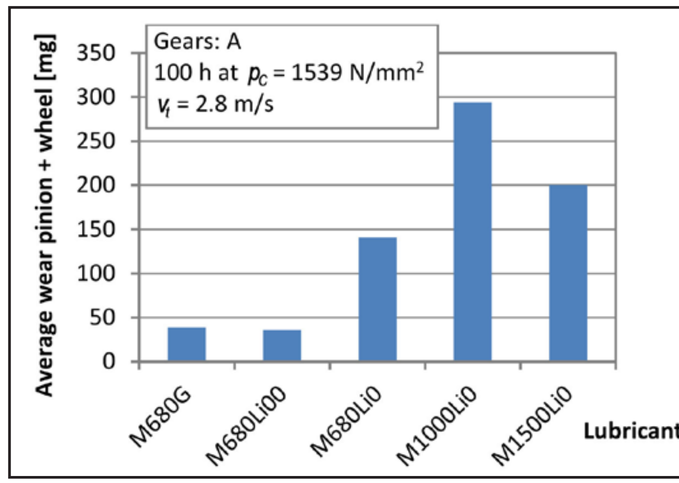


Figure 8 Influence of the base oil viscosity and NLGI grade on the wear behavior of grease with EP additive package (Refs. 3, 14).

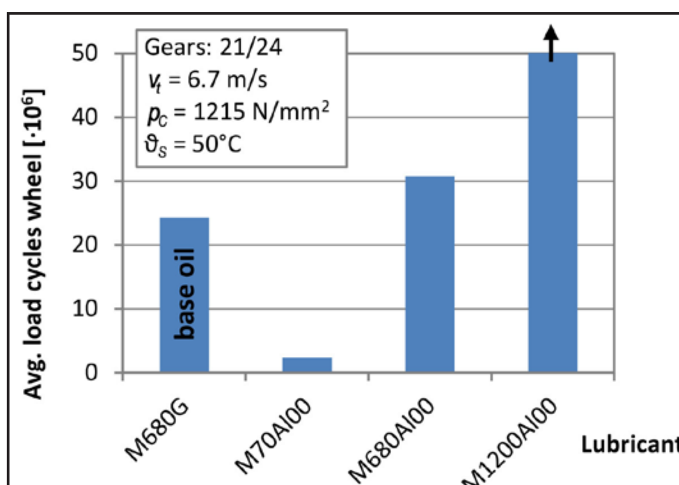


Figure 9 Influence of the base oil viscosity on pitting lifetime of NLGI 00 grease with EP additive package — DGMK 591 (Ref. 3).

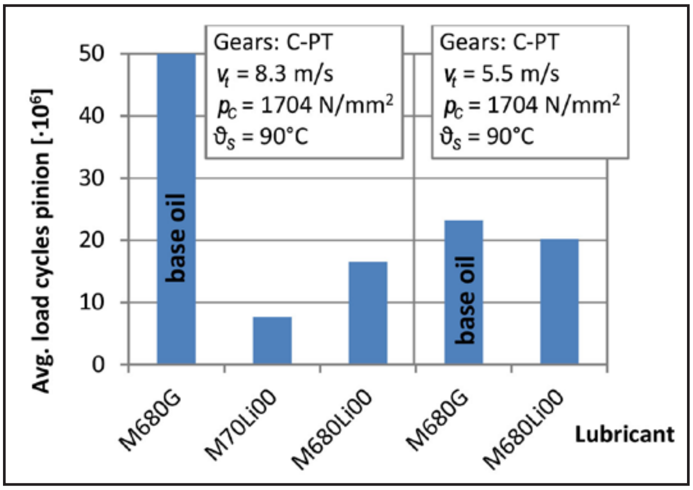


Figure 10 **Influence of the base oil viscosity on pitting lifetime of NLGI 00 grease with EP additive package — DGMK 673 (Ref. 4).**

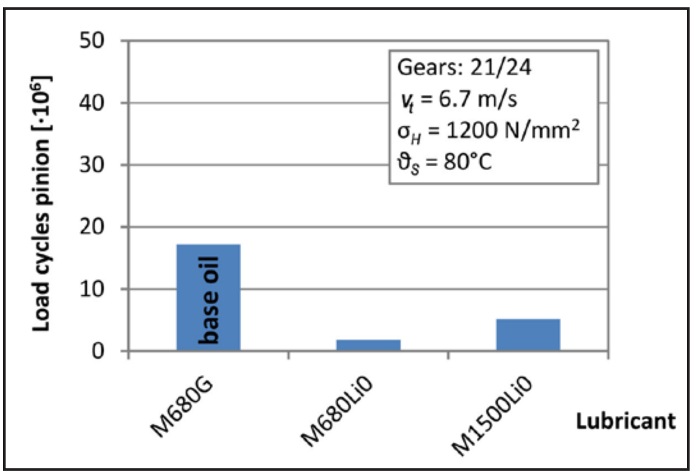


Figure 11 **Influence of the base oil viscosity and graphite on pitting lifetime of NLGI 0 grease with EP additive package — DGMK 670 (Ref. 13).**

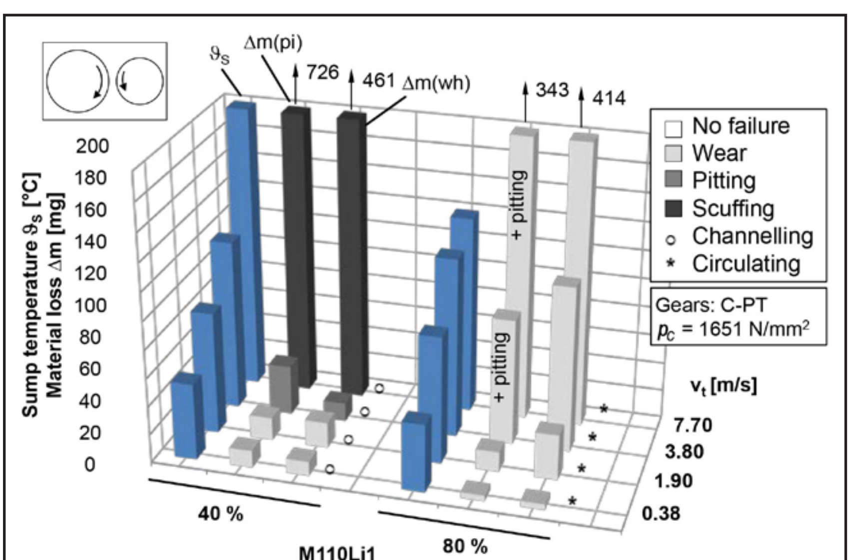


Figure 12 **Analysis of sump temperature and material loss for M110Li1 at different speeds and filling levels (Ref. 15).**

shown) did not fail and showed the lowest sump temperatures ϑS. With the grease M110Li1, for increasing speed and thus increasing transmitted power and loss torque, increasing sump temperatures are observed. Independent of the fill level, M110Li1 shows no failures at the two lowest speeds, apart from very slight wear. Due to channeling and thus limited heat removal, scuffing occurs at maximum speed for 40% fill-level. At 80% fill-level and circulating, heat removal is better and thus scuffing is avoided but pitting and/or high wear occur instead. At a medium pitch line velocity, $v_t = 3.80$ m/s ($n_1 = 1{,}000\ min^{-1}$), pitting occurred for 40% fill-level. In contrast, for 80% fill-level the gearset shows significant material loss due to wear as well as some pitting. Despite the observed circulating for 80% fill-level, possibly not quite as much grease actually reaches the mesh as initially assumed for this lubrication supply mechanism. The grease in the tests forms a "ring" around the gears (compare Fig. 1), thus evidently "circulating." This leads to better heat dissipation, which averts scuffing at higher speeds; but the question remains on how much grease actually reaches the contact. The high-occurring wear would indicate starved lubrication conditions in the mesh.

Summary

The results of the conducted investigations can be summarized as follows:

- ***Scuffing.*** For test conditions at relatively high speed acc. to ISO 14635-1(Ref. 6), grease shows a lower scuffing load-carrying capacity than its base oil. An increase in the scuffing load-carrying capacity can be achieved by increasing the base oil viscosity of the grease, as well as through the addition of the solid lubricants graphite or MoS_2, though this may lead to increased wear. Grease with a lithium soap thickener was found to perform slightly better than grease with an aluminum-complex soap thickener.
- ***Wear.*** At very slow speeds and a circulating lubrication supply mechanism, an increase in the base oil viscosity leads to a reduction in wear. Greases based on PAO-based oil perform slightly better than those based on mineral oil. The addition of the solid lubricants graphite and MoS_2 leads to an increase in wear.

  The wear tests acc. to ISO 14635-3 show that an NLGI 0 grease shows higher wear than an NLGI 00 grease, whose wear behavior was shown to be similar to that of the base oil. With the higher NLGI-grade, presumably the lubrication supply mechanism is dominated by channeling effects which lead to insufficient lubricant replenishment of the gear mesh.
- ***Pitting lifetime.*** At the lower rotational speeds (5.5 and 6.7 m/s), the pitting lifetimes of an NLGI 00 grease and its base oil are comparable; at the higher rotational speed (8.3 m/s), however, the pitting lifetime of the grease is lower than that of the base oil. Increasing the NLGI grade also leads to a reduction in pitting lifetime. This can be explained by the lubrication supply mechanism, where circulating dominates at lower speeds, at higher speeds, or higher NLGI grade. However, channeling effects take the upper hand. Furthermore, increasing the

base oil viscosity leads to an increase in the pitting lifetime.

- ***Flank load-carrying capacity of NLGI 1 grease at different pitch line velocities and fill-levels.*** For the lower sump fill-level (40%), channeling occurs. At the highest pitch line velocity this leads to very high temperatures and results in scuffing. For the higher sump fill-level (80%), circulating occurs — resulting in better heat dissipation from the mesh. This leads to significantly lower sump temperatures at the highest pitch line velocity, in comparison to 40% fill-level (channeling) and scuffing does not occur. Higher wear, however, does result. This points to starved lubrication conditions in the gear mesh, despite the evident circulating of the grease occurring in the gearbox.

Conclusions

Overall, grease is suitable for gear lubrication and high load-carrying capacities can be achieved. The lubrication supply mechanism though strongly affects the load-carrying capacity and, therefore, in order to achieve high load-carrying capacities, the choice of grease and a correct analysis of the operating conditions are important. Furthermore, it is necessary to ensure that sufficient grease is available to the gear mesh at all times and that the grease is not destroyed or degraded. All the results shown are from investigations using dip lubrication. In the field, however, applications with spray lubrication are also common.

Currently further research work is being done on the effect that spray lubrication has on the lubrication supply mechanism and the load-carrying capacity of grease-lubricated gears.

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The Importance of Profile Shift, Root Angle Correction and Cutter Head Tilt

Hermann J. Stadtfeld

Bevel Gear Technology

Chapter 2, Continued

In the previous sections, development of conjugate, face milled — as well as face hobbed — bevel gearsets — including the application of profile and length crowning — was demonstrated. It was mentioned during that demonstration that in order to optimize the common surface area, where pinion and gear flanks have meshing contact (common flank working area), a profile shift must be introduced. This concluding section of chapter 2 explains the principle of profile shift; i.e. — how it is applied to bevel and hypoid gears and then expands on profile side shift, and the frequently used root angle correction which — from its gear theoretical understanding — is a variable profile shift that changes the shift factor along the face width. The end of this section elaborates on five different possibilities to tilt the face cutter head relative to the generating gear, in order to achieve interesting effects on the bevel gear flank form. This installment concludes chapter 2 of the Bevel Gear Technology book that lays the foundation of the following chapters, some of which also will be covered in this series.

— Hermann J. Stadtfeld

Introduction

The goal of the following sections is to develop a deeper understanding for the function, limits and, perhaps, not fully utilized possibilities of bevel and hypoid gears. The gear mathematics developed by the author is based on a triangular vector model that presents a comprehensive tool for simple observations in the generating gear up to complex, three-dimensional developments. All different kinds of bevel and hypoid gears can be observed and manipulated with this model, without alteration of the notation. However, in the most complex level, the lengths and directions of the vectors change according to higher-order functions and depending on the rotational position of the generating gear (Refs. 1–2).

The first chapter of this book, "Nomenclature and Definition of Symbols," should help to avoid or minimize the interruption of the flow in the gear theoretical developments with definitions of formula symbols.

In previous sections, the development of a face milled, conjugate spiral bevel gearset is conducted (August 2015 *Gear Technology*). In the second step, an analogue face hobbed bevel gearset is derived (September/October 2015 *Gear Technology*) that is converted to a non-generated (Formate) version in the third step. In step 4 an offset is added to the Formate spiral bevel gearset that results in a hypoid gearset. Consequences regarding the introduction of the hypoid offset and unique facts regarding general spatial transmissions are also discussed in this chapter. In the next section (November/December 2015 *Gear Technology*), length and profile crowning are added to the Formate bevel gearset to deliver a practically usable angular transmission as it is used in industrial gear boxes. The reader will be able to apply the derivations to any other bevel and hypoid gearset. With results for each calculation step, basic settings are computed, as they are commonly used by modern CNC bevel gear generators in order to cut or grind real bevel gearsets.

To complete the explanations and examples discussed so far, it seems appropriate to elaborate with some graphics on the three most commonly used geometrical features in bevel gear optimization.

Principle of Applying Profile Shift

In the design of bevel gearsets the profile shift of pinion and gear is always applied as a so called "V0 shift." If not otherwise specified, a positive profile shift value of x increases the pinion addendum and reduces the pinion dedendum. The following formal definition will achieve a gear addendum reduction and a gear dedendum increase with the same absolute amounts:

$$x = x_1 = -x_2 \quad (1)$$

Where:

- x Nominal profile shift factor is based on a normal section at mid-face
- x_1 Pinion profile shift factor, equal to the nominal profile shift factor
- x_2 Ring gear profile shift factor, equal to the negative nominal profile shift factor

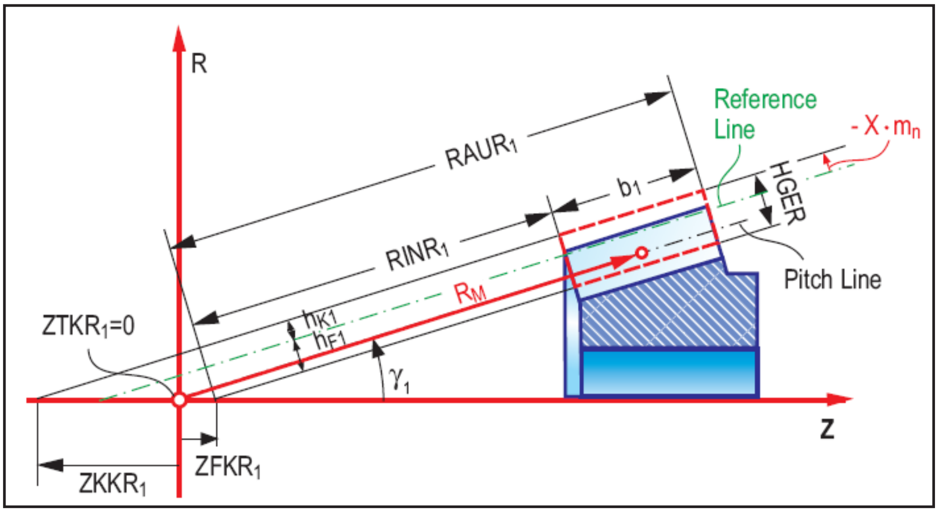


Figure 1 Impact of positive profile shift on pinion blank.

As visible in Figures 1and 2, there is no influence from the profile shift on the position of the pitch line, the pitch angle and the mean cone distance R_M. The pitch line is defined by the gearing law and represents the surface generator of a cone that rolls with the pitch cone of the mating gear without slippage, satisfying the ratio given by the number of teeth of the two mating members.

In the case of non *V*0 cylindrical gear pairs (*V*+ or *V*–), the center distance will change, which will establish new, effective pitch cylinders in the interplay between the two profile-shifted cylindrical gears, according to the gearing law. The two effective pitch cylinders roll upon each other without slippage, with the ratio defined by the number of teeth of the two mating cylindrical gears.

For bevel gears, the analogy to the center distance change is a change to the shaft angle with unchanged mean cone distance R_M. Because a shaft angle change in the course of a gear optimization is not acceptable, it seems a valid conclusion that for bevel gear systems only a *V*0 profile shift is physically acceptable.

The aim of a profile shift is to increase or reduce the profile depth portions above and below the pitch line in order to use other parts of the involute, i.e.—octoide. For bevel gears this means that all machine settings remain the same, while the blanks and the axial blade profile locations are changed. The blade reference point location S890 changes as follows:

$$S890 = h_F * (f_{Depth} + f_{SPFK} + x) * m_n \tag{2}$$

The three graphics in Figure 3 show the initial tooth without profile shift to the left. In the middle of Figure 3 a tooth with positive profile shift is shown, which has a larger tooth root thickness, but exhibits an almost pointed topland. The tooth with negative profile shift is to the right in Figure 3 has a weakened tooth thickness in the root but shows a larger topland. These effects would be more significant if the original tooth thickness *dz* wasn't defined at the actual reference circle for each profile shifted example. This convention is meaningful in order to maintain balanced tooth thicknesses between pinion and ring gear in the course of profile shift optimizations.

In the case of a desired tooth thickness change, profile side shifts x_S are employed, where:

$$x_S = x_{S1} = -x_{S2} \tag{3}$$

$$d_{ZS} = \pi * m_n + 2 * x_S * m_n \tag{4}$$

$$d_{ZS} = d_Z + 2 * x_S * m_n \tag{5}$$

Where:

d_Z nominal tooth thickness

d_{ZS} corrected tooth thickness by profile side shift

The value of x_S is applied with opposite signs to pinion and ring gear in order to maintain functionality and the original backlash of the gearset. The resulting tooth thickness change x_S is based on the normal module and is applied in the normal tooth section at mid-face, if not specified differently.

In the course of a profile side shift the radial positions of the cutting edges have to be corrected accordingly. Attention has to be paid, to that the blade top width does not become too small. Referring to Figure 4, the difference $RCOW_2 - RCOW_1$ for a module m_n above 4 mm should not be smaller than 0.8 mm (face milling). The new blade point radii are calculated with:

$$RCOW_{1S} = RCOW_1 + x_S * m_n \tag{6}$$

$$RCOW_{2S} = RCOW_2 - x_S * m_n \tag{7}$$

$$RCOW_{1S} = RCOW_3 + x_S * m_n \tag{8}$$

$$RCOW_{1S} = RCOW_4 - x_S * m_n \tag{9}$$

The definition of the profile side shift is based on the reference profile of the generating gear as shown in Figure 4.

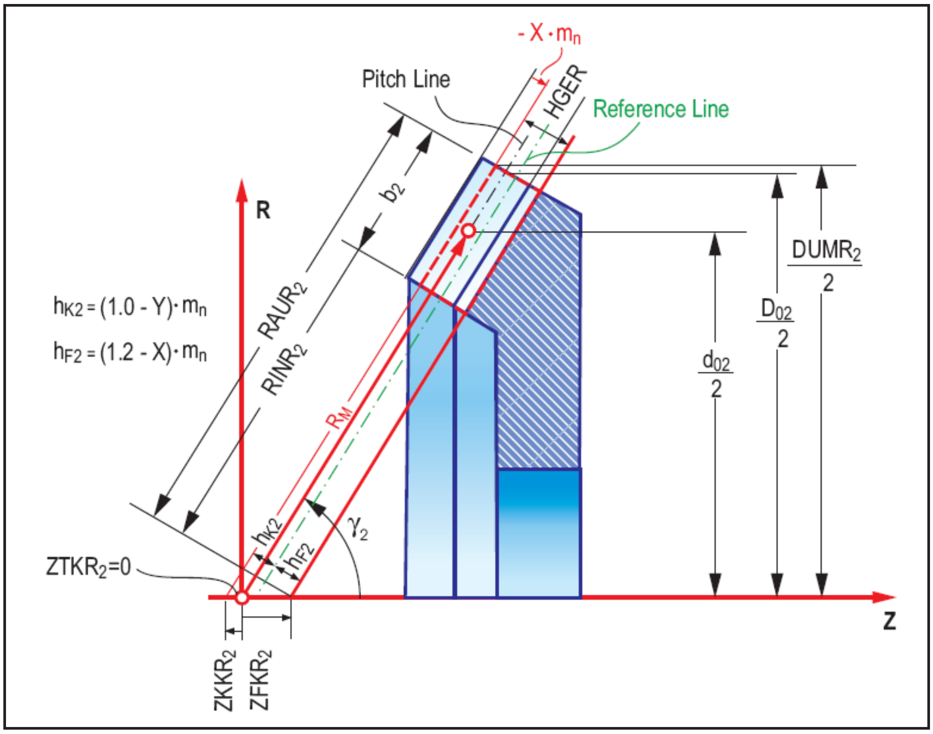


Figure 2 Impact of positive profile shift onto ring gear blank.

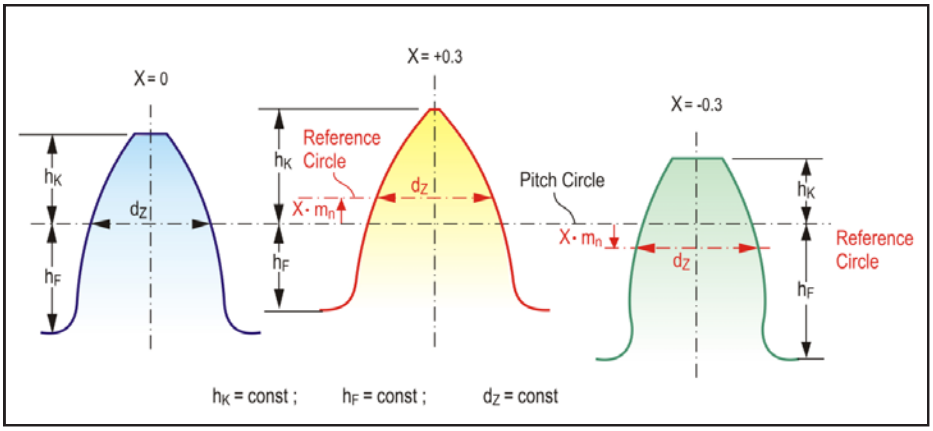


Figure 3 Profile shapes in case of positive and negative profile shift.

The Root Angle Correction

Bevel pinions with a bearing hub on the small diameter often pose a problem in that the hub is "sliced" by the bevel gear cutter in the course of the cutting process. The first suspicion of a possible interference problem occurs when the extension of the root tooth line is viewed as cutting through a part of the hub. The calculated and graphically represented cutter path shows the relationship between the roll position and the closest distance to the work gear axis. Each calculated point is rotated into the drawing plane, where the sum of points is drawn as a curve.

In order to eliminate a cutter/hub interference, the idea of a root angle correction was developed. Figure 5 shows in the top section a cross sectional view of a bevel pinion with a pitch angle that is calculated from the relationship between the pinion and gear number of teeth (*see "Basics of Gear Theory, Part II," July 2015 Gear Technology, Equations 10-12*). The lower part of Figure 5shows the alteration of the original pinion by the root angle correction δ_K. The auxiliary cone with the angle *GATK* was rotated around the reference point in the middle of the tooth about – δ_K. Face and root angle follow this rotation as well. Although the pitch cone is not influenced by this rotation, the generating roll motion in the manufacture of root angle-corrected bevel gears happens around the auxiliary cone. The side effects that occur due to rolling on an incorrect cone can be partially eliminated by tilting the cutter head, as explained in (*see "Basics of Gear Theory, Part II," July 2015 Gear Technology, Figure 23*).

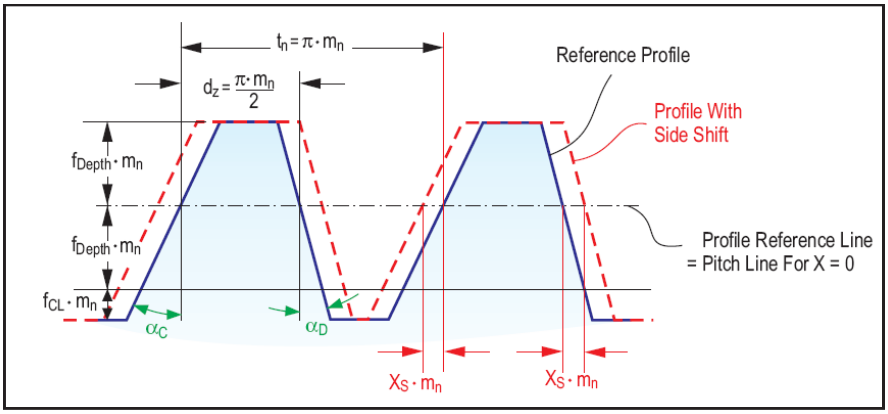


Figure 4 Pinion reference profile with positive profile side shift.

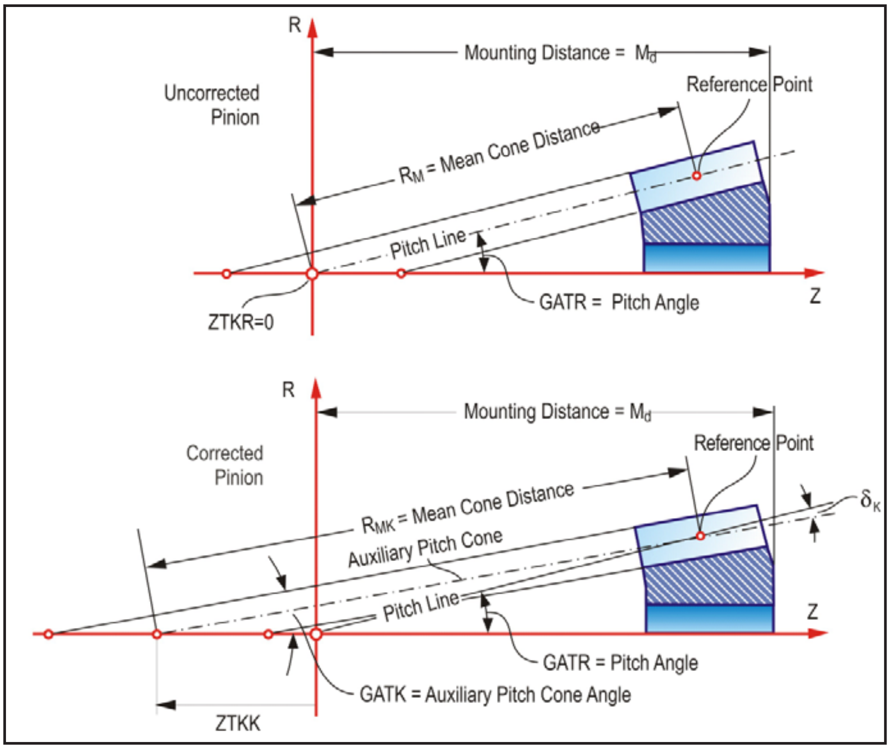


Figure 5 Principle of root angle correction.

A large part of the influence on the flank form due to the root angle correction cancels out between pinion and gear. The remaining part consists of flank twisting, which with same limitations can be used for Ease-Off optimizations. A further interesting aspect of the root angle correction can be observed on pinions with undercut. A reduction of the root angle enlarges the root diameter at the toe (with remaining mean pinion diameter), which reduces or even eliminates existing under-cut. Together with profile shift the introduction of the root angle correction increases the risk of pointed toplands at the pinion toe.

The last paragraph reminds much of the explanation about profile shift. As a matter of fact, an analogy is justified to view a root angle correction as a linear variable profile shift which is zero at mid face and which reaches on the toe a maximum and on the heel a minimum.

Root angle corrections in the vicinity of 2° can be reliably used for optimizations without any negative effect to the rolling behavior of the bevel gearset. However, it is recommended not to apply root angle corrections above 4°.

The Cutter Head Tilt

Cutter head tilt is applied to achieve various effects in the mathematical generating model for bevel gears as well as in older mechanical bevel gear generators. It has to be mentioned in this context, that generally only cutter head tilt is mentioned where in reality the cutter head tilt has a certain orientation in space relative to the generating gear. The following list summarizes the five known kinds of cutter head tilt, i.e. — the effects achieved by implementing certain tilt directions.

Effects due to cutter head tilt:

- Generation of length crowning
- Correction of pressure angles
- Root angle tilt for pinions mated with Formate gears
- Root angle tilt to achieve flank twisting
- Improved generating gear orientation in case of tapered depth teeth

Length crowning and pressure angle corrections are realized with a rotation of the cutter head around the tangent to the cutter track at the mean face position.

The principle is shown in Figure 6. The left photograph shows the un-tilted reference position where in the right photo, the cutter tilt can be recognized.

Pinions which roll with Formate ring gears require large tilt angles around the vertical axis of the generating gear model. Figure 7 shows in the left photo the starting point of an un-tilted cutter head. At the right side, a cutter head tilt with the amount of the pitch angle of the generated pinion is symbolically represented (*see also "Basics of Gear Theory, Part 2," July 2015 Gear Technology*).

A root angle change for the generation of a determined amount of flank twist can be achieved with the tilt principle in Figure 8. A cutter head tilt with the same amount of the root angle change (Fig. 8, left to right) will lead to the desired flank twist. It is required to recalculate the ratio of roll, since the pinion rolls now on a generating gear with a changed cone angle. The new ratio of roll is calculated using equations 10-13 from "The Basics of Gear Theory, Part 2." (July 2015 *Gear Technology*). The cutter head tilt for establishing an improved generating gear orientation consists also of the same principle shown in Figure 8.

Dr. Hermann J. Stadtfeld received in 1978 his B.S. and in 1982 his M.S. degrees in mechanical engineering at the Technical University in Aachen, Germany; upon receiving his Doctorate, he remained as a research scientist at the University's Machine Tool Laboratory. In 1987, he accepted the position of head of engineering and R&D of the Bevel Gear Machine Tool Division of Oerlikon Buehrle AG in Zurich and, in 1992, returned to academia as visiting professor at the Rochester Institute of Technology. Dr. Stadtfeld returned to the commercial workplace in 1994—joining The Gleason Works—also in Rochester—first as director of R&D, and, in 1996, as vice president R&D. During a three-year hiatus (2002–2005) from Gleason, he established a gear research company in Germany while simultaneously accepting a professorship to teach gear technology courses at the University of Ilmenau. Stadtfeld subsequently returned to the Gleason Corporation in 2005, where he currently holds the position of vice president, bevel gear technology and R&D. A prolific author (and frequent contributor to Gear Technology), Dr. Stadtfeld has published more than 200 technical papers and 10 books on bevel gear technology; he also controls more than 50 international patents on gear design, gear process, tools and machinery.

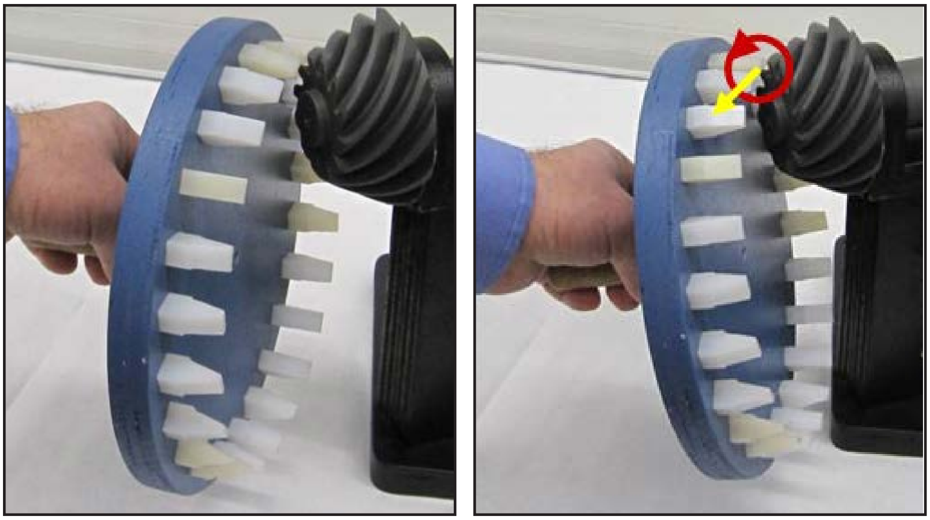


Figure 6 Cutter head tilt for length crowning and blade angle correction: No tilt in left graphic; right graphic with cutter tilt.

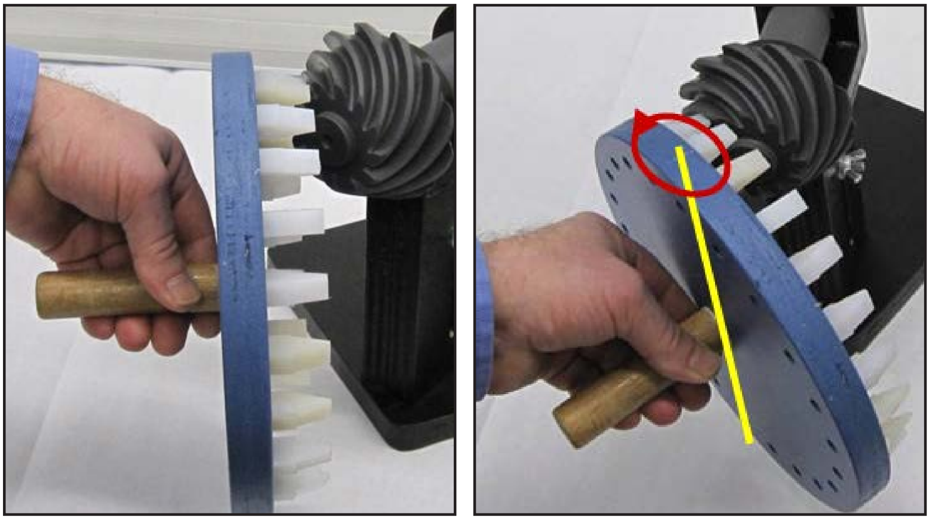


Figure 7 Cutter head tilt of a Formate pinion member.

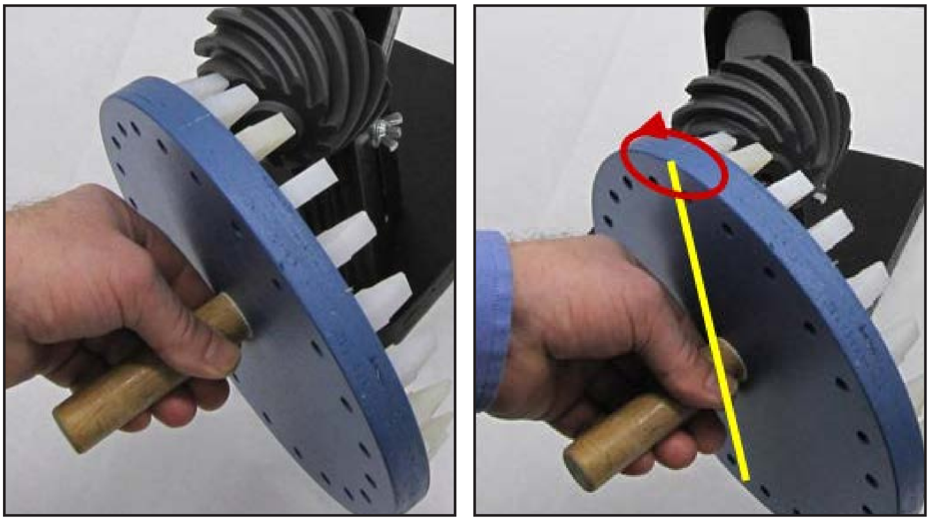


Figure 8 Cutter head tilt for the creation of generating crowning.

Klingelnberg Mexico

CELEBRATES 15TH ANNIVERSARY

November 17, 2015 was a very special day for the seventeen employees of the Mexican subsidiary in Querétaro City and their families: Klingelnberg México celebrated its 15th anniversary. In honor of this occasion, Jan Klingelnberg, CEO of Klingelnberg AG, traveled to the site and presented awards to long-serving employees of the company. "Thanks to our committed employees, Klingelnberg México provides extremely professional support to our customers, both as far as our machines are concerned and also with regard to services and application development — which has now been the case for 15 years. I would like to take this opportunity to thank everyone concerned," Klingelnberg said.

The Latin American subsidiary was founded as Klingelnberg Oerlikon México on November 1, 2000 in the centrally located state of Querétaro — which is a strategic location, particularly with regard to the automotive industry. With this new on-site presence Klingelnberg was covering the increasing demand for local, individual service in this market, which is important to the company. "It all started with five employees," recalls Adrián Hernández, director of the Mexican subsidiary, "we now have seventeen, and can fulfill more than 95 percent of incoming service orders here on site thanks to intensive training. Support from our colleagues in Germany and Switzerland is only required in special cases."

When the subsidiary was established, service was in the main focus of the strategic orientation, but because of the positive demand for Klingelnberg products on the market the field of activities has been gradually expanded: Sales services and the supplying of spare parts were added, and in 2011, the company finally moved into a new building and opened a grinding service center in order to provide customers with comprehensive support. A facility that has been well received: "In the beginning we had five machines on the market," said Adrián Hernández, highlighting the success story. "There are now more than 250, and the market is still on the move."

Fives Group

ANNOUNCES NEW EXECUTIVE APPOINTMENTS

Fives Group has appointed Stéphane Mayer as new head of the metal cutting and composites business line. Mayer has held several aerospace leadership positions including president and CEO of Daher, and CEO of ATR. Mayer is replacing Jean-Camille Uring who will be retiring at the end of 2016, but will provide consulting services for the chairman of the executive board.

Additionally, Fives veteran Wes Paisley has been appointed interim CEO at Fives Machining Systems, Inc., effective immediately. Paisley has been with Fives Group since 2005. He has served as CEO of Fives North American Combustion and CEO of Fives Intralogistics. He also serves on the board of directors for Fives Inc. Paisley succeeds Dan Janka, who has left the company to pursue other opportunities.

Röhm Products of America

APPOINTS PADILLA NATIONAL SALES MANAGER

Röhm Products of America recently hired **Mike Padilla** as national sales manager. With more than 18 years of industry-related experience and strong management skills, Padilla oversees sales in the U.S. and Canada of Röhm's comprehensive offering of chucks, centers, vices, tool clamping and automation systems as well as customized solutions for turning, milling, drilling and grinding.

In his new position, Padilla is responsible for coaching and mentoring the company's regional sales managers as they strengthen existing and develop new customer relationships. He also assists Röhm customers within the aerospace, automotive, energy, engineering, micro technology and rail vehicle manufacturing sectors to ensure trouble-free machining processes.

Padilla has a strong background in engineering and sales. Prior to joining Röhm, he held several positions at Ellison Technologies including accessory manager, sales training project manager, project manager and finally business development manager. Padilla's career also includes engineering and sales positions at Techmatic's Inc. and SMW Systems, Inc.

Padilla served in the U.S. Navy from 1987 to 1995 as a Gunner's Mate Missiles First Class. He supervised a 12-man team that launched missiles in Operation Desert Storm, and his team had 100 percent launcher readiness during that campaign. For his exemplary service and accomplishments, Padilla was honored with numerous awards including a Combat Action Ribbon, Purple Heart, Navy Achievement Medal and Enlisted Surface Warfare Specialist.

Machine Tool Builders (MTB)

WELCOME APPLICATIONS ENGINEERING MANAGER

Machine Tool Builders, Inc. recently announced that **Yefim Kotlyar** has recently joined as the application engineering manager. Kotlyar comes to MTB with a long history in the gear manufacturing business having worked for both machine tool OEM's and gear manufacturing & design companies. He is an accomplished author of a variety of papers on gears, gear manufacturing, gear inspection, cutting tools and cutting tool inspection. He holds a masters degree in mechanical engineering from Marine University, Odessa USSR. He will continue to be an active member of the AGMA, sitting on various technical committees. Kotlyar will assist MTB with applications engineering, sales, machine runoffs, machine and tooling designs, advanced software algorithm development, training of MTB and customer personnel in gear geometry and inspection techniques and best practices.

Ionbond

OPENS CHINA COATING SERVICE CENTER

Ionbond has opened its new coating service center for automotive components in ChengDu, Sichuan Province, China. This operation - the fourth Ionbond coating center in China - is the second facility on the mainland primarily focused on the automotive market. Ionbond ChengDu will build on the success and experience of the Ionbond Wuxi facility which introduced activities for automotive components to China in 2012. The ChengDu site primarily provides DLC coatings for components in engines and injection systems for passenger cars and light trucks.

"This new facility was built to serve the growing need for low friction coatings on automotive components manufactured in western China. It is equipped with the latest manufacturing and testing equipment and follows best practice processes as they are established in other Ionbond automotive component coating centers in Europe and North America, as well as in its sister facility in Wuxi." says André Hieke, segment head automotive.

Diamond Like Carbon (DLC) coatings allow for a significant reduction of power consuming friction in order to meet the increasingly stringent regulations for emission reductions put in place by the Chinese government.

Ionbond has been in the business for coatings of automotive components in Europe for over 25 years, serving OEM and top tier system suppliers in the industry from its coating centers in Venlo NL and Humpolec CZ. Ionbond was recognized with the "Bosch Global Supplier Award 2015" for its technology leadership and quality of the coatings services. In 2014 Ionbond was added to the list of Bosch preferred suppliers.

Gleason Corporation

ACQUIRES HURTH INFER AND RENAMES DISTECH SYSTEMS

Gleason Corporation announced today that it has acquired the gear cutting tools business from Hurth Infer Indústria de Máquinas e Ferramentas Ltda. ("Hurth Infer"). The gear cutting tools business, newly named as Gleason Indústria de Ferramentas Ltda. includes shaving cutters, shaper cutters and chamfering and deburring tools accompanied by tool sharpening services for such products. The acquired business has assumed the current employees supporting the design and manufacturing of these products and will operate in a separate facility at its current location.

John J. Perrotti, president and chief executive officer of Gleason said, "While the economy in Brazil is currently depressed, it remains a significant market for us, offering longer-term growth opportunities. We have long-standing relationships with most of the gear producers in this region and expect that expanding our local manufacturing capabilities will further strengthen those relationships."

Aniello Milone and Rafael Funaro, managing directors of Hurth Infer, commented, "We have great respect for Gleason and believe they will continue with the fine tradition of customer service that Hurth Infer has developed for these products in the Brazilian market. We will work closely with Gleason to assure a smooth transition and maintain a close cooperation to create maximum value for our customers. By this transaction, Hurth Infer expects to focus on and strengthen the manufacturing and support of Hurth Infer's other products, such as broach tools, round tools and related services, and heat treatment services, which were not included in this transaction, in all its facilities located in Sorocaba, Joinville and Cachoeirinha, Brazil."

Gleason

Additionally, Gleason Corporation announced a new name and operating structure for Distech Systems effective January 1, 2016. The automation business will be named Gleason Automation Systems and will operate as a division of The Gleason Works.

Acquired in May 2014, Gleason Automation Systems is a leader in the design and manufacture of factory automation systems. Gleason Automation Systems manufactures a complete line of automated tray stacking systems integrating secondary operations like washing, inspection, gauging, marking, visioning and part tracking. Gleason robotic work cells are adaptable and interface easily to customers' new or existing equipment. Gleason Automation Systems serves various industries, including automotive and machine tool, as well as pharmaceutical and medical applications.

John J. Perrotti, president and chief executive officer of Gleason Corporation said "As we have integrated Distech into our operations along with our increased focus on providing machine systems solutions it made sense to change the name to Gleason Automation Systems. We see many opportunities to build on the current capabilities and provide customers both inside and outside of Gleason's traditional markets with new solutions to improve quality and productivity." Gleason Automation Systems will continue to operate with its current staff at its manufacturing facility in Gleason's facility in Rochester, New York.

Solar Manufacturing

HIRES MIDWEST REGIONAL SALES MANAGER

Solar Manufacturing, Inc. announces that **Adam Jones** has accepted the position of Midwest region sales manager. Jones will maintain and promote sales for Solar in the Midwest United States. Jones will provide Solar Manufacturing customers with exceptional support. Prior to accepting this position, Jones worked for Solar Manufacturing as well as a large manufacturer of carbon and graphite insulation products.

Santasalo

PERFORMS OVERHAUL ON LARGE GEAR UNIT

In 2015, Santasalo performed an overhaul on the largest gear unit in its history, carried out at the company's facility in Jyväskylä, Finland. The overhaul was carried out on the main gear unit of a steel smelting converter at SSAB Europe's Raahe mill in Finland. The converters are an essential part of the steel manufacturing process which produce liquid steel for the next

stage in the process. The overhaul was performed during the rebuild of the complete converter within a challenging 10-day schedule.

In addition to mechanical repairs, the project included an upgrade of the lubrication system which incorporated a new modern lubrication unit and related piping. This was installed to provide pressurized lubrication for the main gear unit and two primary gear units operating the main unit. A CMaS condition management system was also installed into the lubrication system to monitor the condition of the power train based on wear particle detection.

The overhauled gear unit weighs ca. 77 metric tons and the external dimensions are 5.5×5×3 meters. The sheer size of the gear unit and its components combined with the strict delivery time required thorough planning prior to the work in the factory. For example, innovative procedures were used to ensure accuracy when fitting the large conical roller bearing of the low speed shaft. This process utilized mobile 3D-measurement equipment and calculation software.

"We are very pleased with Santasalo's performance and results with the first rebuild project and its lead time," said Seppo Marttio, project manager, SSAB. "The gear units in key positions have now been serviced and the lubrication system has been replaced using the latest available technology. Additionally, we can now live without surprises as the condition management system has been installed. Santasalo has proven to be flexible, high-quality, and reliable supplier and it's very convenient to continue our cooperation in the following two rebuild project during 2016."

Hwacheon Machinery

APPOINTS MANAGING DIRECTOR

Hwacheon Machinery America has appointed **Robert Nedler** to the position of managing director, in charge of sales, service and general operations at Hwacheon Machinery America covering North and South America, according to the company. Nedler previously was vice president - sales and product manager - milling at Hwacheon. He has been with the company since 2012. Nedler replaces Michael Huggett, formerly Managing Director, who has left the company.

A dynamic and results-focused sales leader, Nedler brings more than 30 years of experience in identifying and successfully capitalizing on market opportunities to Hwacheon, which he earned at the Starrag Group, DMG and Yamazen, and as co-owner of Tri-Star Automation.

Nedler said "As one of the world's leading providers of high-quality machine tools and customer service, Hwacheon will continue to deliver the products and services that make our customers more productive and more profitable. For more than 60 years, perseverance, honesty, and devotion have been the principles behind the success of Hwacheon. Going forward, Hwacheon will build on these principles to further improve its competitiveness in the world market, while renewing the tradition of unparalleled service to its clients and maintain the quality of its product.

"One of my primary goals is to develop a responsive sales and service team that will successfully provide the highest level of support to our growing dealer network and to our customers in the general machining, mold and die, energy, medical and aerospace markets," Nedler said.

STAR SU

APPOINTS GEAR TOOL TECHNOLOGY ENGINEER

Star SU has appointed **Dave Rydberg** as gear tool technology engineer for its cutting tool division. In his new role, Rydberg will join the Star SU engineering team in continued development of gear tool applications, tool design, manufacturing and advanced engineering. He brings a wealth of experience in the gear industry, including the last 20 years in engineering roles with Gleason Cutting Tools Corp. Rydberg earned a Bachelor of Arts in Mathematics from the College of St. Francis in Joliet, IL.

SECO TOOLS

ADDS TO EXECUTIVE AND MANAGEMENT TEAMS

On track for continued business growth, Seco has appointed new members to its executive and management teams. David Mrdjenovic is the company's new director of operations, and **Scott Hecht** now serves as market channels and business development manager.

Mrdjenovic joins Seco as a member of the executive staff, and his responsibilities include complete oversight of operations and the engineering group. He has 30 years of well-rounded manufacturing experience that includes both management of plant operations and full purchasing and logistics responsibility. Most recently, Mrdjenovic served as general manager for Exco Extrusion Dies. During his 13-year tenure at Exco, he also served as plant manager of plants located in Chesterfield, Michigan; Wylie, Texas; Medellin, Columbia; and Sorocaba, Brazil.

Hecht brings with him extensive experience as a Seco channel manager since 2014—a role in which his responsibilities included the development of strategic programs with key suppliers. He also possesses strong and widespread operational and industry knowledge from past positions as a distribution manager and vice president of sales within the tooling industry prior to joining Seco.

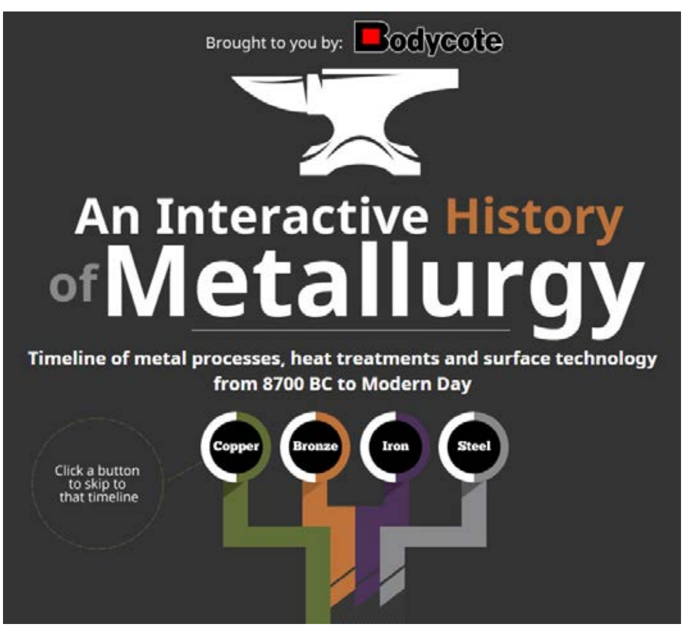
"Seco is pleased to welcome both gentlemen to their new positions," said Rob Keenan, president of Seco Tools. "We are delighted to have them on the team and look forward to many key contributions that will make in operations and support of our channel strategies and increased business growth."

A Detroit native, Mrdjenovic enjoys motor sports and spending time with his wife and two children. Hecht currently resides in Lake Orion, Michigan, with his wife and twin daughters.

Bodycote

LAUNCHES INTERACTIVE HISTORY OF METALLURGY

Bodycote announces the launch of their Interactive History of Metallurgy after taking a look back at the long history of metal processing and heat treatment. Containing over 200 high quality images and numerous videos, Bodycote pays homage to the artisans from thousands of years ago along with the scientists and inventors of more modern metallurgy and engineering by charting important and fascinating discoveries. Starting in 8700 B.C. with the world's oldest known copper artifacts, all the way through to the modern processes that Bodycote undertakes daily, the resource charts the development of metal working from the mystical and utilitarian requirements of early mankind through to the scientific and technical breakthroughs of the 20th century.



Mahr Federal

HIRES DIRECTOR OF MARKETING AND CUSTOMER SERVICE

Mahr Federal has named veteran communications professional **J. Robin Palermo** as director of marketing and customer service. In her new position Palermo will direct and oversee all aspects of the company's marketing strategies and marketing communication programs as well as the customer service team. A marketing professional and creative brand strategist with 25 years experience, she is noted for developing integrated marketing and communications plans and product launch programs across a spectrum of international B2B and B2C businesses.

Said Mahr Federal President, Tony Picone, "In addition to her professional expertise, Robin has a reputation for building strong relationships with staff, suppliers and customers alike, and is recognized for leading high performing teams that drive sales and generate revenue. We're delighted to have her join our team."

Palermo most recently headed her own firm, JRobinP Marketing Strategies and Communications Consultancy in Dedham, MA, and has previously held international positions with ZeeVee, a manufacturer of video distribution equipment; Exigen Services, an IT professional services organization in San Francisco, CA; Instron of Norwood, MA, a manufacturer of advanced material testing hardware and software; and DCI Systems, Inc., of Franklin, MA, a manufacturer of robotic positioning and automated dispense systems and software. She is a graduate of Northeastern University with a BA in business administration and history, and the membership committee head for The Venture Forum, a non-profit organization for the development and education of upcoming entrepreneurs.

Solar Atmospheres of California

NAMES VICE PRESIDENT OF OPERATIONS

Mike Moffit has been named vice president of operations at Solar Atmospheres of California. Moffit has been with the company for 21 years in a variety of departments and served as the quality manager for the past five years at Solar Atmospheres of California.

Moffit will oversee the day-to-day operations of the heat treating facility in Fontana, CA. His responsibilities include the direction and management of maintenance, scheduling, shipping/receiving, customer service, training, purchasing and staffing. He will also work closely with the quality and sales departments to ensure that customer requirements are consistently being met.

Derek Dennis, president of Solar Atmospheres of California states, "I'm very pleased to announce the promotion of Mike Moffit to the position of V.P. of Operations. Mike's many years of hard-work and dedication to the Solar nation has prepared him well for this often times demanding new position. Mike has a strong background in metallurgy and proper heat treat practices. His finely honed customer service skills are an example of Solar Atmospheres' commitment to meeting or exceeding our customer's requirements and expectations. Mike's first task will be to find a suitable replacement for his vacated position as SCA Quality Manager."

Sandvik Coromant

ANNOUNCES AMERICAS MARKET PRESIDENT

Sandvik Coromant has announced **Sean Holt** as the new president of the Americas market area, effective January 1, 2016. An experienced executive in the manufacturing industry, Holt was a key member of the Americas management team as the vice president of engineering. He is now part of the global sales management team reporting to Eduardo Martin, global vice president of sales, whom he succeeds as the head of the Americas organization.

About Holt, Martin states, "Sean brings in-depth knowledge to all facets of our industry. From business development and sales to engineering and R&D, I believe that his experience and skillset will be significant in delivering high-value solutions to our customers."

Reflecting on his new appointment, Holt said, "I am excited for this new challenge. Sandvik Coromant is in a good place with a strong market position and we will continue to build on that. Drawing inspiration from the talented people throughout the company and our network of partners, we will focus on our customers' needs and ensure that we consistently exceed their expectations. In an increasingly globalized market, I will utilize my international experience to broaden our business by reducing operational costs for our customers while continuing to develop a strong organization suited for the future of manufacturing."

Holt (45) has more than 20 years of engineering, business development, sales and executive management experience. He joined Sandvik Coromant in 2000 as a sales engineer in Birmingham (United Kingdom). Since then, he has held several positions such as application development specialist and aerospace manager of market area Americas before taking on the position as vice president, engineering, market area Americas in 2014.

Prior to joining Sandvik Coromant, Holt was a successful entrepreneur. He was chairman of the Industrial Operations Board and is now a member of the board of directors of the Commonwealth Center for Advanced Manufacturing (CCAM). Holt earned his degree in mechanical engineering from the University of Nottingham.

February 24-26–2016 Gear Materials: Selection, Metallurgy, Heat Treatment and Quality Control Clearwater Beach, Florida. Instructors Raymond Drago and Roy Cunningham will describe the advantages and disadvantages of gear materials, explain heat treatment processes, define best practices and more. The design of an optimum gear set requires the coordinated effort of the gear design engineer, the gear metallurgist, and the bearing system engineer. The instructors of this course are a gear design engineer and a metallurgist who have worked collaboratively on projects for more than 40 years. Learn the roles of each of these professionals and how collaborative efforts can provide better outcomes. Additional information on gear-related problems, failures, and improved processing procedures will be reviewed. Gear design engineers, management, metallurgists and materials engineers; laboratory technicians; quality assurance technicians; furnace design engineers; and equipment suppliers would benefit from this course. For more information, visit *www.agma.org*.

March 2-5–The MFG Meeting 2016 Palm Desert, California. The MFG Meeting 2016 brings together a broad spectrum of manufacturing business owners and top industry executives for a four-day forum on how manufacturers can work together to restore manufacturing to its rightful place as an engine that drives the U.S. economy. Jointly produced by the Association for Manufacturing Technology (AMT) and the National Tooling and Manufacturing Association (NTMA), this event tackles the issues that affect the entire realm of manufacturing. In 2016, topics will include leadership, economics, cyber security, strategic succession and more. The focus will be on the next generation of manufacturing workers and the teamwork needed for future success. For more information, visit *www.themfgmeeting.com*.

March 22-23–AWEA Wind Project Siting and Environmental Compliance Conference 2016 Charleston, South Carolina. The AWEA Wind Project Siting and Environmental Compliance Conference bring wind industry leaders together for discussions about the current state of siting and environmental compliance and network. Key insights within energy development, operations, evolving trends and strategies for improving the project permitting process and maximizing the output of operating assets will be discussed. The program will be a good mix of state-of-the-art methods for addressing ongoing challenges within the wind industry. For more information, visit *www.awea.org*.

March 22-24–2016 Gearbox CSI: Forensic Analysis of Gear & Bearing Failures. Concordville, Pennsylvania. Instructors Raymond Drago and Joseph W. Lenski, Jr. help gear designers gain a better understanding of various types of gears and bearings. Attendees will learn about the limitation and capabilities of rolling element bearings and the gears that they support so they can properly apply the best gear-bearing combination to any gearbox, whether simple or complex. Gear design engineers; management involved with the design, maintenance, customer service and sales should attend this event. For more information, visit *www.agma.org*.

March 22-24–Aggregates Academy & Expo 2016 Nashville, Tennessee. AGG1 is the leading aggregate exposition and educational resource brings together decision-makers and buyers from companies that produce crushed stone, sand and gravel in the marketplace. Sponsored by the National Stone, Sand & Gravel Association, AGG1 education tracks include sessions on operations, automation, safety and business management. Workshops include strategic sales training and basic supervisory training. The show is co-located with the World of Asphalt Show & Conference focusing in-depth, industry-focused programming in the asphalt industry. For more information, visit *www.nssga.org*.

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

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

April 11-15–MACH 2016 Birmingham, UK. MACH 2016 offers the latest manufacturing advances, developments and innovations under one roof. This unique trade show includes live working machinery and brings together the industry's finest manufacturers over a range of technologies including milling, turning, metrology, additive manufacturing and tooling. Organized by the Manufacturing Technologies Association, the event is a great barometer for the prospects of manufacturing in the United Kingdom. MACH 2016 will attract more than 23,000 visitors and 6,000+ exhibitors showcasing the latest engineering-based manufacturing technologies. For more information, visit *www.machexhibition.com*.

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State/Province: ________________ ZIP+4/Postal Code: ________________

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4 → What is your primary JOB FUNCTION (check ONLY one)

- ❏ Corporate Executive (B)
- ❏ Manufacturing Production Management (C)
- ❏ Manufacturing Production Department (D)
- ❏ Manufacturing Engineering Management (E)
- ❏ Manufacturing Engineering Department (F)
- ❏ Product Design, R&D Management (H)
- ❏ Product Design, R&D Department (I)
- ❏ Purchasing (L)
- ❏ Marketing, Sales or Communications (M)
- ❏ Quality Control Management (P)
- ❏ Quality Control Department (Q)
- ❏ Other (Please describe) (N)

  ____

5 → My company's principal product or service is:____________________

6 → How are YOU involved with gears (check all that apply)?

- ☐ My company MAKES gears (20)
- ☐ My company BUYS gears (22)
- ☐ I DESIGN gears (23)
- ☐ I am a SUPPLIER to the GEAR INDUSTRY (please specify product or service) (24)

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Is there a colleague within your company that might benefit from having their own copy of ***Gear Technology*** magazine?

Name: ______________________________

Title: ______________________________

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Mind-Boggling Gears

Alex Cannella, News Editor

Square, rectangular, triangular, oval, even fish-shaped — Clayton Boyer's Weird Gears come in every shape except for circular, and they all work.

If you're interested in giving them a gander, check out Boyer's Youtube video (just search "weird gears" and it'll be right there at the top) to see them in motion.

Obviously, fish-shaped gears aren't entirely practical from an industrial standpoint, but the unique way they click together is a form of art in and of itself. Years of woodworking and playing around with gear sculpting has given Boyer a knack for making gears click together in seemingly physics-defying ways.

"I love things that move," Boyer said. "Movement is fascinating. If it doesn't move, it might as well be a rock. I've made table-rocks, and chair-rocks, and bowl-rocks, and picture frame-rocks, but it wasn't until I moved into the realm of kinetics that I found the real joy hidden in the wood."

A retired chiropractor living in Hawaii, Boyer spends his days masterfully crafting clocks and kinetic sculptures, and has been for as long as he can remember. His first recollection of the craft was a *Popular Mechanics* article he read when he was 10 detailing how to make a wooden clock.

He's designed and built countless different clocks, as well as everything from the weird gears set to little walking wooden robots and even a "steampunk impulse engine." The weird gears, in fact, are sort of the quirky cousin of Boyer's full body of work. While gears certainly take center stage in a clock (and the way Boyer lays out his clocks could safely define them as art pieces), he still builds them to work, which means functionality first, mind-boggling aesthetic second. The weird gears, in comparison, flip those priorities around, and it's no surprise that the sight of that-which-should-not-work garners a reaction.

"I have mounted these irregularly shaped gearsets and spread them around my shop for visitors to pick up and play with," Boyer said. "The irregular gears are so unusual, and don't look like something that should work, so when a person gives them a turn, and they actually do work, these gears never fail to create a huge smile. Even after all these years, they still delight me, as well. Out in the shop, I find they give the hands something to do during those times of meditative cogitation when trying to solve a mental puzzle.

"Gears and cogs are fascinating, and irregularly shaped gears are even more so. I have been collecting odd and irregular gears for quite some time. When I would find drawings or pictures of old machinery with odd gears, I would attempt to redraw the gears accurately, and then recreate them at the scrollsaw."

Even more interesting than Boyer's works of art, however, is what he does with them. He doesn't sell his clocks as complete packages. He won't even sell them to you in pre-cut pieces to assemble. The only way you can get your very own Boyer clock is to buy the plans to one and make it yourself. Though his work could be commercialized, Boyer has always been more concerned about connecting with other "clocksters" and guiding would-be clockmakers just getting into the field.

"Since the very beginning of making my plans available, it has always been my goal to spread to other woodworkers the joy that I find in creating these wonderful mechanisms," Boyer said. "There is so much personal satisfaction in creating. Building your own mechanism, whether it is a clock, or kinetic sculpture, orrery or calendar, gives a tremendous sense of self-satisfaction, and along with that there is also a sense of pride in having created something functional, and something that is singularly unique."

And Boyer's website has certainly become a hub for clocksters, with countless people showing off their own recreations of Boyer's designs, a blog, and collaborative efforts such as the above pictured "Shark Bait," which Boyer made with the help of Forrest Burnett. In a stroke of serendipity, one of his works, the Celestial Mechanical Calendar Orrery, won the "*Popular Mechanics* Genius Award" in 2010 from the very magazine that inspired his initial passion for the craft.

But for Boyer, it's still all about creating.

"I always feel that my favorite piece is the sculpture I am working on at the time," Boyer said. "There is a passion that draws us together. That new sculpture is showing or teaching me something new. It's always been a journey of learning. Each of these mechanisms is different from the others, and has taught me something novel or unique. It could be a new building technique, or a variation on gear ratios, or even something as basic as which planet comes after Jupiter in our solar system."

For More information

Clayton Boyer
www.lisaboyer.com/Claytonsite/Claytonsite1.htm