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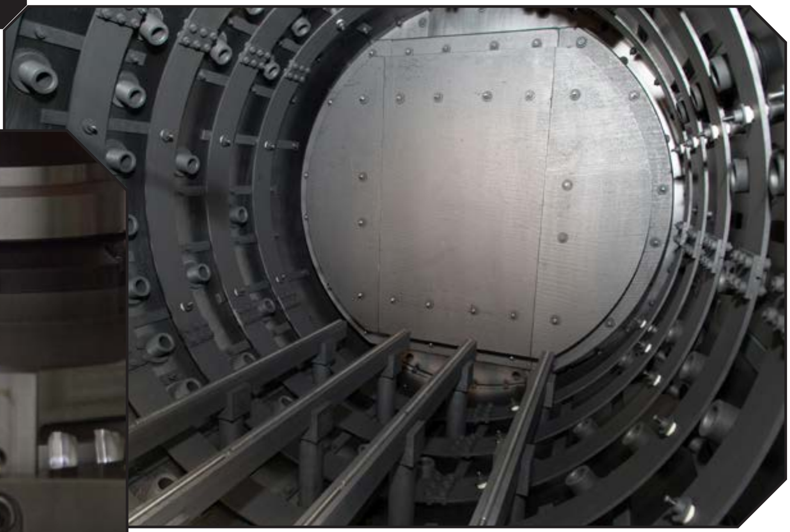

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Vol. 32, No. 7

departments

Photos by David Ropinski

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Gear cutting machines and automation systems from a single source.

With a comprehensive program of machines, gear cutting tools and automation systems Liebherr can offer the right solution for the economical manufacturing of cylindrical gears, tailored to individual requirements.

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- Pallet handling systems
- Rotary-pallet handling systems
- Robot integration
- Gear cutting tools

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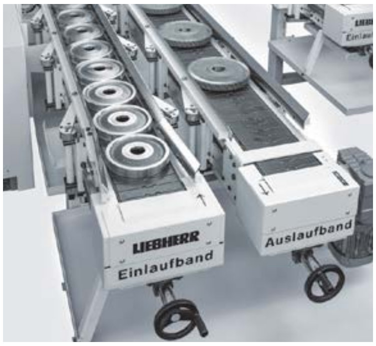
See us at Gear Expo 2015
Booth 1809



Liebherr Gear Technology, Inc.
1465 Woodland Drive
Saline, Michigan 48176-1259
Phone.: +1 734 429 72 25
E-mail: info.lgt@liebherr.com
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Buyers Guide: Recently Added

The *Gear Technology* Buyers Guide is your fastest way to find information on gear industry product and services vendors. Check back often, because we're always improving the site and adding new companies to the listings:

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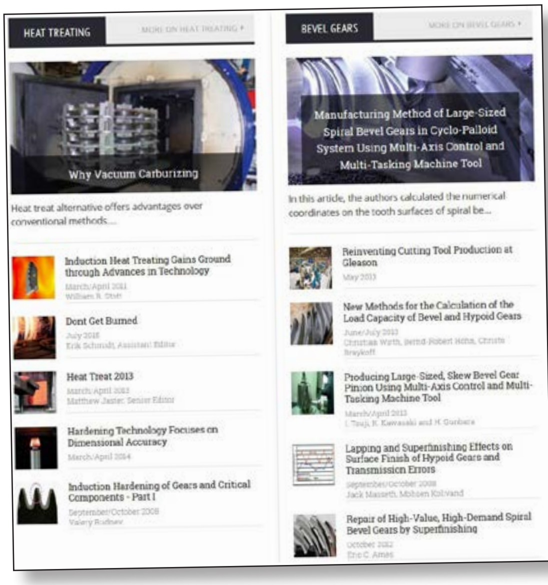
This Month's Highlighed Topics:

Every month we feature two topics from our extensive archive of 31 years of back issues. On the home page you can find a sampling of these key topics, along with links to the archive. Stop by *geartechnology.com* to see this month's featured topics:

Bevel Gears

Heat Treating



Gear Talk with Chuck

Gear Technology technical editor and resident blogger Chuck Schultz weighs in on some important gear industry topics:

In *Representing Our Trade*, Chuck talks about the dwindling number of go-to "gear guys" (and gals!) available to answer gear-industry newcomers' questions.

In *How Reliable is Our Information,* Chuck discusses our reliance on standards, the traceability of the information contained in them and the importance of knowing the data your gear designs are based upon.

You can join the discussion, too, by visiting *www.geartechnology.com/blog*

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RANDALL PUBLICATIONS LLC
1840 JARVIS AVENUE
ELK GROVE VILLAGE, IL 60007
(847) 437-6604
FAX: (847) 437-6618

EDITORIAL

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

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

Senior Editor
Jack McGuinn
jmcguinn@geartechnology.com

Assistant Editor
Erik Schmidt
erik@geartechnology.com

News Editor
Alex Cannella

Editorial Consultant
Paul R. Goldstein

Technical Editors
William (Bill) Bradley, Robert Errichello, Octave Labath, P.E., John Lange, Joseph Mihelick, Charles D. Schultz, P.E., Robert E. Smith, Mike Tennutti, Frank Uherek

DESIGN

Art Director
David Ropinski
dropinski@geartechnology.com

ADVERTISING

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

Materials Coordinator
Dorothy Fiandaca
dee@randallpublications.com

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

ON-LINE

Digital Content Manager
Kirk Sturgulewski
kirk@geartechnology.com

CIRCULATION

Circulation Manager
Carol Tratar
subscribe@geartechnology.com

Circulation Coordinator
Barbara Novak
bnovak@geartechnology.com

RANDALL STAFF

President
Michael Goldstein

Accounting
Luann Harrold

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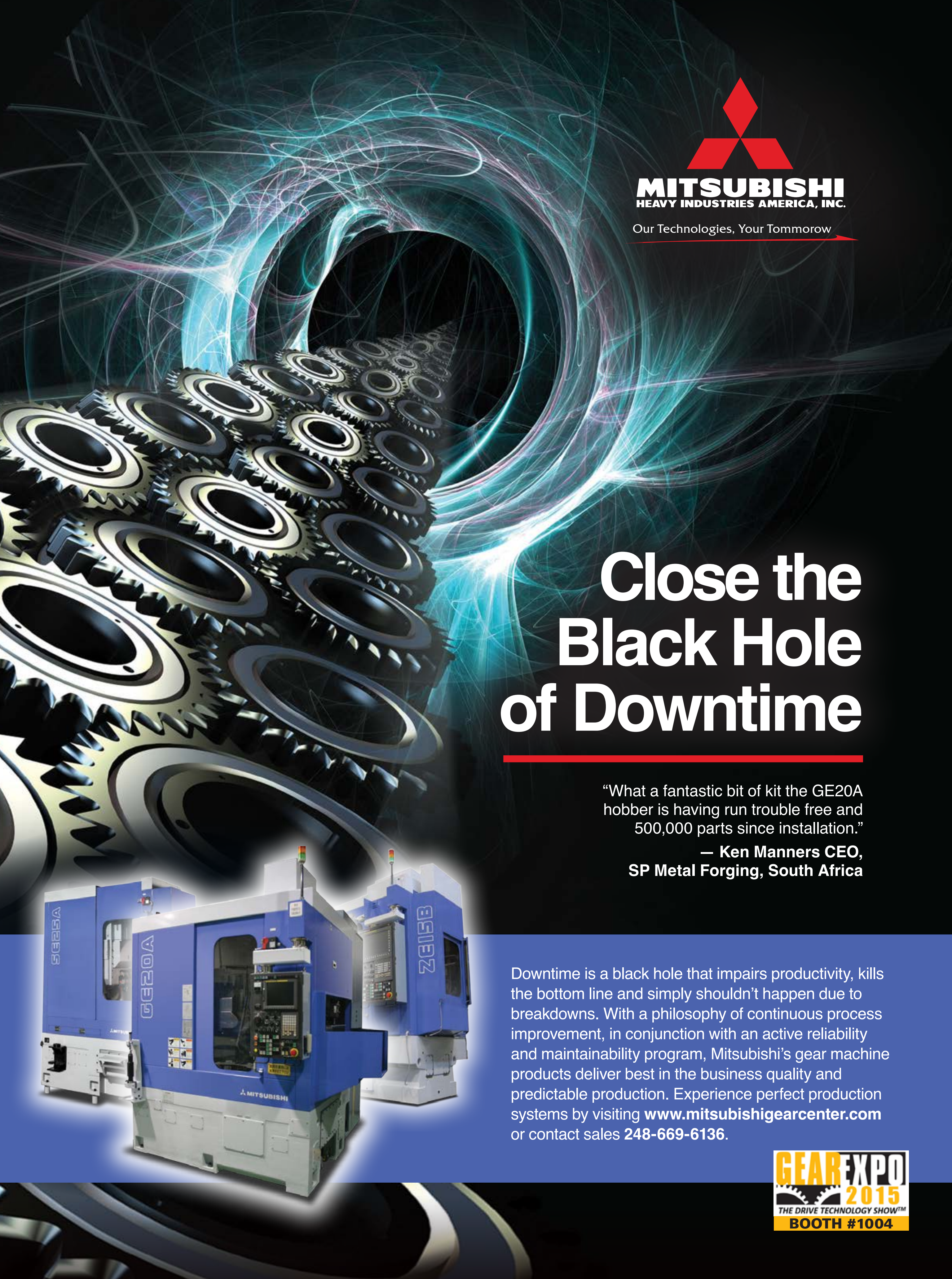
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Close the Black Hole of Downtime
“What a fantastic bit of kit the GE20A hobber is having run trouble free and 500,000 parts since installation.”
— Ken Manners CEO, SP Metal Forging, South Africa
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Downtime is a black hole that impairs productivity, kills the bottom line and simply shouldn’t happen due to breakdowns. With a philosophy of continuous process improvement, in conjunction with an active reliability and maintainability program, Mitsubishi’s gear machine products deliver best in the business quality and predictable production. Experience perfect production systems by visiting www.mitsubishigearcenter.com or contact sales 248-669-6136.
GEAR EXPO 2015
THE DRIVE TECHNOLOGY SHOW™
BOOTH #1004

You Don't Have to Climb a Mountain

Publisher & Editor-in-Chief
Michael Goldstein

You have questions. Everybody does.

If only there were some source of endless knowledge, experience and wisdom to guide you through your gear-related problems. If only there were some philosopher on a mountaintop whose sole purpose was to bring enlightenment to your gear noise problems, to unravel the mysteries of profile shift, to provide insight to a critical gear manufacturing problem or to explain the meaning of life (gear life, that is).

If there were such a gear guru, you'd probably climb that mountain, wouldn't you?

Well, you don't have to climb a mountain. You just have to make the trek to Gear Expo. I promise it will be well worth the trip, because *Gear Technology* is making life easy for those seeking gear knowledge. At our booth (#2030), we'll have not just one guru, but more than 10, arranged in groups of three or four at a time, ready to answer your questions as part of our *Ask the Expert LIVE* event. I wrote in depth about this in last issue's editorial, but you can also see our ad on pages 60-61 for a full list of the experts and sessions at the show.

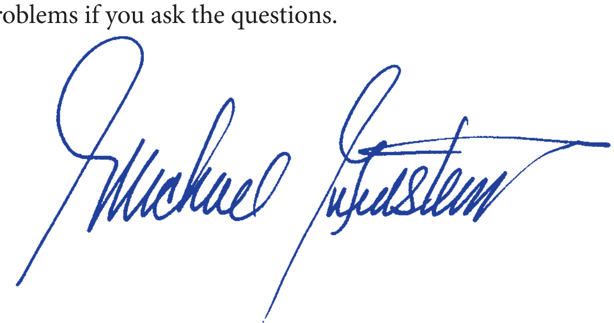
Sadly, most of you who read this magazine won't be able to make it to Gear Expo. But there's good news! We'll be video recording each of the live sessions and making them available after the show via our website. That way, everyone can share in the wisdom.

More importantly, you don't have to attend in order to get your questions answered. In addition to live questions from our in-person audience, our experts will be answering some of those submitted by readers like you.

Of course, there will be a limited amount of time during Gear Expo, so we may not be able to answer all of the questions. Fortunately, *Ask the Expert* isn't just a one-time event. Answers to reader questions appear in nearly every issue of the magazine as part of our regular *Ask the Expert* column.

So please consider sending your toughest gear questions for our panel's consideration. You can submit your questions either by visiting *www.geartechnology.com/asktheexpert.php* or by e-mailing them directly to Senior Editor Jack McGuinn (*jmguinn@geartechnology.com*). You'll also see examples of past questions and answers if you visit the Ask the Expert page online.

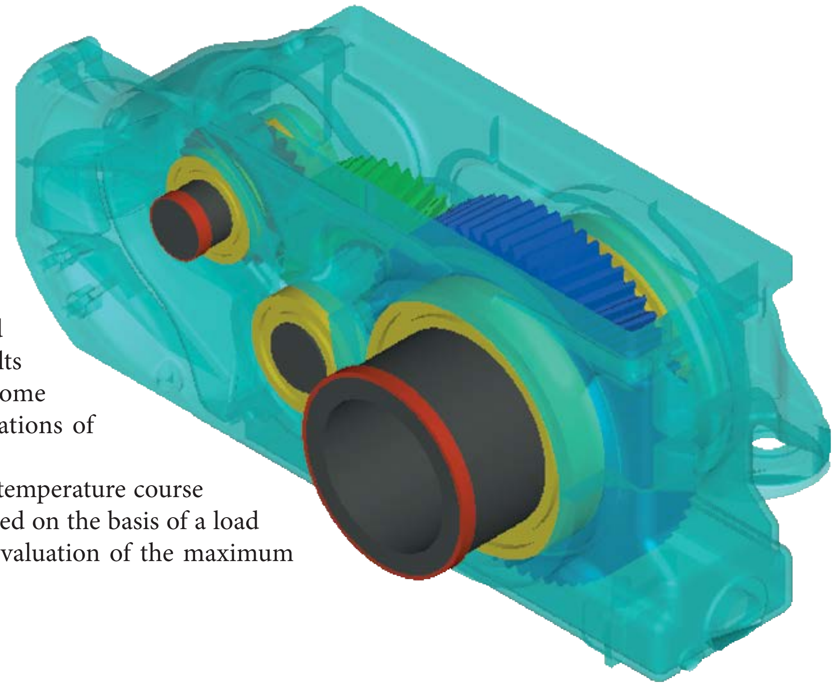
Just remember that you can only get the answers to *your* problems if you ask the questions.



P.S. Those of you coming to Gear Expo should definitely stop by our booth (#2030) whether you participate in *Ask the Expert LIVE* or not. While you're there you can begin or renew your FREE subscriptions to *Gear Technology* and *Power Transmission Engineering*. If you prefer, you can take care of it now, by clicking on the "subscribe" button at the top of the page at *www.geartechnology.com*. Your continued subscriptions are a great way to thank us for the services we provide. By signing on the dotted line, you help us demonstrate to our advertisers the importance of our magazine to the industry.

KISSsoft Module KS2

OFFERS ENHANCED HEATING CALCULATION FOR GEARBOXES



The efficiency calculation and thermal analysis according to ISO/TR 14179 (module KS2) has recently been extended with several useful functionalities: The power loss calculation has been implemented using the contact analysis of gears, which allows the user to consider the influence of microgeometry.

The power losses as well as the dissipated heat can be adjusted to the measurement results with individual correction factors. The outcome for this is a reliable basis for thermal calculations of gearboxes with similar designs.

The possibility of the determination of the temperature course was added. The temperature course is calculated on the basis of a load spectrum or a driving cycle and allows the evaluation of the maximum temperature occurring during operation.

For more information:
Phone: +41 55 254 20 50
www.KISSsoft.AG

Sandvik Coromant CB7015 CBN Grade

DELIVERS HIGH QUALITY FINISHING OF TRANSMISSION COMPONENTS

Sandvik Coromant's CB7015 is a CBN grade for a broad range of applications and designed to deliver improved finish quality in the production of transmission components. The CB7015's primary function is turning case-hardened steels (58-65 HRc). Due to the Safe-Lock clamping system, the CBN grade with a wear resistant ceramic binder is also usable for dry machining. It complies with all standard shape and position tolerances.

The CBN product range from Sandvik Coromant includes inserts with standard corner radii and wiper inserts as well as an Xcel version. The wiper geometry offers a range of process optimizations including improved finishes for standard cutting data. It also provides higher finish quality with increased feeds – roughness grades below 3.2 µm can consistently be achieved. With Xcel geometries and feeds of 0.011", roughness grades of 1 µm can be achieved.

In addition, the Xcel insert, with up to eight cutting edges, enables shorter production times and reduced tool costs per component. Dry machining avoids the costs for coolant use, offers reduced capital investment and low-cost chip disposal, all of which help to further reduce machining costs.

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

Ajax TOCCO

SELLING 5/10 KW TOCCOTRON AC INDUCTION HEATING SYSTEMS

Ajax TOCCO Magnethermic recently delivered 5/10 kW TOCCOtron AC induction heating systems to an international on-site heat treating firm. These systems are designed for portable/on-site preheating prior to welding applications.

The customer chose these systems over larger 35 kW induction heating systems due to lower equipment costs. At 5 kW continuous output, the customer stated that the 5/10kW TOCCOtron AC systems satisfied the majority of their small to medium preheat prior to welding applications and was capable of heating 50 kg of steel to 200°C in 30 minutes.

The customer also cited a simple, robust design in addition to the light-weight (hand carried), 100% aircooled design as other factors in their decision.

High-frequency induction heating cables can be configured for round, flat or irregular surfaces. No tools are required for installation and use. All electrical connections are made with quick disconnects and circular military style connectors. Other applications include bearing/sleeve shrink fitting, coatings curing, coatings removal, die heating and bulk heating applications.

For more information:
Phone: (800) 547-1527
www.ajaxtocco.com

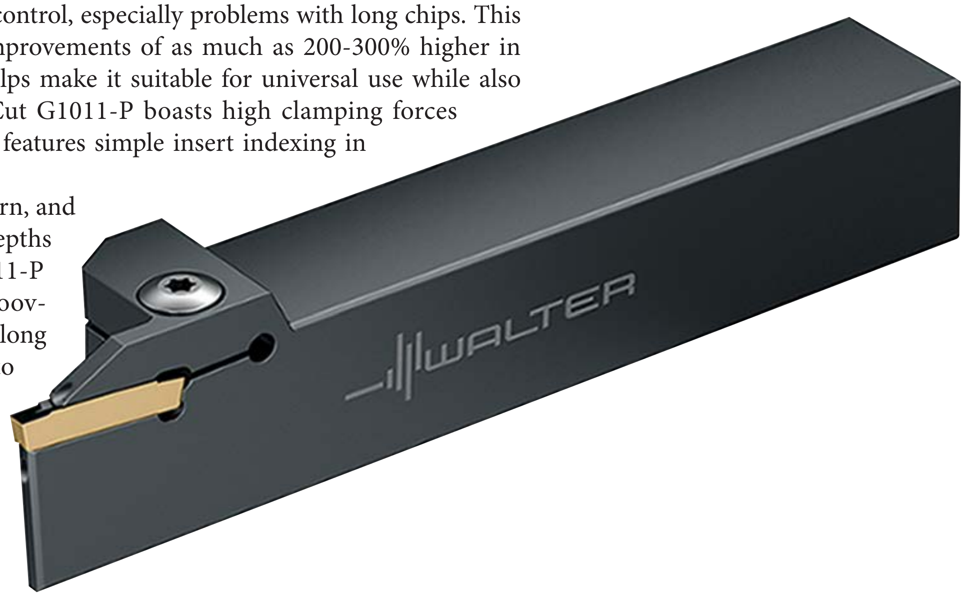
Walter

CUT GROOVING TOOL DELIVERS IMPROVED CHIP CONTROL AND TOOL LIFE

Walter recently introduced the Walter Cut G1011-P, a new grooving tool that can enhance surface quality, extend tool life, and improve process reliability.

Available in shank versions of 0.750" and 1.00" (also 20 and 25 mm), this internally cooled tool features precision coolant delivered to both the flank and the chipbreaker of the insert to address problems with chip control, especially problems with long chips. This results in surface quality and tool life improvements of as much as 200-300% higher in some cases. Its short tool head length helps make it suitable for universal use while also boosting chip evacuation. The Walter Cut G1011-P boasts high clamping forces because of optimum screw position, and features simple insert indexing in normal or inverted position.

Used on turret turning centers, Swiss turn, and multi- spindle machines, with cutting depths of up to 0.827" (21 mm), the new G1011-P is designed for parting off and deep grooving on stainless steels, high-temp alloys, long chip-forming steels and other difficult to machine materials.



For more information:
Phone: (800) 945-5554
www.walter-tools.com/us

Suhner Spiral Bevel Gears

OFFER HIGH POWER, LOW BACKLASH AND LOW NOISE

Each year, increased engine and motor power require more powerful angle gear heads. Engineers in the tool-making and industrial hand tools industries — as well as those in various other mechanical engineering fields — call for higher rotating speeds while maintaining smooth and easy movement of the tool. Smoother-running gears are also needed to combat dynamic noise. Apart from bearing and housing stiffness, the overall design and gear dimensions are essential for gear system optimization.

For these reasons, Suhner gears are cut using the Palloid and Cyclo-Palloid processes. Palloid-toothed gears are based on a technical development from straight-toothed to spiral-toothed bevel gears. Thereby the teeth are hobbed in a continuous procedure with a conical hob. The combination of this continuous process on a single thread tool leads to accurate pitch of the teeth.

Since Cyclo-Palloid gear hobbing meets and exceeds all high-quality manufacturing prerequisites, one-off, small and large lot size production can be achieved equally. Since the teeth are hobbed in a continuous process, the module (Mn) can be freely selected. Therefore, flexibility for the gear dimensioning and bevel gear calculation is provided.

While both tooth systems have similar insensitivity characteristics for bearing, a high contact ratio as well as a very accurate pitch, the cost efficiency and the high load root radius of the Palloid system should have special mention.

A further development on the proven Cyclo-Palloid toothing (soft-cut) is the process known as "HPGS hard cut." Through this cutting process, the thermal deformation caused from heat treatment will be eliminated with boron nitride coated blades. Therefore, the surface quality on the tooth flanks will reach grinding quality, according to DIN 3965, Part 3 (Quality 4 -6).

In combination with the material, the surface treatment and the adjustment of the required lubrication, spiral bevel gears are one of the best solutions to redirect the maximum torque in other directions. All of these can be achieved with small space and high mechanical efficiency.

Because of the sophisticated combination of the different spiral bevel gear angles, the circumferential force is divided into several components that can lead to significant axial forces. Therefore, gear design depends a lot on the bearings. The bearings have to absorb all the axial forces so the bevel gears do not move under load.

Any movement would affect the contact pattern of the teeth, which would result in edge wear that could destroy the entire gear. Just as important as the bearing is the stiffness and the geometrical accuracy of the case. All the advantages of spiral bevel gears can be had when gears are optimally positioned and perfect tooth contact is maintained.

When dimensioning the gear geometry, several criteria must be considered: required ratio, number of teeth and space/conditions. The criteria must be decided at the start of the engineering process. When the shaft angle ≠ 90° or the axis is offset, hypoid gears are required.

The Suhner Company, which celebrated its 100th anniversary in 2014, has locations worldwide and over 650 employees. Suhner offers standardized transmission and power transfer elements for many different applications. A wide selection of elements and devices in different sizes and versions are available. Gear sets are manufactured by high quality standards, guided by a thorough and critically developed value system.

Suhner designs, manufactures and supplies in standard measurements to customer's drawings. If you need further information, Suhner's computer-assisted calculating method, technical support and/or a quotation for the drive solution you require, please contact Suhner today.

For more information:

Suhner Manufacturing
P.O. Box 1234
Rome, GA 30162-1234
Phone: (706) 235-8046
usa@suhner.com
www.suhner.com

Cimcool Cimpulse Metalworking Fluids

FORMULATED FOR USE IN HIGH-PRESSURE SYSTEMS

Milacron Fluid Technologies' brand Cimcool recently announced the launch of Cimpulse.

Cimpulse 51MP, Cimpulse 45MP and Cimpulse 33MP are new fluids in the Cimcool family. Cimpulse products are multifunctional and designed to allow metalworking shops to utilize one fluid in their entire shop. In most cases, a Cimpulse fluid can be used to consolidate all the different fluids being used within their plant.

Cimpulse fluids have been formulated for use in both high-pressure systems and standard flood applications. Cimpulse metalworking fluids utilize a hybrid blend of lubricants to deliver increased stability and reduced tool wear as well as provide long sump life.

Cimpulse 51MP for example, is a multipurpose non-chlorinated, triazine- free fluid that provides users high-pressure foam and corrosion control. It keeps machines and parts clean and provides emulsion stability, long sump life and good bio-control.

"We are confident that Cimcool's Cimpulse metalworking fluids will change the way metalworking shops think about fluids," said Jack Teat, president of Cimcool Fluid Technology. "Cimpulse is a revolutionary fluid technology unmatched in the market. We believe that a Cimpulse fluid can help all of our customers reduce their inventory and improve their metalworking operations."

For more information:
Phone: (513) 458-8100
www.cimcool.com

CIMPULSE™
ONE FLUID ALL SHOPS

Marposs iWave2 Wireless Gauge

HAS MEASURING RESOLUTION OF 0.0001 MM

Marposs Corp. recently announced it will introduce its new iWave2 wireless manual gauge in booth #619 at the Quality Show.

The iWave2 gauge features a durable, ergonomically designed handle with rechargeable Li-ion battery that incorporates a computer with a 1.8" TFT color screen for displaying the measurement value in the operator's hand. Interchangeable nosepieces convert the gauge for ID, OD or length measurements. Measurement values can be transmitted via Bluetooth wireless technology to a gauge computer located within a 10 m distance. The iWave2 gauge has a measuring resolution of 0.0001 mm.

In addition to the measurement value, the gauge's color graphical display with selectable portrait/landscape view presents a variety of information for the operator. The iWave2 gauge features a bar graph column with measurement units, good/scrap part indication, wireless strength and battery levels, confirmation of measurement transmission and an absolute/relative option setting.

The iWave2 gauge is programmable for stand-alone use via Android phone/tablet or PC. Several functions are available with the iWave2 gauge when used with Marposs Quick SPC statistical soft-

ware, including on/off switching commanded by guided sequence; calibration history; and simultaneous zeroing of multiple devices.

The gauge incorporates soft touch buttons that are impervious to moisture. Battery duration is approximately 16 hours, while the gauge's inductive recharging system ensures continuous use 24/7.

For more information:
Phone: (248) 370-0404
www.marposs.com

Heimatec U-tec Flexible Adapter

'REPRESENTS REAL IMPROVEMENT IN LATHE AND MILL/TURN TOOLING DESIGN'

Heimatec recently announced that its U-tec flexible adapter system is now available on all right-angle heads in the company's line. According to Heimatec President Preben Hansen, the company plans to include its U-tec adapter system on all angle heads going forward. Hansen said this development will provide the system's rigidity and quick-change capabilities to users doing deep hole drilling with extended tools.

U-tec is the company's patented flexible tool adapter system that allows a standard ER output live tool to accept various adapters for different applications. This allows users to changeover tools on almost any lathe or mill using a single live tool without having to commit to a quick-change system on the initial purchase. A facemill adapter, for example, can be quickly positioned into the standard holder, without the need for a completely new base being installed. This is meant to reduce inventory costs, as well as changeover time, for the busy shop.

"The U-tec system represents a real improvement in lathe and mill/turn tooling design. U-tec allows great user flexibility, while a polygonal drive system ensures extremely high power transmission stability and faster set-up with absolutely no loss in performance or accuracy, because the live tool base remains in position and only the adapter and collet get swapped out," Hansen said.

The collet nuts on the U-tec system have internal threading for rigid mounting. This new tool adapter system enables the actual cutting tool to be brought into closer proximity to the bearing, thus further improving performance in use. This is due to the short and compact tool length design. Internal coolant up to 2000 psi (140 bar) is standard.

Every adapter in the U-tec system, complete with any necessary clamping nuts and adapters for arbor, Weldon, CAT 40 and CAT 50, is now available in shell mill, face mill, ER extension, side lock, shrink fit, hydraulic and blank styles. U-tec angle heads are compatible with most automatic tool changers, feature 360° manual positioning and include torque arms and a stop block. Torque rated up to 150 Nm (110 ft-lb).

For more information:
Phone: (847) 749-0633
www.heimatecinc.com

The Modern Approach to Transmission System Design and Analysis

Jamie Pears

Over the last 15 years, there has been significant growth in the number of transmission types as well as their complexity: manual, conventional automatic, dual clutch, automated manual, continuously variable, split power and pure EV transmissions. Alongside this, most manufacturers are now simultaneously developing conventional, hybrid and all-electric vehicles, with each type requiring different driveline architectures.

A continuous drive to deliver optimal efficiency alongside reduced weight and cost also means that newer powertrains feature much closer integration of the gearbox, prime mover and energy recovery systems and rely on sophisticated control systems to ensure optimum performance and efficiency at all times.

This shift in technical complexity has occurred against a backdrop of increased competition and demands for great efficiency, as well as a need to comply with changing legislative and industry standards. More than ever, vehicle manufacturers must innovate and bring to market powertrains that are comparatively unproven.

For the engineering teams tasked with developing these new powertrains, resources are being pushed harder than ever, and development processes are now very much under scrutiny.

Typically, manufacturers have used a range of individual CAE software tools and methods to simulate and design separate components such as gears, meshes, gear microgeometry, shafts and bearings.

Whilst the sophistication and accuracy of these tools are not in question, the fact that many calculations are made without considering the effects of the entire system can lead to later problems during the manufacturing process, which in turn can prove incredibly time consuming and expensive to correct. For example, powertrain noise and vibration issues might go undetected until the first hardware prototypes have been tested.

The transfer of data (or lack thereof) between different design and analysis tools can compound the problem. In some cases, basic concept design changes can take weeks to ripple through various departments, often requiring manual updating of models, which is both slow and error prone. This can be a major hindrance to the creation of optimal, cost-effective designs.

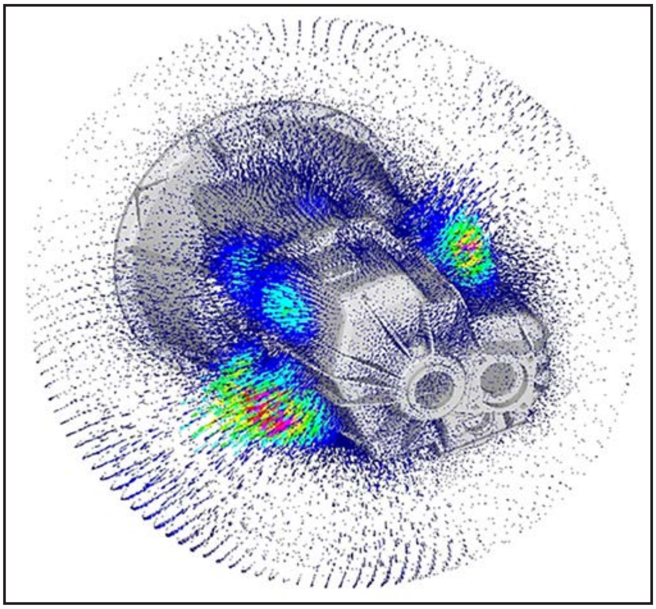


Figure 1 Acoustic radiation predicted using results generated by RomaxDesigner.

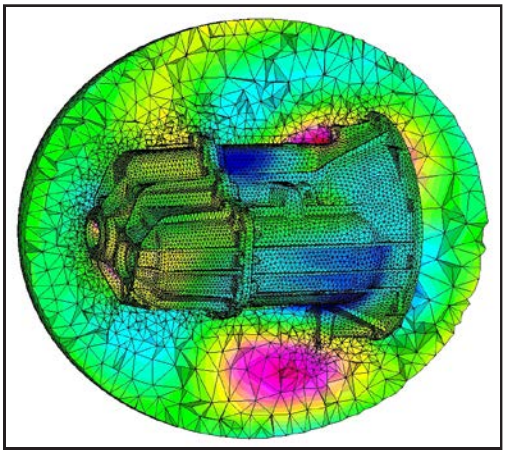


Figure 2 Acoustic radiation predicted using results generated by RomaxDesigner.

Component-level software tools have traditionally been unable to provide the over-arching system-level analysis needed within modern integrated design approaches. Many manufacturers recognize that this critical issue needs to be addressed, but when it comes to implementing a strategy to achieve this, it can be a case of "easier said than done."

Here are some examples of the actions you can take to address real-world challenges posed in the design and development process:

Pressure for Faster and Lower-Cost Development

Cost reduction and faster time-to-market are becoming the mantra for today's driveline engineers. Carmakers are requiring shorter and cheaper development cycles, meaning less time to work and a heightened pressure from senior management to get things right the first time. The fallout from this means design and analysis phases must be more efficient and more streamlined.

In order to address this, it is imperative that action is taken during the earliest parts of the design and analysis phase, widely identified as the key area in which process improvements can be made. Traditionally, the earliest stages of production are carried out in isolation with prototypes tested and problems fixed later during the production process. The fallout from this includes slow development cycles, high development costs, opportunity for miscommunication and errors, and limited opportunity for innovation.

Romax's Right First Time approach aims to update designs early on in the design process, where changes can be made with comparative ease, and in turn minimize late changes in the design and production process. In order to achieve this, the developers at Romax have identified six critical development stages:

- Educate & Evangelize: Senior management up to the highest levels need to understand the benefits provided by early analysis and its strategic importance in design and development
- Assess: Firms must complete a full audit of their design and development process – to understand the scale of the challenge and better target activity
- Identify: It's important to find the "quick win" areas where analysis can add immediate value
- Implement: Organizations must deploy appropriate analysis tools in the area(s) identified – and do so with commitment based on senior management buy-in and sponsorship
- Focus: Firms must ensure they have effective analysis tools at the concept design stage that are able to consider layout, center distance, gear and bearing sizing, loads, packaging, NVH, etc.
- Improve: Firms must be prepared to continuously monitor, update and develop their processes – continuous improvement will consolidate and extend the gains being made

Providing more focused analysis during the earliest planning stages enables comparisons to be made with previous designs and with competitive products more easily. For the manufacturers, this will help determine more realistic target setting as well as allowing them to ensure that any changes can be made quickly and efficiently with minimal long-term impact.

Addressing Demands for Improved Performance

Modern-day consumers are conditioned to constantly expect more power, better performance, more features, a smaller carbon footprint, and all for the same cost or less. The result is increased pressure to ensure that any potential design targets and product criteria do not clash.

Across an automotive transmission, engineers have to balance conflicting requirements of efficiency and noise, while reducing weight without compromising durability. All such requirements are interdependent, and therefore it's imperative that before any actions are taken, you are able to consider the impact on other components within the design chain.

One of the clearest examples of this can be demonstrated when looking at the hybrid and electric vehicle (HEV) markets. As the demand for hybrid and electric vehicles continues to grow, one of the main challenges that manufacturers struggle with is improving noise, vibration, and harshness (NVH).

While the automotive sector has made steps toward improving NVH — thanks to improvements across design, analysis, development and manufacturing processes — challenges still exist for the hybrid and electric vehicles sector. EV and HEV design is altogether a more complex process than designing traditional drivetrains; EVs do not benefit from the "masking" effect of the noise from internal combustion engines, while HEVs represent a particular challenge because vibrations from both the engine and the motor must be considered, along with the interactions between them.

In order to address this, simulation needs to be at the forefront when trying to reduce NVH. Many manufacturers work with finite element analysis and multibody dynamics tools that try to predict vibration response of the drivetrain system. However, these processes can prove to be so time-consuming that they're often only used too late in the design process for the problems to be resolved.

If manufacturers have access to software that can simulate different solutions in the earliest design phase before they are produced, organizations can save vast amounts of cost and time. To support this it is important to ensure companies have the right CAE tools and development processes in place.

Putting this into Practice – GKN Case Study

GKN Driveline has applied Romax Technology software and consulting to focus the optimization of gearbox efficiency in electric motor-driven transmissions without compromising noise and durability.

After identifying the main contributors to power loss, investigating how changes to macro- and micro-geometry would affect efficiency, and optimizing the geared system in *RomaxDesigner*, GKN Driveline manufactured the resulting gears and evaluated experimentally the driveline efficiency. Results showed improvements across the speed and torque range of interest of up to 2 percent without compromising on durability and NVH. This provided valuable insights into how GKN Driveline continuously initiates performance improvements in its customer applications.

Hybrids and EVs: a Market Opportunity

GKN Driveline develops the latest driveshaft and geared component technologies. "During first hype of electrifica-

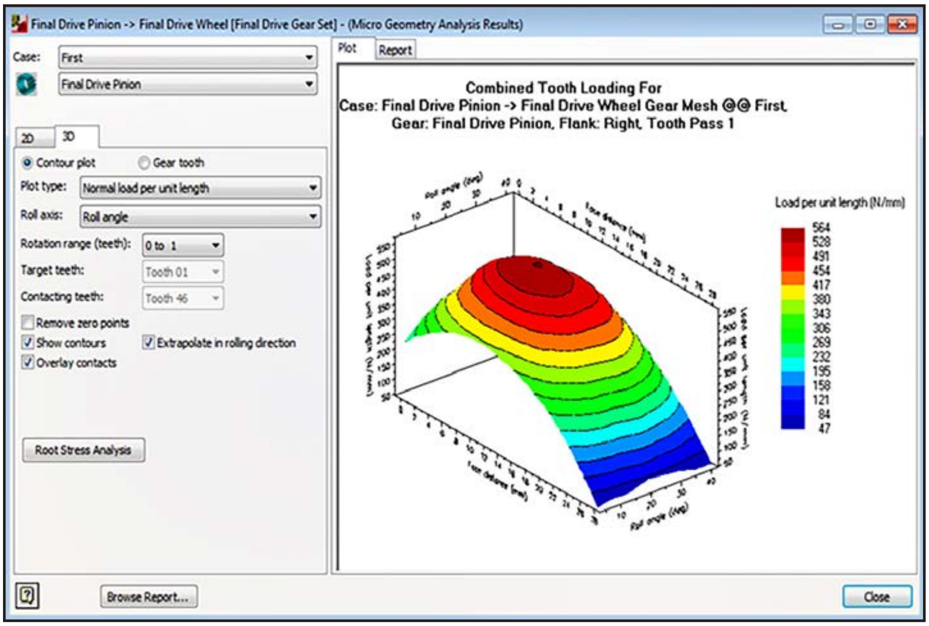


Figure 3 Tooth contact in RomaxDesigner.

tion four to five years ago, everyone talked about quick introduction of battery-electric vehicles," says Theo Gassmann, vice president of Advanced Engineering. "The reality was that the technology wasn't ready — for instance, battery technology is too expensive — and customers aren't ready, particularly regarding range limitations. So the EV market experienced a slow start." He says this led companies to change strategy, embracing a hybrid approach to develop the marketplace.

"GKN Driveline, as market leader in driveline technology, is growing fast in conventional and electrified driveline systems. Coming from AWD systems, we successfully launched transmissions for hybrid and electric vehicles in the last years. Transmission has not been our core business but we utilized our driveline expertise and technologies to expand our portfolio successfully."

Gassmann says transmission issues for EV and HEV are broadly similar to non-electric applications: "Powertrain efficiency, durability and NVH. Differences come regarding the duty cycle and loads, between coast and drive. The driveline is different. And when you have to invest in battery capacity, you don't want to waste energy in the transmission. The biggest challenge is arguably NVH. Missing masking noise from combustion engine and lightweight-design leads to an early focus on NVH improvements."

The Value of the Right Analysis System

Conventional methods to increase transmission efficiency can have adverse effects on durability and quiet running; lack of engine noise in EVs renders current design practices unacceptable. In addition, the pressure to improve efficiency of the eDrive gearbox in GKN Driveline's all-wheel drive hybrids required a new approach. "We've worked with Romax for several years, in a step-by-step process that started in Japan then moved into Germany and Sweden," says Dr. Artur Grunwald, supervisor of Advanced Geared Systems Calculations.

"We saw the value of analyzing the whole system, to identify where the greatest benefits could be gained, then working to balance efficiency, durability and NVH across the entire system.

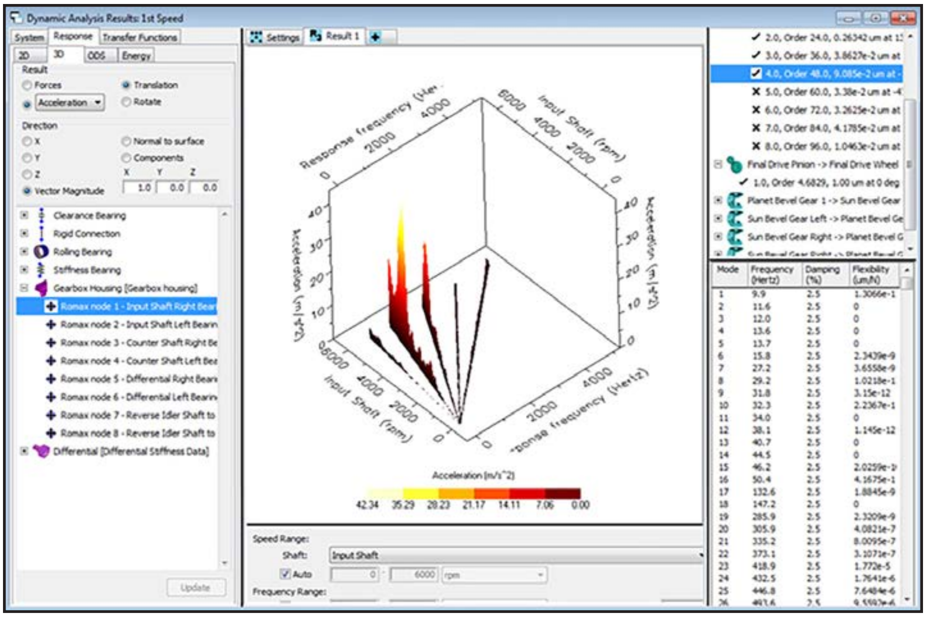


Figure 4 Vibration response calculation in RomaxDesigner.

RomaxDesigner provided the accuracy in modeling and analysis, and we worked with Romax people on a project and consulting basis to learn how to best use the software and apply our engineering expertise.

"We use *RomaxDesigner* for problem solving and for system optimization from concept to production design. Perfect components don't always equal a perfect system when combined. That's why we use *RomaxDesigner*: it shows where you can have the most impact and where the benefits lie. It's one of the few software systems capable of this type of system analysis. Our goal is, systematically, to separate the useful parameters from the possible in order to enable the biggest benefit at acceptable cost level."

Taking a Whole System Approach to Optimize Design

Romax's abilities to improve efficiency were tested in a project that saw an eDrive gearbox connecting an electric drive to the rear axle of a PSA Peugeot Citroen passenger car, with a conventional internal combustion drive connected to the front wheels. The original gearbox was analyzed using *RomaxDesigner*, which explored potential improvements to gear geometries, comparing predicted NVH and durability with the original design.

GKN Driveline manufactured a redesigned set of gears, with extensive tests confirming overall efficiency improvements and, in the all-important coast condition that determines energy recuperation performance, the 1–2 percent gain across the speed and torque range required. "The efficiency of the gearbox was assessed by calculation of the component losses from gears, bearings, seals and oil churning," Dr. Grunwald says.

"Efficiency results from the simulation are compared against frictional torque measurements taken during testing under a range of torques and speeds. The methodology used allows advanced parametric studies to be carried out in an all-in-one approach with *RomaxDesigner* to consider the effect of a wide range of design changes on efficiency at the same time as durability and NVH performance."

He adds, "We also have several years' experience of working with Romax people, who have been extremely reliable and professional. We clearly benefit from that valuable experience. As a business, we want to develop a common understanding of simulation issues and use consistent methodologies from concept to production. Our requirement to take a whole-system approach will increase with future projects and applications, and across different regions and product ranges. The way *RomaxDesigner* integrates with other software packages also saves us time. Its ability to provide interfaces and to share results for interpretation by our engineers is another reason we use it internationally."

Gassmann adds, "We're moving into a new era of hybrids and electric cars. Genuinely high-performance products demand the effective application of system know-how from concept to production, so you can find the best possible balance."

Meeting the Demands of a New World

Calls for innovation can be triggered by a variety of factors. It could be from a demand to keep up with competition, a demand to incorporate technology enhancements, or even a demand to satisfy compliance and legislative changes.

In line with this, it is important to understand the impact on not just the internal design process, but also the need to account for external variables.

Probably the best example of this can currently be seen in Europe, notably the EU's plans for addressing growing carbon emissions amongst all passenger vehicles. Currently, the EU has put in place a comprehensive legal framework designed to reduce CO_2 emissions from new light-duty vehicles as part of efforts to ensure it meets greenhouse gas emission reduction targets under the Kyoto Protocol and beyond. Car manufacturers are obliged to ensure that new fleet cars do not emit more than an average of 130 grams of CO_2 per kilometre (g CO_2/Km) by 2015 and 95g by 2021.

The fallout of this has seen major OEMs, led by some of the industry's biggest car manufacturers, actively developing low-carbon, electro-mechanical drivelines and vehicle technologies to address consumer demands while still meeting the requirements of the EU.

While it is reassuring to see positive actions being taken, what often isn't considered is the impact of real-world variables on those early design phases. Earlier this year, a study carried out by Romax in collaboration with Loughborough University in the U.K. revealed that fuel consumption in the automotive industry can differ by as much as 20 percent when comparing real-world drive cycles to that of rig and simulated tests based on legislative drive cycles. This demonstrates the significant variances which exist when it comes to fuel efficiency.

The findings, which stemmed from the impending EU legislations, were part of a three-year investigation into the factors that influence energy consumption across hybrid electric vehicles, and how real-world driving differs from legislative test cycles. The interesting point of note is that the findings clearly demonstrate that while traditional design tools used by manufacturers tend to focus on efficiency against a single drive cycle, they don't account for the robustness of a vehicle's performance against a set of drive cycles or against external factors such as locational influence.

Tests are carried out in a very regimented environment and rarely account for outside influences and as a result, the data achieved from this is rarely put to effective use. In light of this, it is imperative that organizations start to make the most of data streams available to them, and doing so at the earliest points of the concept design stages. Embracing this would dramatically smooth the transition from one drive cycle to another, with significant cost reductions being seen through greater fuel efficiencies.

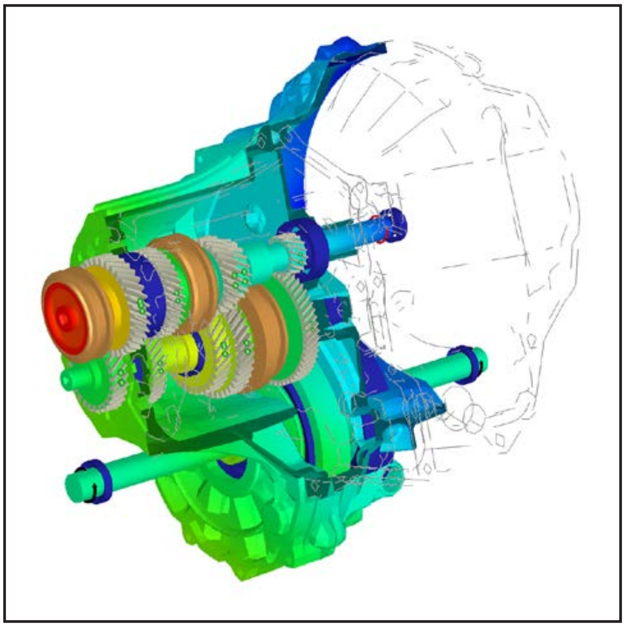


Figure 5 Mode shape analysis in RomaxDesigner.

As a final thought, it is important to recognize

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at www.geartechnology.com

that OEMs have and will continue to use a wide array of individual software tools and methods to simulate and design driveline components. The problem that arises is that no matter how good these standalone tools or individual analysis processes are, they often fail to account for unforeseen problems or external variables, when combining components into the complete system.

As demand for faster, smarter and more cost-effective design increases, so does the need to provide innovative simulation tools, which can encapsulate the entire driveline system, allowing for it to be modeled and simulated quickly, accurately, repeatedly and as early in the process as you want.

As a company, this is what we at Romax are committed to providing our customers. Our solutions are designed with the intentions of being integrated into the overall design and development process, with end-to-end tools designed to address all elements from product planning to manufacturing.

This quarter, Romax is announcing its new comprehensive gear design tool, embedded into its *Concept* product. This will enable gear design to be part of a fully integrated system-level design and development process which includes system durability, efficiency and NVH, rather than being the standalone activity which it often is today. See Romax at booth #1402 at Gear Expo 2015, October 20–22 in Detroit.

For more information:
www.romaxtech.com

Dr. Jamie Pears is the Head of Product Management at Romax Technology. He has a M.Sc. and Ph.D. in Physics from Nottingham University, UK. He joined Romax Technology in October 2000 as a software developer working on the RomaxDesigner analysis code and the RomaxNVH software. Since then he has been involved in engineering projects as the NVH Team Leader, performing consultancy for many worldwide customers. He has also served as R&D Manager and Software Team Manager. His current role involves setting the overall direction of the Romax Technology software products, communicating with customers and directing the software development team.

Gear Expo 2015 Product Preview

A close look at the technology on display

Carl Zeiss Industrial Metrology — Booth #1645

Carl Zeiss Industrial Metrology will feature the Zeiss DuraMax. With DuraMax, Zeiss offers a compact 3-D coordinate measuring machine. DuraMax Gear marks the evolution of DuraMax into a shopfloor gear wheel measuring machine.

"This enables us to fulfill the requests of many customers and introduce gear wheel measuring technology with small machines that can be used as close to production as possible," says Alexander Dollansky, product manager at Carl Zeiss Industrial Metrology, LLC.

The key features of DuraMax Gear are its suitability for a rough production environment, the high permissible temperature fluctuations, the proven and pioneering Zeiss measuring software and its small footprint.

DuraMax is designed for process control on the production floor, for quick in-between inspections of small workpieces and for testing volume parts directly in production. Because of its accuracy, DuraMax is also designed for many requirements in gear wheel measuring technology. DuraMax Gear comes with the required software and hardware, including stylus material for a broad range of applications. If the product being tested changes, standard inspection procedures often require new, expensive modifications. DuraMax Gear, however, is a CNC all-rounder that, when combined with CAD-based Calypso and Gear Pro involute measuring software, quickly, easily and reproducibly measures all changes. DuraMax Gear is available as a tabletop machine or with an optional base. Its design enables part loading from four sides.

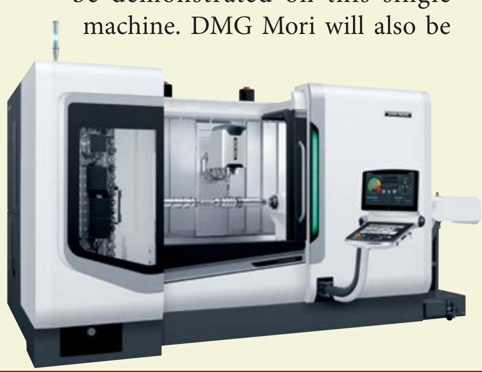
For more information:
Phone: (763) 744-2400
www.zeiss.com/metrology

DMG Mori — Booth #1813

DMG Mori will demonstrate its gear milling portfolio with a focus on GearMILL software and various gear milling processes on multi-tasking machines. The solution's approach, which combines the machine, tooling, inspection and software, will be on display to demonstrate different ways of making gears.

"The demonstrations center around the flexibility of the machines, which leads to greater productivity," says Nitin Chaphalkar, product manager for the gear market for DMG Mori.

The booth will also have a display of their GearMILL software with latest machine cycle developments and part inspection capabilities. Machining of a variety of gears such as spiral bevels, spur, helical and internal gears will be demonstrated on this single machine. DMG Mori will also be presenting its solutions during presentations at the solutions center. The machine exhibited will be a NTX 2000 machine (a multi axis lathe) with second spindle and lower turret. This machine is capable of producing all types of gears using InvoMilling, flank milling (end mills), hobbing, gashing and power skiving processes. DMG Mori's gear expert team will be on site to discuss possible machining processes for your parts and recommend solutions.



For more information:
Phone: (855) 364-6674
us.dmgmori.com

EMAG — Booth #1304

The new platform VT and VL Series for shafts and chucked components will be on display for visitors to experience the EMAG modular inverted vertical lathe design.

With the goal to develop a system of modular machines geared for use in the manufacturing of medium and large batch runs, EMAG offers flexible solutions on a standard platform. Single spline hobbing, for example, will be displayed on a VT vertical lathe for shafts. With the capability of offering gear cutting on a standard machine, EMAG modular machines offer increased flexibility. Machining is carried out in four axes at a maximum speed of 6,000 RPM. The process employs two turrets with twelve tool stations each, equipped with turning tools or driven tools. One common feature of all four VL machine sizes is the shared modular design. Their

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.
Call 630-969-7640 or visit arrowgear.com

2301 CURTISS STREET, DOWNERS GROVE, IL 60515 | 630-969-7640 | ARROWGEAR.COM small footprint reduces floor space costs and increases flexibility in floor layout options. Every VL and VT machine features an integrated O-automation system for transporting workpieces.

When combined with the self-loading pick-up spindles, this automation concept ensures shorter cycle times and higher productivity. To accommodate machine operators, all the service units are easily within reach, with the various units (electrics, hydraulics, cooling system, cooling lubricant and central lubrication system) accessible at any time so that the machines can be maintained with ease. While the standard lathes are commonly used for gear blanks, a wide range of technologies can be incorporated into the machines, including turning, grinding, hobbing, chamfering, induction hardening and laser welding.

The technologies in the EMAG Group cover the entire spectrum of metalworking, including non-traditional processes. Laser welding is essential in lightweighting automotive components while electro-chemical machining (ECM) is a deburring option.

Introducing the latest addition to this technology portfolio, Eldec will display induction hardening systems with a modular induction (MIND) machine at the show. Featuring Simultaneous Dual Frequency (SDF) technology where two different frequencies are applied to the workpiece, MIND machines can apply mid-frequencies to penetrate deeper and heat the root of the gear tooth simultaneous to high frequencies to accurately heat the tip of the tooth. Eldec hardening systems compliment the workpieces machined by EMAG lathes to create more efficient, complete production lines. The flexible machine concepts and complete systems from EMAG offer modular and customized solutions for the production of workpieces in nearly every industry.

For more information:
Phone: (248) 477-7440
www.emag.com

Emuge — Booth #1901

Emuge Corp. recently announced a comprehensive line of high-performance tools for threading demanding nickel/super alloy materials to 46 HRC. The new program includes tools ranging from taps with unique new geometry designs to solid carbide thread mills designed for challenging aerospace, powergen and oil industry applications. A full line of sizes from no. 4 to ¾" are available in UNC, UNF and Metric, 87 sku's in total.

Emuge's Nickel Alloy Program includes new DF-NI and C-NI taps. With Emuge's industry-first Variable Helix Correction (VHC) technology, DF-NI taps feature a specially ground relief geometry in the primary cutting zone that is designed to generate a smaller and tightly rolled chip formation for enhanced chip control to prevent damage caused by chips jamming in the tap teeth. With a 10° right hand spiral flute, VHC taps are also available in STI thread sizes for jet engine components. New C-NI taps offer an advanced left hand helical flute form with rake and relief to optimize chip evacuation in the forward direction and add strength to the cutting teeth.

Both taps are designed with special relief geometry in the chamfer and thread section to help overcome the high hardness and elastic memory of precipitation hardened nickel alloys. Taps are manufactured with premium HSS-E and are TiCN coated for exceptional heat and wear resistance. Modified bottoming chamfer (2-3 threads on VHC taps) is designed to reduce torque and increase tool life. Taps are 3BX class of fit for internal UNJ threading applications. DIN length is available for improved chip clearance in hard-to-reach applications.

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

Euro-Tech — Booth #1704

Mytec is introducing its new line of mechanical arbors and chucks with accuracy down to .0004" plus high expansion rates up to .010" or greater in a stainless steel construction.

Mechanical arbors and chucks are designed for workholding where high forces are incurred or auto load applications where high clearance is required. A closed expansion system, which is impervious to dirt and chips, combined with high wear resistance, offers increased service life. If space permits, Hydra expansion elements from Mytec-Hydraclamp are generally equipped with an adjustment piston. This makes it possible to set expansion for fine clamping, particularly in the case of thin-walled workpieces, so deformation can be avoided.

Also on display will be Frenco's INO system spline gages, an internal standard for the external dimensional measurement of spline gages based on national and international standards suited to even the most sensitive and complex components and systems. This product line provides a quick method of inspecting involute splines, serration splines and straight sided splines to ensure interchangeability of parts even between different manufacturers. Frenco spline gages are constructed of HX, a wear-resistant, high alloy, powder steel. This wear-resistant material allows for an improved extension in inspection intervals.

For more information:
Phone: (262) 781-6777
www.eurotechcorp.com

Erwin Junker Machinery — Booth #1026

The Junker Group will present its product diversity in gear manufacturing: Grinding machines from Junker and Zema in addition to air filters from LTA.

Junker's portfolio has recently been expanded to include non-cylindrical grinding of camshafts for low to medium lot sizes. By using up to two high-performance grinding spindles, bearings journals and cam lobes can be rough and finish ground in a single clamping set-up. High powered grinding spindles, in combination with proven CBN grinding technology, guarantee the highest removal rates and performance.

The Lean Selection cam is capable of grinding all cam lobe profiles and geometries at high-speed – from concave to elliptical – and is suitable for manufacturing everything from prototypes to large production runs.

Zema will be demonstrating how its Numerika G-800 accomplishes the precision grinding of gear shafts. This durable, cylindrical grinding machine with its hydrostatic × and Z axes and hydrostatic grinding spindle reaches the tightest tolerances reliably and is suited for an unlimited array of work pieces. In addition, Zema also offers machines for ID/OD grinding and large shafts with diameters of up to 1 meter (40 inch) and up to 4 meters (157 inch) in length. The conversational control systems (Fanuc Based) offered by Zema are operator friendly, simple and convenient to use.

LTA Lufttechnik GmbH is extending its portfolio to include a filter which has been kept deliberately simple and will be launched in the market under the name Basic Line. LTA has developed the new entry level model to allow customers from the metalworking industry to benefit from a simple yet fully functional oil and emulsion mist filter.

The electrostatic filter is available in two versions: The smaller of the two has a single-stage filter, the larger comes with two filters in series. The filters are configured for coolant pressures of up to 40 / 80 bar internal cooling and a machine room of up to 6 m^3. Despite the suction capacity of 1,200 m^3/h, the blower uses minimal energy, as LTA exclusively installs fans in accordance with the ERP directive. The filter elements used also contribute towards simple handling: They are optically monitored and fully washable. Their compact design allows the BASIC Line filters to be mounted on all machine tools.

For more information:
Phone: (847) 488-0406
www.junker-group.com

Exsys Tool —Booth #1731

Exsys Tool, Inc. will showcase its new line of high-quality Eppinger gearboxes and custom gear-making services for a wide variety of industries. Exsys just recently expanded its offerings of productivity enhancing systems into the gear sector.

Expo attendees will find spiral bevel, planetary, planetary bevel, hypoid, and cycloid-type gearboxes at Exsys's booth, many of which are produced by Eppinger. They will also learn how to acquire specialty custom-made gears produced to their specifications.

Eppinger offers BT (bevel torque) and BM (bevel maximum torque) compact spiral bevel gears designed to bring high torque and maximum efficiency to gear applications that require a high degree of reliability and variability. Each of these bevel gearbox types offer minimized tooth clearance and optimal transmission properties via precision axes and bearing seats combined with Gleason bevel gears built to withstand high loads.

The single-component steel housings for these bevel gearboxes have mounting threads on all sides to ensure stable attachment in a variety of installation positions. The heavy-duty bevel gears inside these housings offer high-transmission precision and reduced stress on the bearings. A friction-locked, zero backlash connection of the crown gears on the drive shaft reduces the mass of the gearing component. Eppinger also offers PE (planetary eco) and PP (planetary precision) gearboxes designed for applications that require low backlash, high efficiency, shock resistance and a high torque-to-weight ratio. They have a modular design that combines ground gears and precision gear components.

The present range of planetary gearboxes comprises five sizes, with each size offered as a single, dual, or triple stage design. Each gearbox variant is also available as a precision design with reduced backlash. The wide range of sizes and designs allows users to achieve overall transmission ratios from i = 3:1 to i = 512:1 in a variety of applications.

Eppinger's BP (bevel planetary) gearboxes combine features of the company's BT series gearboxes with the pre-stages of its PE gearboxes, creating an innovative solution for various applications. The stable housing design and hardened, super-finished gear components of these gearboxes help ensure smooth running and constant backlash control.

These planetary bevel gearboxes achieve high-output torque and transmission ratios up to i = 320. Currently offered in eight sizes, the planetary bevel gearboxes easily mount to a wide range of motors.

For more information:

Phone: (800) 397-9748
www.exsys-tool.com/en

Gleason — Booth #1017

The Gleason Corporation will be showcasing a selection of its grinding and inspection machinery.

The Genesis 200GX threaded wheel grinding machine is Gleason's latest addition to the Genesis series and offers many features. The two spindle concept combines increased productivity with minimized idle and set up times. Fast, easy software-guided setup of the machine allows you to set up machines from one workpiece to another in just 20 minutes using only one tool. Fully automatic workflow after setup until grinding the first workpieces and the ability to interface with Gleason GMS machines via QR codes increases productivity. Easily accessible machine components make maintenance simpler and more efficient while standard dimension grinding wheels and dressing tools allow you to use your existing tools. All of this in an energy efficient small footprint machine designed to meet the needs of customers in high-productivity, high-quality environments.

The Gleason 300GMSP analytical gear inspection system is designed to operate in production environments while yielding reliable measurement results. A patent-pending base design includes an active leveling system to attenuate a broad spectrum of normal production environment vibrations, yielding measurement values in parallel with those achieved in controlled calibration laboratories, but without the delay of having to move to the lab location.

Thermal fluctuations normally associated with shop floor environments are proactively compensated for as well, allowing for the best possible and most reliable inspection results. The system identifies and applies a compensation for factory floor influences in real time. The 300GMSP is designed and tested to perform as a turn-key gear inspection system in the manufacturing environment.

Visitors to Gleason — Booth #1017 will also be introduced to a number of other products, technologies and services, including: Gleason's complete line of gear cutting tool solutions and advanced workholding solutions.

For cylindrical gear production, visitors will find a full array of hobs, form relieved milling cutters, solid carbide hobs, shaper cutters, chamfering and deburring tools, shaving cutters, honing tools, coated diamond and CBN grinding wheels, diamond dressing wheels and diamond dressing rolls. Visitors will have the opportunity to learn more about recent advancements in gear hobbing technology including G90, a tooling material which closes the performance gap between HSS materials and tungsten carbide. Visitors will also find an assortment of power skiving tools and learn how Gleason is the total source for supporting this process.

Gleason's bevel cutting tool display will feature new bevel gear cutting tools for cutting and grinding straight, spiral and hypoid bevel gears. Of particular note is the PentacPlus –RT, which can be built faster and more precisely than stick blade cutter systems of the past. With blade seating stiffness equal to the high stiffness of the PentacPlus, this new system offers increased surface finish, tool life and cycle time.

Gleason designs and produces a complete range of quick-change, tool-less workholding equipment for bevel gear, cylindrical gear and non-Gleason production machines. These systems reduce set-up and change-over times for gearing applications up to 600 mm in diameter. Quik-Flex Plus, Gleason's next generation of modular, quick-change workholding systems which requires a single tool, less time and minimal operator experience will be on display for the first time at Gear Expo.

Also on display will be Gleason's line of hydraulic workholding solutions. The holding force, increased accuracy and contamination free design are designed for dry gear processing applications. In addition, the stir-able modular workholding designs allow off-spindle assembly and truing to reduce changeover time as well as the amount of total runout in the fixture.

Gleason will also have offerings from Gleason Global Services, Gleason Plastic Gears and Distech Systems.

Gleason customers can rely on factory trained service professionals located throughout the Americas, Europe, and Asia, working around the clock to deliver the full range of aftermarket service and support capabilities including service programs for preventive maintenance, machine inspection, troubleshooting and repair and machine relocations. Learn about Gleason's complete range of machine rebuilding and re-controls now offered for all types of Gleason machines. In many instances this work can be completed right in the customer's factory in less than two weeks. Gleason is a leading source of education for gear technology and it will be promoting its customer training classes which offer a full range of courses and education forums ranging from the beginner to the most advanced user covering all aspects of gear design, production and inspection.

Offering plastic gear design and injection molded plastic gears including helical gears, spur gears, planetary gears and internal gears, Gleason Plastic Gears provides customers with the benefit of a plastic gear with no weld-line for a stronger, more accurate, and economical drive train, eliminating the additional expense of secondary machining. Gleason will display some of its most recent innovations and have experts available to answer any plastic gear related question.

Distech Systems specializes in the design and manufacture of factory automation systems serving a variety of customers in the automotive and other industries. Combining customized automation technology with Gleason products for gear (and non-gear) production allows for more complete product for Gleason customers.

For more information:
Phone: (585) 256-6776
www.gleason.com

Index — Booth #1653

Index recently developed a "bevel gear hobbing" package, which consists of a specially designed control cycle and four Index cutter heads with module-dependent inserts. Equipped with these features, the Index R200 and Index R300 turn-mill centers become gear cutting machines on which spiral bevel gears can be produced – from bar stock, with front and rear end machining, complete in one setup or as a pure two-spindle gear cutting machine.

By hobbing using a continuous indexing method – which corresponds to the Klingelnberg Cyclo-Palloid method 1) – spiral bevel gears can be produced with constant tooth height in a module range of 0.6 to 4 mm.

Compared to the conventional process chain with classic gear cutting machines, users can achieve shorter cycle times and better geometry and position tolerances.

"The starting point of the development by Index lies in its own manufacturing governed by the principle: quality-determining components are made in-house," says Dr. Volker Sellmeier, Index-Werke head of technology development. "When the tool holder production was reorganized several years ago, the decision was made to produce the required bevel gears ourselves."

Bevel gear cutting requires a machine with high rigidity and a B-axis as the basis. Due to their increased static, dynamic and thermal properties, the turn-mill centers of the Index R-series are designed to gear-cutting, provided they are equipped with the "bevel gear hobbing" technology package. The R machines' axis configuration with two milling spindles on Y-B-axes running in hydrostatic bearings makes it possible to machine on the main and counter spindle simultaneously in five axes.

The ability of the turn-mills to accomplish complete gear-part machining on the front and rear ends simultaneously results in shorter total cycle times and lower cost per piece.

"When we machine typical bevel gears with module 1.15 mm and approximately 25 teeth for our tool holders completely from bar stock, we achieve a cycle time of less than 3 min. The share of gear cutting amounts to about 30 seconds," Dr. Sellmeier says.

In a classical gear process chain, the workpiece has to be set up on several individual machines for turning, drilling, and milling, gear cutting and deburring. Index's approach is to run all operations on the turn-mill center. Bevel gears are turned, drilled, milled and finally cut on a single machine. Even brushes for deburring can be set up. The soft machining process is thus completely autonomous, according to Index with a process-reliable gear quality of IT5. This is then followed by hardening. A final finishing process is usually required only for the mounting distance and the polygonal shaft/hub connection.

The Index solution works for both contract manufacturers, which need to produce small lot sizes with high flexibility, and mass producers, which want to produce bevel gears in large quantities at minimal cost. The investment is relatively low compared with specialized machines. Also the consumption costs are kept within manageable limits, since the cutter heads are equipped with interchangeable inserts.

Flexibility is high: In addition to bar stock machining, which is best primarily for small quantities, for series production the R machine can be used as a pure gear cutting machine, working on the main and counter spindles simultaneously.

"This requires the use of an automated workpiece-loading and unloading system that loads the blanks and removes the finished parts gently," said Dr. Sellmeier. "We offer a quadruple gripper with two stations on the main and counter spindle that picks up the finished parts, rotates and then loads new blanks. This way we use the machine as a kind of double-spindle machine, cutting the time per piece in half."

Two cutter heads are required per bevel gear. They differ slightly in their cutting circle radius in order to produce the longitudinal crowning. Index offers the cutter heads in four different sizes that can be fitted with up to six carbide inserts and feature internal cooling.

In contrast to the typical Cyclo-Palloid method with an interlocking cutter head, the Index method uses two separate cutter heads per bevel gear.

A control cycle developed by Index is another essential part of the technology package. The user enters there the same parameters as on a conventional gear cutting machine. These include, for example, machine distance, eccentricity and auxiliary angle. The cycle translates these values into the movements of each axis so that at the end the same relative movements are effected as on a conventional gear cutting machine.

For more information:
Phone: (317) 770-6392
www.index-usa.com

Kapp Group —Booth #2222

Kapp Niles will be showcasing its ZE 800 profile gear grinder while R&P Metrology GmbH will present its PM 750/1250 portable gear inspection system.

The ZE 800 offers a compact yet highly productive solution for a range of applications. The machine is capable for 25 module (1 DP) external gears and is prepared for internal grinding using either CBN or dressable wheels. It will be shown with new software features including hob and worm grinding.

R&P's PM 750/1250 is the first portable gear checker/CMM with dual functionality for use in the lab or on the production floor. Its flexibility enables the measuring of larger gears on production machines that may not have onboard inspection. The design makes it moveable within the plant. The optional "docking station" with granite base and rotary table allows the PM 750/1250 to become a stand-alone, fully featured four axis generative gear inspection machine when not required for portable measurement.

Kapp CBN tools for direct grinding, and DIA dressers for grinding and honing are also featured at the booth, along with grinding experts, on hand to answer questions.

For more information:
Phone: (303) 447-1130
www.kapp-niles.com

KISSsoft —Booth #1830

KISSsoft is a modular calculation system for the design, optimization and analysis of machine elements and complete gearboxes.

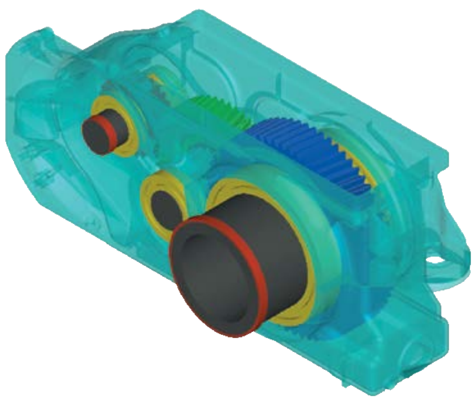
The scope of the software ranges from a single machine element up to the automatic sizing of complete gearboxes. KISSsys is KISSsoft's system add-on that enables the modeling of complete gear units and drive trains and is valuable for multi-stages gear transmissions or shifted transmissions. KISSsys also provides the calculations for efficiency and losses, static analysis with housing stiffness and modal analysis.

The software includes internationally recognized calculation standards and a large variety of design and optimization options, based on the experience of KISSsoft's customers and development engineers, ensuring that the software is always at the forefront of technology.

At the Gear Expo, KISSsoft will be presenting the latest version of the software. KISSsoft 03/2015 is being released with a number of innovations that have been implemented.

KISSsoft will be at booth 1830. Dr. Kissling and Dr. Beermann, founders of KISSsoft, will be on hand to answer questions. A free trial version of the KISSsoft Release 03/2015 is available at *www.kisssoft.com.*

For more information:
+41 (55) 254-20-50
www.kisssoft.com



Liebherr Gear Technology —Booth #1809

For Platform 2 (LSE/LFS 200 to 500) and Platform 3 (LSE/LSF 600 to 1600) machines, Liebherr Gear Technology is introducing a smaller shaping head option which facilitates electronically controlled machining of spur and helical gear teeth.

"The smaller SKE 120 shaping head enables users to machine a considerably wider range of components on our Platform 2 and Platform 3 gear-shaping machines," says Dr. Hansjörg Geiser, manager development and design gear cutting machines at Liebherr-Verzahntechnik GmbH. "We are thus better able to meet contract manufacturers' gear-cutting requirements."

The new SKE 120 shaping head with highly dynamic rotary drive and moveable shaping head slide occupies less space at a stroke length of 120 mm. The design engineers used the space gained to enlarge the stroke position travel range on Platform 2 machines. The

SKE 120's stroke position travel range, at 650 mm on Platform 2 machines, is more than twice as large as that of the SKE 240, which is 300 mm. The same applies to Platform 3 machines where the difference is 350 mm. Even 900 mm are feasible if raised column slides are used. The shaping spindle is hydrostatically mounted and channeled.

Some workpieces require a longer stroke length (for wider teeth), while others require a wider stroke position travel range (longer workpieces with correspondingly higher gear teeth). The optionally available NC swivel column slide, which lets you produce conical gear teeth at a shaping spindle angle of between -1° and +12°, has been optimized to achieve a higher degree of rigidity. If NC swivel column slides are not used, the shaping spindle angle can be adjusted by up to ±0.45° using a cam.

The direct-drive electronic lead guide provides users with latitude and flexibility. They only need enter a helix angle of between 0° and 45° and the control system calculates the rest. The new SKE 120 shaping head differs primarily from the larger shaping head with electronic lead guide, SKE 240, by a smaller stroke length. The crank drive features automatic mass counterbalance, which ensures optimum concentricity. The spindle itself has a somewhat narrower design than the SKE 240, which has a positive impact on interference conditions.

SKE 120 and SKE 240 shaping heads featuring the electronic lead guide provide contract manufacturers with a range of new opportunities. For example, frequent workpiece changeovers are easier.

To be able to machine different helix angles on gears, the motion of the shaping head must replicate the gear´s helix angle. This can be performed by a mechanical lead guide. Set-up times are shortened because where an electronic lead guide is used only the shaping tool needs to be changed, if at all.

An added benefit is that customers do not have to invest in multiple lead guides. They are not dependent on the control's processing time, which makes them even more flexible. Added opportunities are provided in combination

with the stroke position adjustment detail.

A further requirement was the ability to manufacture efficiently and to optimum quality, in addition to the flexible range of workpieces. The process itself is highly productive, given the high number of strokes at 1,200 double strokes per minute. This figure is based on a dynamic drive mechanism combined with effective control technology at optimum rigidity.

Liebherr developed its Type LSE range of machines based on its proven LFS machines. Besides the option of using electronic lead guides, these machines also enable you to correct helix angles. Tooth flank angular deviation (fh) can be corrected simply and precisely when setting up the shaping machine.

It is possible to retain the helix angle for subsequent tempering. For even better quality, µm corrections can be undertaken: the machine achieves tooth flank quality grade 4 as per DIN3962-2.

Along with increased quality and flexibility requirements, materials have also changed. For example the tensile strength of workpieces to be shaped has increased substantially. The LFS/LSE machines have been designed to shape high-strength materials.

Liebherr has already applied the results of internal tests in this segment using appropriately configured and coated replaceable cutting inserts to industrial applications and put these in practice. The choice of high-alloy substrates with correspondingly efficient coatings demonstrates that machining performance and tool service lives can be enhanced.

For more information:
Phone: (734) 429-7225
www.liebherr.com

Koepfer America —Booth #1822

Koepfer America will showcase a selection of gear hobbing machines.

First is the "Repowered" Koepfer Model 160 gear hobbing machine. This K160 Repowered machine is part of the K-Repowered services offered by Koepfer America. This service offers a complete CNC re-control package for existing Koepfer models 160 and 200 gear hobbing machines. This re-control renews the reliability of customers' existing Koepfer hobbing machines.

The Koepfer Model 200 horizontal gear hobbing machine offers increased flexibility, automation, and quality for the hobbing of fine- to medium-pitch gears. German engineering has developed this model for over 20 years, leading to a machine designed for manufacturing facilities across the globe. Koepfer America will feature a Koepfer Model 200, highlighting its easy setup, quick changeover, flexible automation, and rigid construction.

From Helios Gear Products, Koepfer America will also display the first Ra-Cut fine-pitch carbide hobs, which feature up to double the number of cutting faces on an otherwise like design. Ra-Cut hobs can achieve higher-quality finish cut gears and increased productivity using re-hobbing or skiving processes.

For more information:
Phone: (847) 931-4121
www.koepferamerica.com

Klingelnberg — Booth #1410

Klingelnberg will be exhibiting its capabilities with a presentation of cutting-edge technology "made in Germany" in the form of the G 30 bevel gear grinding machine and the P 26 precision measuring center.

Klingelnberg, utilizes this platform for an intense professional exchange on equal footing. Not only will visitors encounter a team of Klingelnberg experts who are available for professional dialogue, but Klingelnberg will also unveil its "home-made" technology from two different business units with its G 30 bevel gear grinding machine and P 26 precision measuring center.

The Oerlikon G 30 bevel gear grinding machine continuously advances the vertical concept for grinding technology. All bevel gear machines in this series are equipped with a heat-stable, vibration-damping machine bed. An optimized axis arrangement ensures reduced approach paths and less load on the drive components – and a stiffer design of the overall system. The G 30 can be optionally equipped with a side loading door, allowing for easier loading in automatic mode using a machine integrated loading shuttle or handling robot. For series production, the machine also offers a range of process monitoring functions.

Klingelnberg has also continued to develop the P 40 measuring center. A height adjustable electric control console and the vibration isolation that can be integrated, now provide even better prerequisites for shop-floor use in the new P 40.

The fully automatic CNC-controlled precision measuring center is designed as a compact unit for the workpiece diameter range up to 400 mm. At the heart of the P 40 is an accurate, durable rotary table. Configured as a measuring axis (C axis), it provides concentric seating of the workpieces to be tested. In combination with the three linear measuring axes, tangential (X axis), radial (Y axis) and vertical (Z axis),

the precision measuring centers trace and inspect the functional surfaces of gearings and general drive components in generator mode.

Measuring centers are equipped with heavy-duty, stable beds and guide bodies made of cast iron. At the same time, all bearings and guides are backlash-free at the measuring axes. These form the basis for the measuring centers' high basic mechanical accuracy. The integrated 3-D measurement system enables both discrete-point probing and scanning, continuous measured value logging. The powerful GINA software makes it possible to evaluate the results quickly and easily.

For more information:
Phone: (734) 470-6278
www.klingelnberg.com

Marposs Corp. — Booth #2039

Marposs Corp. will demonstrate its Artis process monitoring system for gear cutting applications at Gear Expo 2015. The Artis CTM V6 system will be installed on a Kashifuji KE 201 CNC hobbing machine powered by a Fanuc Oi-CNC control, which will be demonstrated in the Involute Gear & Machine Co. booth #1029.

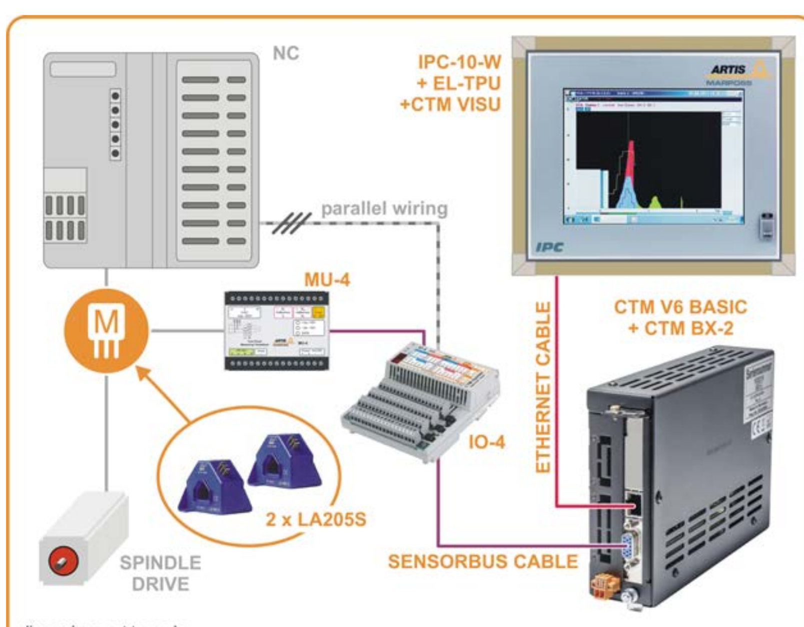
The Artis system for gear cutting has the ability to detect and track tool wear, provide a real and graphical tool life count and trending according to the cutting conditions, and instantly stop the process lights-out in case of chip welding, damaged or broken teeth or other conditions such as peeling coatings.

The Artis system utilizes an algorithm representing the life cycle of a hobbing tool that can be used to identify the optimum time to take the tool out of service for re-sharpening based on its actual condition. Additionally, a system of machine mounted sensors monitors process parameters including spindle torque, spindle vibration, true power consumption and a number of others depending on the specific application. Using these inputs, the system then captures the signature of each operation in the process and automatically generates a "good" tolerance band for the process based on that signature.

While the concept of monitoring process inputs is not unique, the Artis system couples it with powerful software specifically designed to detect the exact kinds of anomalies produced by worn and/or damaged hobs from conditions such as chips weld, peeling coatings or broken teeth. The Artis software can identify and quantify each of these signatures to generate either an approaching end-of-life warning for normal wear, or an automatic machine stop in case of actual tool damage.

In the case of normal wear, the Artis system notifies with ample time to schedule the downtime required to minimize the impact on production.

For more information:
Phone: (616) 891-1091
www.marposs.com



Mazak — Booth #1322

At Gear Expo 2015 in booth 1322, Mazak will use its Integrex i-100ST, equipped with the latest Mazatrol SmoothX CNC, to demonstrate how advanced multitasking machines can effectively perform today's gear-making processes, from hobbing to skiving to gashing.

Mazak multitasking machines, including the Integrex i-100ST and over 90 other model configurations, when paired with the right software and CAD/CAM system, can serve as adaptive gear machining solutions that produce precision gears of all shapes and sizes. Unlike dedicated gear cutting equipment, these machines have the flexibility to perform a variety of operations in a single setup.

Shops with occasional gear work, for example, can use a Mazak multitasking machine to turn a part's I.D. and O.D., process its mating features, and power skive its gear tooth pattern. Performing all of these functions on one machine improves overall accuracy because every part feature runs true to the gear teeth. And, when the machine is not busy with gear work, it can continue to earn its keep by processing a range of complex, non-gear components.

One of the most compact models in the Mazak multitasking machine family, the Integrex i-100ST, processes small complex workpieces in single setups. It employs two 15-hp, 6,000-rpm turning spindles, a nine-tool lower turret and a 10-hp, 12,000-rpm milling spindle. Each turning spindle features a 6" chuck with a 2.4" bore size that can accommodate bar stock of up to 2" in diameter. The machine's 36-tool magazine accommodates tools up to 5.1" in diameter when neighboring stations are empty and up to 3.5" in diameter when stations are occupied.

Gear Expo attendees will be among the first to see the Integrex i-100ST equipped with the new Smooth Technology process-performance platform, which has transformed the way the company's multi-axis machines perform. According to Mazak, new CNC technology, progressive machine design and unequaled engineering resources set the foundation for the platform and, together, provide users with unsurpassed ease of operation and unmatched productivity.

The Mazatrol SmoothX CNC, a key element of Smooth Technology, operates four times faster than Mazak's previous-generation controls. Gear makers, especially, will benefit from faster rotary axis speeds, which allow the machine tool to quickly perform gear hobbing and skiving operations.

Gear Expo attendees can also inquire about the company's other gear production options while in booth 1322. The company's larger multitasking machines with full 5-axis capabilities are known for being able to produce low-volume spiral-bevel gear sets. The Integrex e-1550V/10, for example, can machine a spiral-bevel gear set with a 29-tooth, 22"-diameter pinion gear and a 114-tooth, 6'-diameter gear ring in a matter of days as opposed to months.

For more information:
Phone: (859) 342-1700
www.mazakusa.com

Machine Tools Builders — Booth #1804

At Gear Expo 2015, MTB will display a P900 gear hobbing machine rebuilt with all mechanical linkages, gearing and other driving mechanisms replaced with new, modern servo drives and electronic controls via CNC. All guide ways have been refinished, seals and bearings replaced, hydraulics completely replaced, lubrication systems replaced, and a new electrical system installed. During the course of the rebuild, the machine was converted to CNC control for the X (radial), Y (tangential), Z (axial), C (worktable), and A (hob head swivel) axis, along with the B (cutter) spindle. Overall features will include a hob head swivel converted to CNC, enclosure with manually operated door and access panels for maintenance and a new magnetic style chip conveyor.

MTB is also showcasing a Challenger muscle car, which has been retrofitted and customized.

At MTB, classic machine design challenges are overcome by shortening the drive (gear) train for efficiency and accuracy, and by converting them to servo-driven ballscrews. Motors are designed with the proper torque and speed to move the axes at the required accelerations and speeds, which is very similar to the dynamics of supercharging an engine. MTB finds the processes of rebuilding cars and gearing equipment to be very similar. The remanufacturing or rebuilding of a machine includes a rebuild, a recontrol and modifications to reduce or eliminate as much as possible the mechanical linkages, gearing and other driving mechanisms. Generally these are then replaced with new modern servo drives, and electronic control via CNC or PLC motion cards. The reduction in the number of bearings, seals, shafts and other mechanical elements translates to less mechanical wear areas, and a more reliable and accurate machine tool. As a result, it's a modern machine tool.

Several members will be available for questions. Christoph Donner (from Donner+Pfister AG) will be visiting from Switzerland to answer questions and provide insight on gear checking and measurement systems, along with upgrades to MAAG gear grinding machines. Rick Claeyssen, heat treatment 30 plus year veteran, will be available to answer questions and provide insight on atmosphere equipment. Ken Flowers (MTB co-owner and engineer) will be available for answering gear related questions.

For more information:
Phone: (815) 636-7502
www.machinetoolbuilders.com

Reishauer — Booth #2242

Reishauer AG will be demonstrating the RZ 160. The concept is based on the RZ 150 series. The RZ 160 has been increased in size and all relevant components have been adapted to handle higher loads and forces which occur when grinding larger gears. The RZ 160 can grind gears with an outside diameter of 160 mm and modules up to 4 mm.

The RZ160's design focuses on adaptability to the different production requirements of numerous customers. The machine can be fitted with one or two work spindles. The version with two work spindles is used to minimize the loading times. When grinding gears with space limitations, one can use the changeable Profile Grinding Spindle, enabling the use of a small plated or dressable wheel to grind gears using the discontinuous profile method. Both versions of the RZ 160 can be equipped with a fixed or CNC-controlled axis for swiveling the dressing tool. This option can increase the flexibility of the dressing tools since the same tool can be used for a range of gears as compared to the fixed dresser where the tools are normally workpiece specific.

Felsomat, a member of the Reishauer Group, has developed an automation system that is designed to match to the specific requirements of the RZ 160. In combination with the Felsomat FRC600 robot cell, the machine is suited for small to medium lot sizes. Available options include composite checking, de-oiling, SPC and NOK drawers.

Reishauer will be demonstrating polish grinding on a helical gear used in a truck transmission. The grinding wheel has two different sectors and compositions. One area is used to grind and remove the heat treat distortion while the other is for polishing the tooth surface.

The geometry of the grinding wheel is produced by using conventional dressing systems. Grinding various workpieces requires a variable shift jump to reach the polish grinding sector. The shift feed rate and the shift jump can be optimized for polish grinding depending on the dressing frequency.

This process achieves a surface finish of Ra .10 µm. In addition to the improved surface, the polish ground process rounds out the edges at the transition of the workpiece flank and face. The topography of the flanks remains unchanged.

Many of Reishauer's common features are present in the RZ 160, including the Reishauer Generating Module for gear quality, Reishauer LNS Low Noise Shifting technology for low gear noise emissions, Polish and Fine Grinding for surface roughness reduction, Reishauer Twist Control grinding technology to create defined values for flank twist and the Reishauer HMI for fast change over and set-up times.

Reishauer will be at booth 2242 at Gear Expo.

For more information:
Phone: (847) 888-3828
www.reishauer.com

Riten — Booth #2201

Riten Industries will display its Raptor series of live centers, specially engineered for gear hobbing and gear grinding.

Unlike the prevailing foreign import, these centers are made and serviced in the U.S., and are available for immediate delivery. Other featured products are the Adjusta-Point live center that corrects for off-center workpiece center holes, and the C4T live center with permanent bearing protection. Also on display are face drivers and a sampling of the world's largest selection of live and dead centers.

For more information:
Phone: (800) 338-0027
www.riten.com

Star SU — Booth #2109

Star SU will be showcasing its Bourn & Koch 25H Horizontal Hobbing CNC Machine. The machine hobs shafts, gears, and special parts up to 25 mm in diameter. It is designed without hydraulics reducing wear parts and heat.

Also on display will be a variety of gear cutting tool solutions, including: gear hobs, milling cutters, gear shaper cutters, shaving tools, chamfer and deburring tools, master gears, ring and plug gauges, and broaches. The company also offers precision tool re-sharpening services and advanced coatings, including Oerlikon Balzers Altensa and Alcrona Pro, which can extend the life of your tools and lower your costs.

Star SU partners Profilator/GMTA and Sandvik Coromant will also be

present in the booth during this year's show. Star SU has formed an alliance with Profilator to manufacture Scudding tools for the global market. Scudding can complement shaping, broaching and other gear cutting processes to produce gear and spline teeth for both cycle time and tool cost.

See the latest in indexable gear milling solutions from sandvik coromant. As national sales channel partner for Sandvik Coromant's line of indexable gear milling solutions, Star SU presents several new solutions and products enabling optimal production of small to large batch sizes, both in dedicated machines as well as multi-task machines.

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

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Gear Expo 2015 Booth Listings

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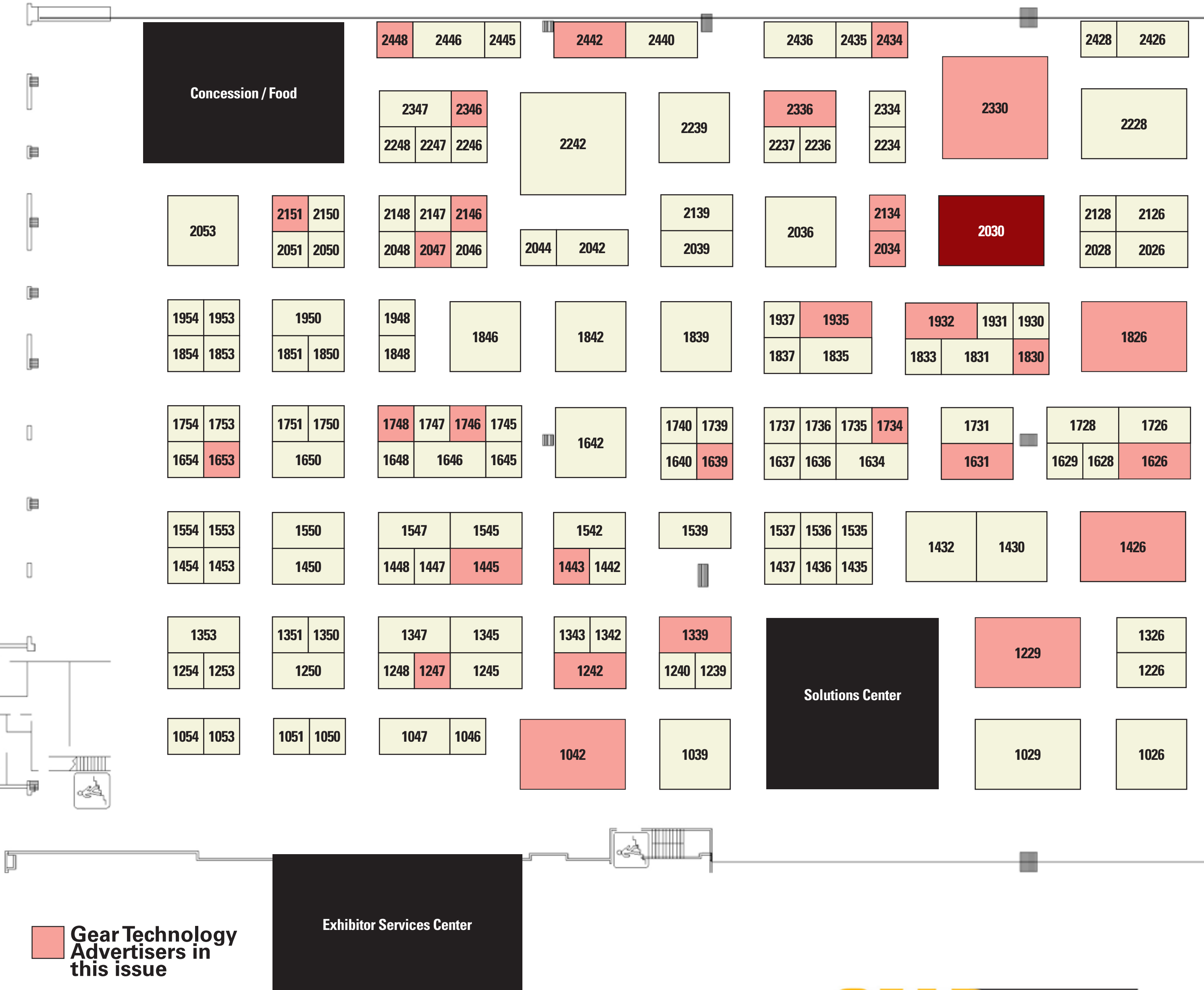

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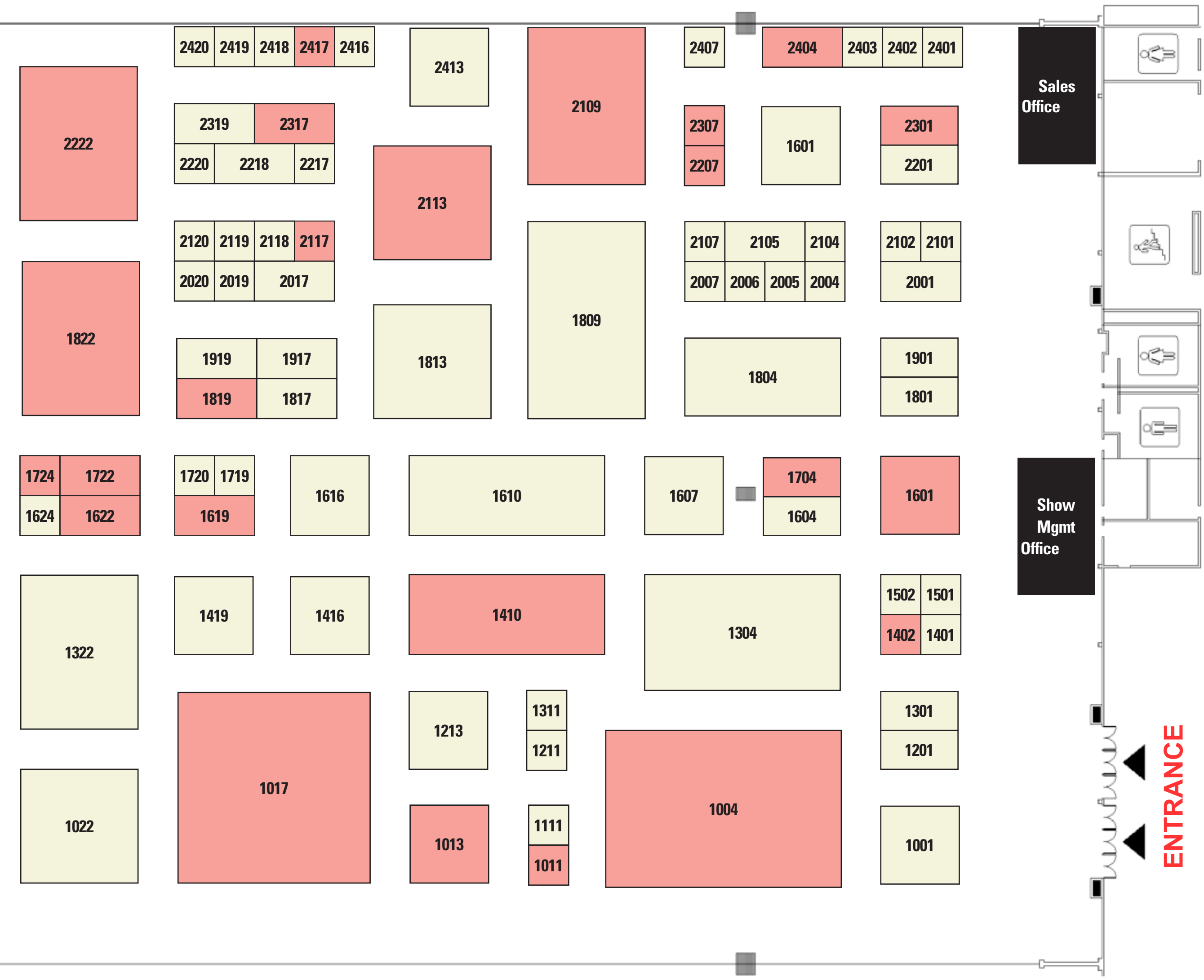
Tuesday, October 20 — 9:00 a.m. - 6:00 p.m.
Wednesday, October 21 — 9:00 a.m. - 5:00 p.m.*
Thursday, October 22 — 9:00 a.m. - 4:00 p.m.
*Networking reception on Wednesday, 10/21 from 5:00 p.m. until 6:00 p.m



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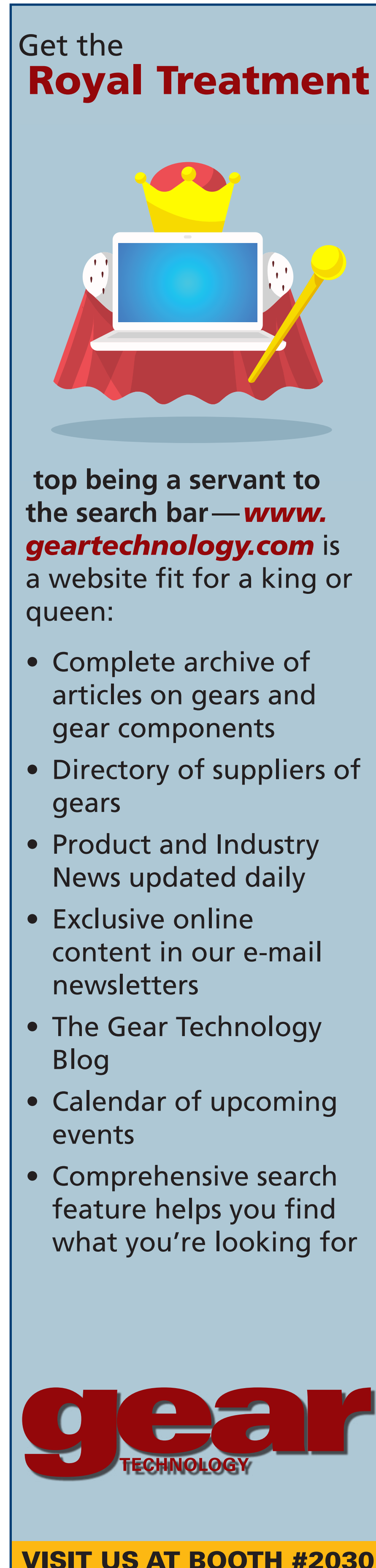
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GEAR GRINDING —Tuesday, 10/20 – 10:30 a.m.

- Dr. Hermann J. Stadtfeld, Gleason Corporation, VP Bevel Gear Technology/R&D
- Dr.-Ing Andreas Mehr, Liebherr, Technology Development, Grinding and Shaping
- Enrico Landi, Machine Tools Product Center Director, Samputensili, Star-SU
- Harald Gehlen, Head of Application Engineering, Reishauer

CUTTING TOOLS —Tuesday, 10/20 — 2:00 p.m.

- Dr.-Ing. Nicklas Bylund, Sandvik Coromant, Manager Engineering Competence Center
- Dr. Hermann J. Stadtfeld, Gleason Corporation, VP Bevel Gear Technology/R&D
- John O'Neil, Engineering Manager for Gear Cutting Tools, Star SU

GEAR DESIGN —Wednesday , 10/21 — 10:30 a.m.

- Prof. Dr.-Ing. Karsten Stahl, Technical University of Munich, Head of the Gear Research Center (FZG)
- Frank Uherek, Rexnord, Principal Engineer, Gear Engineering Software Development
- Dr. Hartmuth Müller, Klingelnberg, Chief Technical Officer
- Octave Labath, Gear Technology Technical Editor

ASK ANYTHING —Wednesday, 10/21 — 2:00 p.m.

- Prof. Dr.-Ing. Karsten Stahl, Technical University of Munich, Head of the Gear Research Center (FZG)
- Dr. Hartmuth Müller, Klingelnberg, Chief Technical Officer
- Chuck Schultz, Principal, Beyta Gear Service
- Octave Labath, Gear Technology Technical Editor

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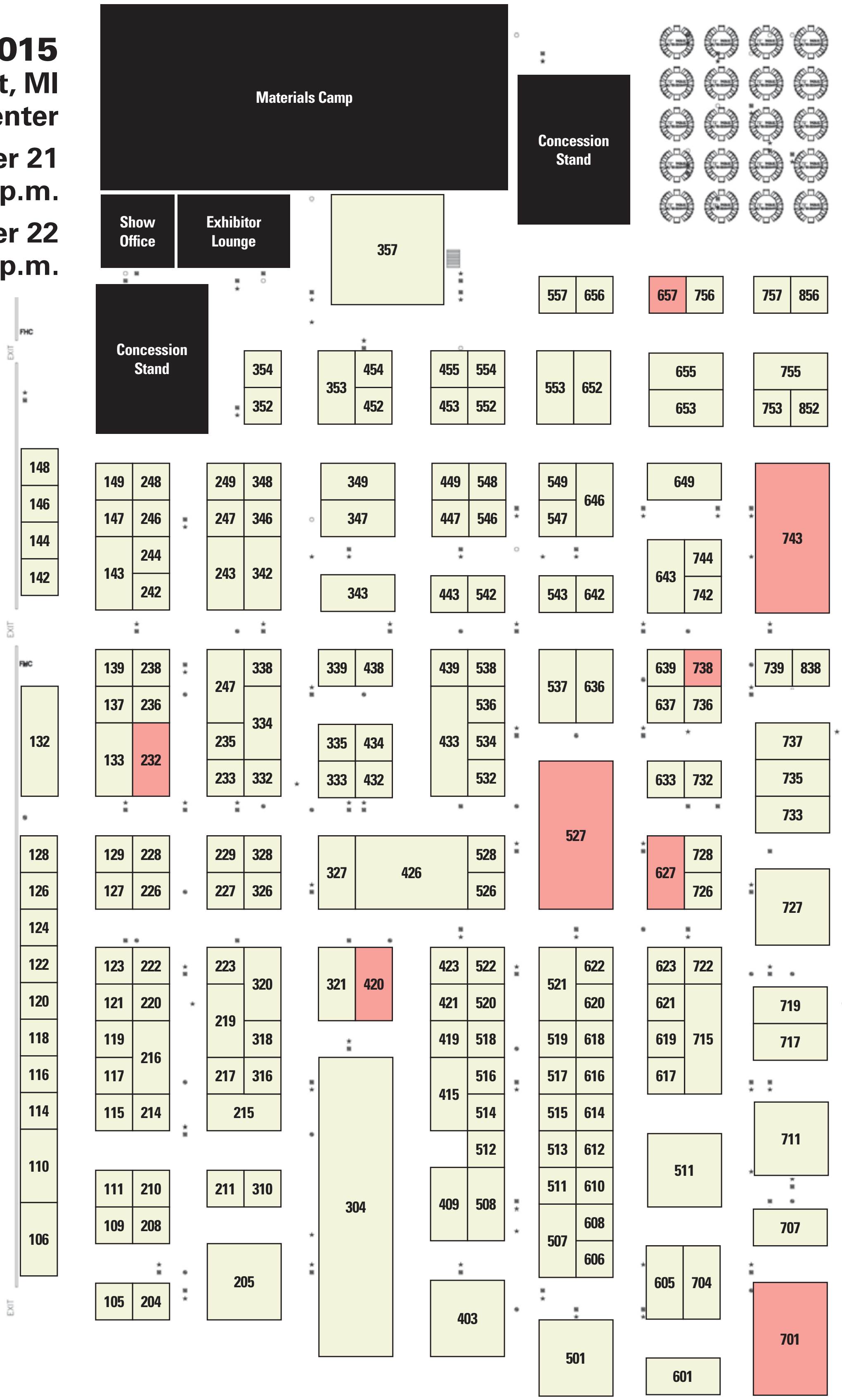
Thursday, October 22 — 9:00 a.m. – 4:00 p.m.



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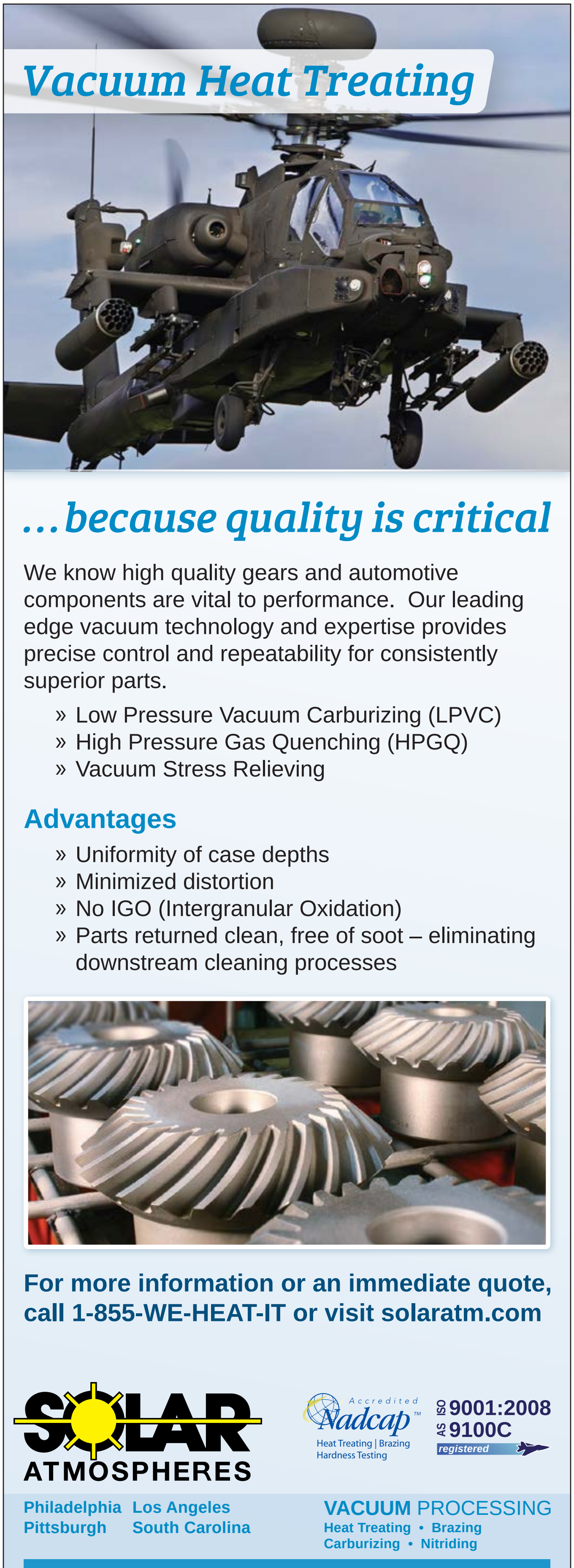

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Gear Macrogeometry

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 #1

I have outsourced gear macrogeometry due to lack of resources. Now I received the output from them and one of the gears is with −0.8× module correction factor for m = 1.8 mm gear. Since bending root stress and specific slide is at par with specification, but negative correction factor −0.8× module — is quite high — how will it influence NVH behavior/transmission error? SAP and TIF are very close to 0.05 mm; how will that influence the manufacturing/cost?

Expert response provided by Chuck Schultz, P.E.

Taking your last question first: SAP (Start of Active Profile) and TIF (True Involute Form) are essentially different names for the same gear feature. The formulas used vary slightly, but it would be surprising if the results were too far apart. This shouldn't affect manufacturing cost as long as the cutting tool used is designed to keep the top of the root fillet and undercut below the TIF/SAP diameter.

It is very difficult to predict NVH results from gear geometry alone. That said, rack offset coefficient influences Profile Contact Ratio (*Mp*), which has a huge influence on the smoothness of power transmission. Higher *Mp* tends to give smoother transmission, as does lower pressure angle and higher Face Contact Ratio (*Mf*) in helical gears. Without knowing the specifics of your gearset, we cannot calculate *Mp* or *Mf*.

Rack offset coefficients (X1 and X2) can be higher than 1.0 and lower than -1.0, and still provide smooth running gears. Kiralla (Fig. 1) felt having all recess action (X1 = 1.0 and X2 -1.0) provided great benefits but most designers try to keep X1 less than or equal to .50, with a corresponding X2 of greater than -.50 (Fig. 3). The involute curve allows for conjugate action over the full range of 1.0 to -1.0, so your -.80 for X2 (Fig. 2) is extreme to some eyes but nothing unusual for others.

Some basic reminders on rack offset coefficient:

- As X increases, the operating pressure angle increases
- On "standard centers" the summation of X1 and X2 is zero (Fig. 5)
- If both X1 and X2 are positive, the operating centers will be larger than standard

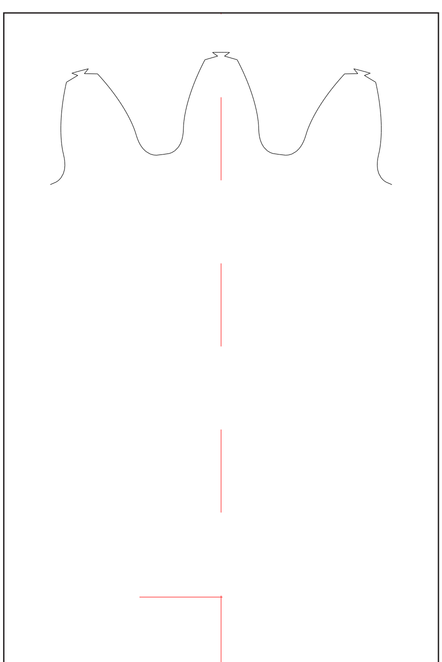

Figure 1 1×24.d×f is x1=1.0/x2=-1.0 — as Kiralla advises.

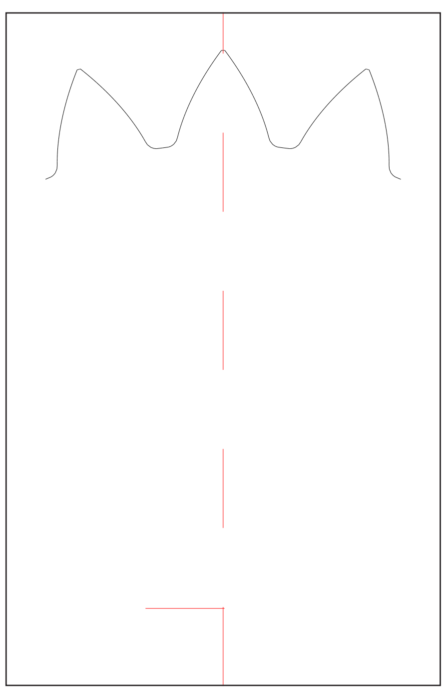

Figure 2 × 824.d×f is x1=.8/x2=-.8 — as Reader question has.

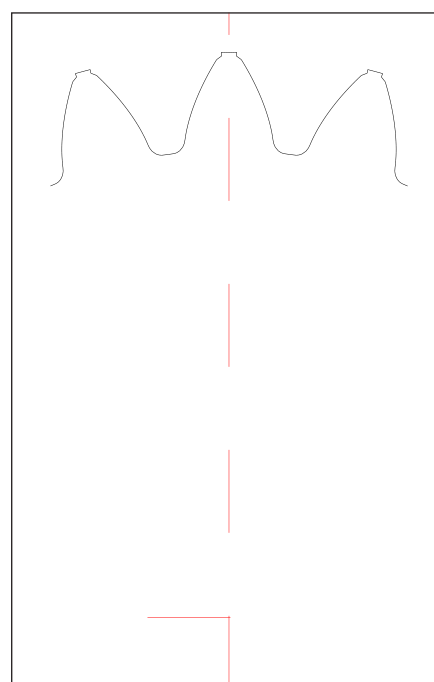

Figure 3 5×24, d×f is x1=.5/x2=-.5 — the "acceptable limit" for most designers.

- If both X1 and X2 are negative, the operating centers will be smaller than standard
- Pressure angle increases with higher X values and drops with negative X values

Gear Technology has published many papers on rack offset theory over the years that can be accessed from the website. It never hurts to ask your gear designer to explain the decisionmaking process that produced the final geometry. There is seldom only one "right" answer when it comes to gear design. This is part of what makes the trade so interesting and at the same time frustrating. Experience can help get to an acceptable solution faster, but it can also blind us to potential improvements available from a different approach.

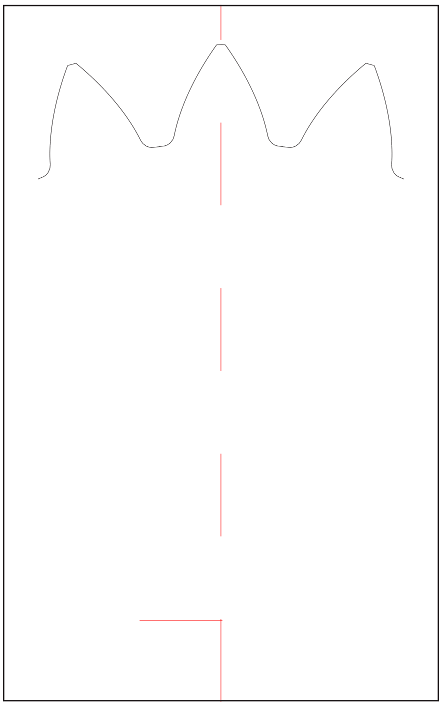

Figure 4 **25×24.d×f is ×1=.25/×2= - .25 — or the conservative engineer limit.**

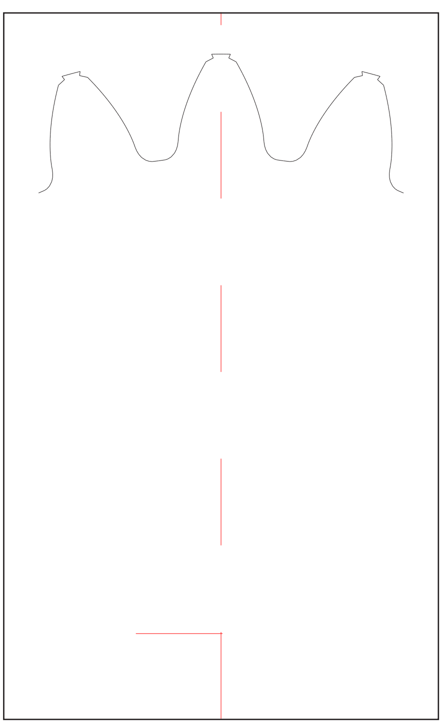

Figure 5 **24 spur gear. d×f is x1=x 2=0 — "standard" geometry.**

Many companies have a general recipe that they follow in designing gearsets that gives them good results in a minimum design time with few potential risks. Sometimes these recipes are not completely understood legacies of a different time and different conditions.

An example I recall is a colleague who insisted helical gears should never have helix angles over 20 degrees. Pressed for a scientific reason why, he reviewed all his reference materials and never found it written down anywhere. Perhaps it was related to bearing life, he decided. When shown that acceptable bearing life could be obtained with higher helix angles (Fig. 4), he removed the 20 degree limit from the "old family recipe." (**Chuck Schultz** is a *Gear Technology* technical editor and owner of Beyta Gear Service — *chuck@beytagear.com*.)

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geometry

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Liebherr/Barber Colman Hob Settings

QUESTION #2

I would like some instructions for setting the degrees and minutes on a Liebherr or Barber Colman hob. Our machines use a Vernier scale to match the lead angle of the cutter to the part to form straight teeth. There is a dispute on how to do this task, and I wanted insight from another professional.

Expert response provided by Hans Grass, vice president, Machine Tool Group, Star SU LLC.

Regardless of what model and brand of hobbing machine, the hob head angle is set to the same angle as the lead angle of the hob for spur gears. In other words, the angular position of the hob head is adjusted to line up the lead of the hob to be parallel to the axis of the work.

For example: for an RH hob, and the hob head is on the LH side of the work spindle for a vertical hobbing machine, the hob head angle is set CW from zero, looking from the center of the work spindle towards the hob head. This is the best definition without knowledge of the plus/minus marking of the Vernier scale, depending on the manufacturer of the machine.

Helical gear example: For an RH helix angle of the workpiece, the hob head angle is set to a CCW angle equal to the helix angle minus the hob lead angle for the above mentioned hob head arrangement and definition of rotational direction.

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Hans Grass, vice president, Machine Tool Group, Star SU LLC

Development of a Face Hobbed Spiral Bevel Gearset

Hermann J. Stadtfeld

Bevel Gear Technology

Chapter 2, Continued

This article is the fourth installment in *Gear Technology's* series of excerpts from Dr. Hermann J. Stadtfeld's book, *Gleason Bevel Gear Technology*. The first three excerpts can be found in our June, July and August 2015 issues.

In the previous chapter, we demonstrated the development of a face-milled spiral bevel gearset. In this section, an analogue face-hobbed bevel gearset is derived.

— Hermann J. Stadtfeld

For this example the following data are given:

Method	continuous indexing with Gleason face hobbing	
Tooth depth along face width	parallel	
Shaft angle	Σ	90°
Offset	$a = TTX$	0 mm
Number of pinion teeth	z_1	13
Number of ring gear teeth	z_2	35
Outer ring gear pitch diameter	D_{02}	190 mm
Face width	$b_1 = b_2$	30 mm
Mean spiral angle	$\beta_1 = \beta_2$	30°
Pinion hand of spiral	$HOSP_1$	left-hand
Nominal cutter radius	R_w	88 mm
Number of cutter starts	Z_w	17
Pressure angle	$\alpha_C = \alpha_D$	20°
Profile shift factor	$x = x_1 = -x_2$	0
Tooth depth factor	f_{Depth}	1
Top-root-clearance factor	f_{CL}	0.2
Profile side shift factor	$x_S = x_{S1} = -x_{S2}$	0
Pinion addendum	h_{K1}	$(f_{Depth} + x) * m_n = 1.0 m_n$
Pinion dedendum	h_{F1}	$(f_{Depth} + f_{CL} - x) * m_n = 1.2 m_n$
Ring gear addendum	h_{K2}	$(f_{Depth} - x) * m_n = 1.0 m_n$
Ring gear dedendum	h_{F2}	$(f_{Depth} + f_{CL} + x) * m_n = 1.2 m_n$

Wanted are the design data of the pinion and ring gear blanks as well as the cutter specifications and the basic machine settings.

Calculation of Blank Data

Since the subject of this section is, as in the previous section ("Gear Mathematics for Bevel & Hypoid Gears," *Gear Technology*'s August 2015 issue), a spiral bevel gearset with parallel depth teeth and the same dimensions and tooth numbers, the blank dimensions in both cases are also identical. Tables 1 and 2 repeat the actual design data for the blanks of pinion and ring gear.

Table 1 Numerical ring gear blank specifications

Ring Gear - Blank Data			
Variable	**Explanation**	**Value**	**Dimension**
z_2	number of ring gear teeth	35	-
$RINR_2$	inner cone distance (along root line)	69.56	mm
$RAUR_2$	outer cone distance (along root line)	99.56	mm
$GATR_2 = \gamma_2$	pitch angle	69.62	°
$GAKR_2$	face angle	69.62	°
$GAFR_2$	root angle	69.62	°
$ZTKR_2$	pitch apex to crossing point	0.00	mm
$ZKKR_2$	face apex to crossing point	–4.27	mm
$ZFKR_2$	root apex to crossing point	5.12	mm
$DOMR_2 = m_{f2}$	face module	4.63	mm
HGER	whole depth of teeth	8.80	mm

Table 2 Numerical pinion blank specifications

Pinion - Blank Data			
Variable	Explanation	Value	Dimension
z_1	number of teeth pinion	13	-
$RINR_1$	inner cone distance (along root line)	58.42	mm
$RAUR_1$	outer cone distance (along root line)	88.42	mm
$GATR_1 = \gamma_1$	pitch angle	20.38	°
$GAKR_1$	face angle	20.38	°
$GAFR_1$	root angle	20.38	°
$ZTKR_1$	pitch apex to crossing point	0.00	mm
$ZKKR_1$	face apex to crossing point	–11.49	mm
$ZFKR_1$	root apex to crossing point	13.78	mm
$DOMR_1 = mf_1$	face module	4.63	mm
HGER	whole depth of teeth	8.80	mm

Calculation of the Cutter Head Geometry

It must first be mentioned that based on the continuous indexing, the relative cutting velocity of the blades is not oriented tangentially to the circumference of the cutter. Figure 1 shows a triangular vector graphic. While $R_{Wi\text{-}1}$ rotated counter-clockwise, the cutter roll circle rolls on a base circle. The tip of the cutter head vector moves therefore not from "A" to "B", but from "A" to "C". The relation between roll circle and base circle is equal to the relation of the number of cutter head blade groups to the number of generating gear teeth. The addition of the base circle radius and the radius of the roll circle amounts to the radial distance Krumme (Ref. 4) applied an unrolling of the arcs in order to determine the angle δ_W which is enclosed by the current cutter radius and the dashed drawn epicycloid. Here the infinitesimal observation shown at the top of Figure 1 is proposed, which confirms the result from Krumme. Subsequently, the blade offset angle can be calculated as follows:

$$\delta_W = \operatorname{asin}\{(d\varphi * R_M * \cos ß * Z_W/Z_E) / (d\varphi * R_W)\} \quad (1)$$

After canceling of $d\varphi$ and the substitution:

$$R_M * \cos ß / Z_E = m_n/2 \quad (2)$$

The result is the following formula:

$$\delta_W = \operatorname{asin}\{(m_n * Z_W) / (2 * R_W)\} = 22.73° \quad (3)$$

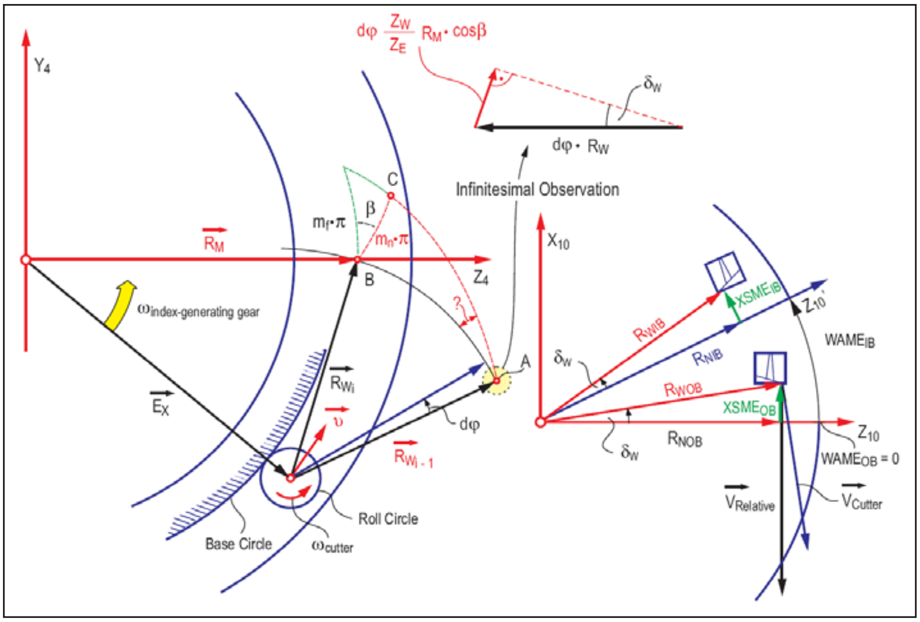

Figure 1 **The continuous working cutter head.**

This angle δ_W describes the precise relations of the relative cutting velocity direction for the applied nominal cutter radius between cutter blades and the plane generating gear. The relationships between cutter blades and real generating gears and real work gears will differ slightly from the calculated relative velocity direction δ_W. However, the value δ_W is well-suited for first estimations and for the design of cutter heads.

Based on the continuous indexing motion, not only an epicyclic flank form but also a spiral angle — which is increased by δ_W — is created. It now becomes interesting to introduce the blade offset angle δ_W in order to control the orientation of the technological blade angles similar to the single indexing method. The blade offset angle is used to calculate the corresponding blade offset values *XSME* (Fig. 1).

The nominal cutter radius of 88 mm was chosen about equal to the mean cone distance R_M. This seems to be a good choice for a bevel gearset manufactured in face hobbing, since the effective curvature radius of the epicycloid at the mean cone distance turns out smaller than the cutter radius. Although the nominal cutter radius is already given, the effective radii for the inside and outside blades of ring gear and pinion cutter must be calculated according to the chosen cutting method. Since the chosen method is Gleason TRI-AC, which uses equally the cutter circumference spaced inside and outside blades without profile shift ($x = 0$), the following graphics and calculations are applicable (Fig. 2).

Figure 2 shows the pinion cutter head (top) and the ring gear cutter head (bottom). The generating plane intersects the blades at the height of the calculation point. The generation of the correct tooth thickness (except the backlash) happens in case of equally spaced blades automatically. The blade tips protrude about their respective dedendum height (h_F) beyond the generating plane. This makes the blade contours in Figure 2 not exactly congruent, but by the backlash values different on the flanks and by the clearance values different at the roots. Just like in the previous section, as now with this second flank generating example, a conjugate mating pair should be achieved. For this purpose the backlash is set to zero for this calculation.

The following calculations are used to determine the required cutter head and blade parameters:

$$\boldsymbol{ALFW_1 = ALFW_2 = ALFW_3 = ALFW_4} = \alpha = 20.00° \quad (4)$$

The blade offset angle δ_W is depending on the individual gear design and is calculated as:

$$\delta_W = \arcsin((Z_W * m_n) / (2 * R_W)) = 22.73° \quad (5)$$

The normal radius R_N of the cutter head is the adjacent side to the angle δ_W in a rectangular triangle with R_W as hypotenuse:

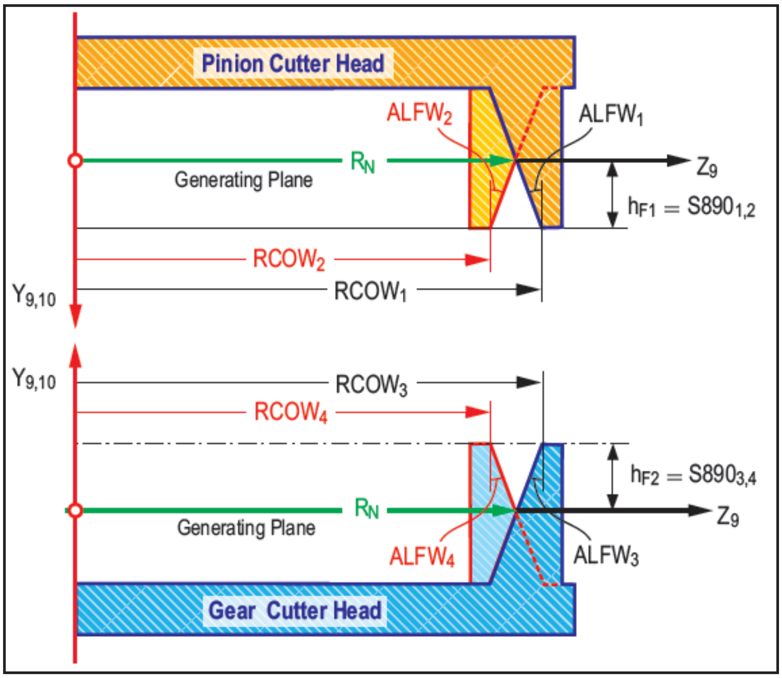

Figure 2 **Pinion and ring gear cutter geometry.**

$$R_N = R_W \cdot \cos\delta_W = 81.17\,\text{mm} \quad (6)$$

The calculation of the normal blade point radii is calculated (Fig. 2) (the module and the h_F values are equal to those in the previous section in the August 2015 issue):

$$\boldsymbol{RCOW_1} = R_N - SPLF/4 + h_{F1} \cdot \tan ALFW_1 = 82.92\,\text{mm} \quad (7)$$

$$\boldsymbol{RCOW_2} = R_N + SPLF/4 - h_{F1} \cdot \tan ALFW_2 = 79.42\,\text{mm} \quad (8)$$

$$\boldsymbol{RCOW_3} = R_N - SPLF/4 + h_{F2} \cdot \tan ALFW_3 = 82.92\,\text{mm} \quad (9)$$

$$\boldsymbol{RCOW_4} = R_N + SPLF/4 - h_{F2} \cdot \tan ALFW_4 = 79.42\,\text{mm} \quad (10)$$

The blade height above the face of the cutter head (distance from coordinate system 9 to blade tip) amounts to:

$$\boldsymbol{S890_1} = \boldsymbol{S890_2} = h_{F1} = 4.80\,\text{mm} \quad (11)$$

$$\boldsymbol{S890_3} = \boldsymbol{S890_4} = h_{F2} = 4.80\,\text{mm} \quad (12)$$

The blade offset is the opposite side of the angle δ_W in a rectangular triangle with R_W as hypotenuse:

$$\boldsymbol{XSME_1} = \boldsymbol{XSME_2} = +R_W \cdot \sin\delta_W = 34.00\,\text{mm} \quad (13)$$

$$\boldsymbol{XSME_3} = \boldsymbol{XSME_4} = -R_W \cdot \sin\delta_W = -34.00\,\text{mm} \quad (14)$$

The blade following angles *WAME* around the cutter head axis (Fig. 1) in case of equal blade spacing amount to:

$$\boldsymbol{WAME_1} = 180° / Z_W = 10.59° \quad (15)$$

$$\boldsymbol{WAME_2} = 0.00° \quad (16)$$

$$\boldsymbol{WAME_3} = -180° / Z_W = -10.59° \quad (17)$$

$$\boldsymbol{WAME_4} = 0.00° \quad (18)$$

All parameters printed in bold are required for the definition of the pinion and ring gear cutter heads. Those results are summarized in Table 3.

Calculation of Basic Settings for the Cutting Machine

The cutter head center in Figure 3 is placed in a position in order to generate the same spiral angle of 30°, which cannot be found in the extension of the flank line normal but along a straight line that is rotated clockwise about δ_W. The calculation of the basic settings for the present example are shown below. Those calculations are identical to the calculations in the previous section (August 2015 issue), *excepting the newly introduced angle* δ_W. The solution vector in this observation is the eccentricity vector E_X, which already contains several of the wanted machine settings.

The triangular vector of the ring gear generation:

$$\vec{E}_X = \vec{R}_M - \vec{R}_W \quad (19)$$

with:

$$\vec{R}_M = \{0., 0., R_M\} = \{0., 0., 86.34\} \quad (20)$$

$$\vec{R}_W = \{-R_W \cos(\beta - \delta_W), 0., R_W \sin(\beta - \delta_W)\} = \{-87.29, 0., 11.14\} \quad (21)$$

$$\text{resulting in: } \vec{E}_X = \{87.29, 0., 75.20\} \quad (22)$$

The following machine settings can be obtained from the E_X vector:

$$\text{Center roll position: } \boldsymbol{W450_{3,4}} = \arctan(E_{XX} / E_{XZ}) = 49.27° \quad (23)$$

$$\text{Radial distance: } \boldsymbol{TZMM_{3,4}} = \sqrt{E_{XX}^2 + E_{XZ}^2} = 115.22\,\text{mm} \quad (24)$$

$$\text{Sliding base: } \boldsymbol{TYMM_{3,4}} = E_{XY} = 0.00\,\text{mm} \quad (25)$$

Additional machine settings can be found from the graphical relationship in Figure 3:

$$\text{Machine root angle: } \boldsymbol{AWIM_{3,4}} = -90° - \gamma_2 = -159.62° \quad (26)$$

$$\text{Machine csenter to crossing point: } \boldsymbol{TZ2M_{3,4}} = 0.00\,\text{mm} \quad (27)$$

Table 3 Cutter head and blade specifications			
Cutter Head and Blade Data			
Variable	Explanation	Value	Dimension
$S890_{1,2}$	reference point to blade tip pinion	4.80	mm
$S890_{3,4}$	reference point to blade tip gear	4.80	mm
$WAME_1$	blade phase angle pinion convex	10.59	°
$WAME_2$	blade phase angle pinion concave	0.00	°
$WAME_3$	blade phase angle ring gear convex	–10.59	°
$WAME_4$	blade phase angle ring gear concave	0.00	°
$XSME_{1,2}$	blade offset in pinion cutter head	34.00	mm
$XSME_{3,4}$	blade offset in ring gear cutter head	–34.00	mm
$RCOW_1$	cutter point radius pinion inside blade	82.92	mm
$RCOW_2$	cutter point radius pinion outside blade	79.42	mm
$RCOW_3$	cutter point radius ring gear inside blade	82.92	mm
$RCOW_4$	cutter point radius ring gear outside blade	79.42	mm
$ALFW_1$	blade angle pinion inside blade	20.00	°
$ALFW_2$	blade angle pinion outside blade	20.00	°
$ALFW_3$	blade angle ring gear inside blade	20.00	°
$ALFW_4$	blade angle ring gear outside blade	20.00	°

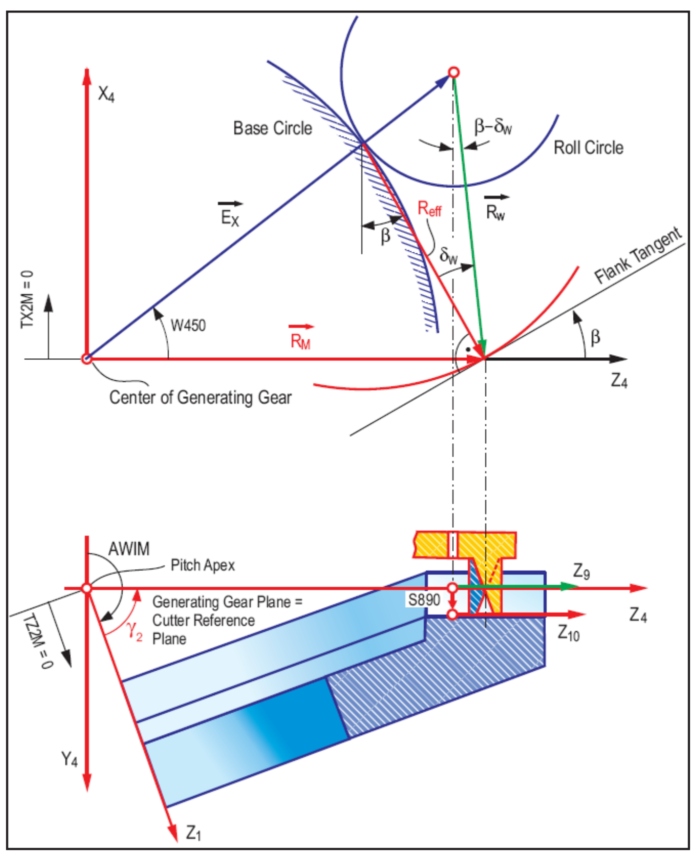

Figure 3 **Ring gear, basic machine model, upper graphic: → front view; lower graphic → top view.**

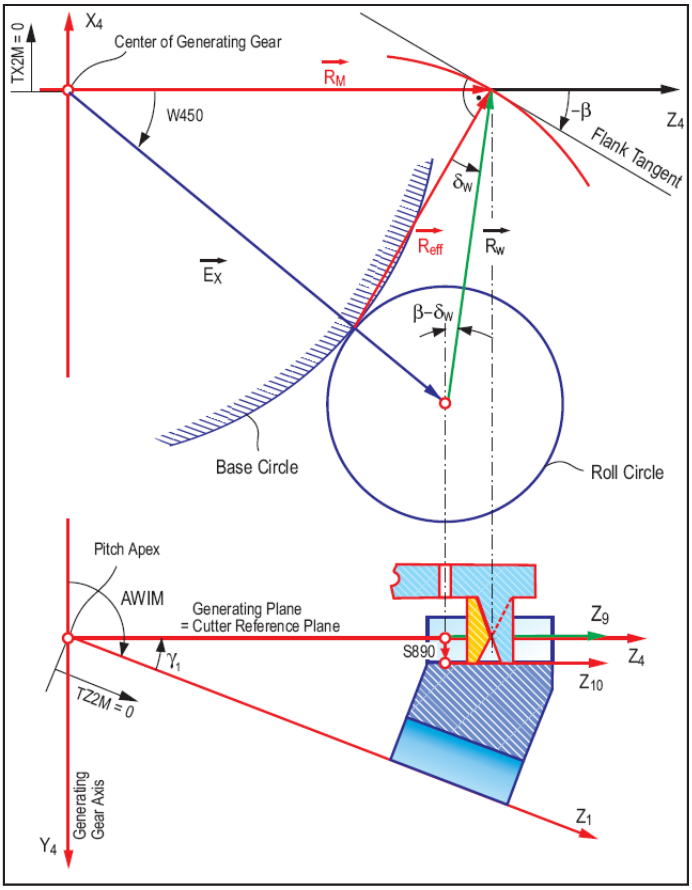

Figure 4 Pinion, basic machine model, upper graphic: → front view, lower graphic → top view.

$$\text{Offset in the machine: } \boldsymbol{TX2M_{3,4}} = 0.00\,\text{mm} \tag{28}$$

Further values such as cutter head tilt $\boldsymbol{WXMM_{3,4}}$ and tilt orientation $\boldsymbol{WYMM_{3,4}}$ are also zero in the observed conjugate design.

For the exact definition of the ring gear to be generated, the ratio of roll between generating gear and work gear as well as the indexing ratio between cutter head and work gear are still missing. From Equations 11 and 12 in Chapter 1 ("Basics of Gear Theory, Part 2," July 2015 *Gear Technology*) the ratio can be computed with:

$$\boldsymbol{UDIF_{3,4}} = \sin\gamma_2 = 0.937425 \tag{29}$$

The ratio of roll number requires at least a mantissa with 6 digits, since the influence onto the gear geometry is correspondingly sensitive. The indexing ratio is the number of work gear teeth divided by the number of cutter starts:

$$\boldsymbol{UTEI_{3,4}} = Z_2 / Z_W = 2.058824 \tag{30}$$

For the value of the indexing ratio, the input of at least 5 digits behind the decimal point is recommended.

The triangular vector of the pinion generation:

$$\text{With: } \vec{R}_W = \{R_W \cos(\beta - \delta_W), 0., R_W \sin(\beta - \delta_W)\} = \{87.29, 0., 11.14\} \tag{31}$$

$$\text{Resulting in: } \vec{E}_X = \{-87.29, 0., 75.20\} \tag{32}$$

The following machine settings can be obtained from the E_x vector:

Table 4 Geometrical and kinematical machine settings

Machine Basic Settings			
Variable	**Explanation**	**Value**	**Dimension**
$WXMM_{1,2}$	cutter head tilt pinion	0.00	°
$WXMM_{3,4}$	cutter head tilt ring gear	0.00	°
$WYMM_{1,2}$	swivel angle pinion	0.00	°
$WYMM_{3,4}$	swivel angle ring gear	0.00	°
$W450_{1,2}$	center roll position pinion	–49.26	°
$W450_{3,4}$	center roll position ring gear	–49.26	°
$TYMM_{1,2}$	sliding base position pinion	0.00	mm
$TYMM_{3,4}$	sliding base position ring gear	0.00	mm
$TZMM_{1,2}$	radial distance pinion	115.22	mm
TZMM34	radial distance ring gear	115.22	mm
$AWIM_{1,2}$	machine root angle pinion	–110.38	°
$AWIM_{3,4}$	machine root angle ring gear	–159.62	°
$TX2M_{1,2}$	pinion offset in the machine	0.00	mm
$TX2M_{3,4}$	ring gear offset in the machine	0.00	mm
$TZ2M_{1,2}$	machine center to crossing point pinion	0.00	mm
$TZ2M_{3,4}$	machine center to crossing point gear	0.00	mm
$UTEI_{1,2}$	indexing ratio of pinion cutting	0.764706	-
$UTEI_{3,4}$	indexing ratio of ring gear cutting	2.058824	-
$UDIF_{1,2}$	ratio of roll for pinion cutting	0.348187	-
$UDIF_{3,4}$	ratio of roll for ring gear cutting	0.937425	-

$$\text{Center of roll: } \boldsymbol{W450_{1,2}} = \arctan(E_{XX} / E_{XZ}) = -49.26° \tag{33}$$

$$\text{Radial distance: } \boldsymbol{TZMM_{1,2}} = \sqrt{E_{XX}{}^2 + E_{XZ}{}^2} = 115.22\,\text{mm} \tag{34}$$

$$\text{Sliding base: } \boldsymbol{TYMM_{1,2}} = E_{XY} = 0.00\,\text{mm} \tag{35}$$

Additional machine settings can be found from the graphical relationship in Figure 4:

$$\text{Machine root angle: } \boldsymbol{AWIM_{1,2}} = -90° - \gamma_1 = -110.38° \tag{36}$$

$$\text{Machine center to crossing point: } \boldsymbol{TZ2M_{1,2}} = 0.00\,\text{mm} \tag{37}$$

$$\text{Offset in the machine: } \boldsymbol{TX2M_{1,2}} = 0.00\,\text{mm} \tag{38}$$

Further values, such as cutter tilt $\boldsymbol{WXMM_{1,2}}$ and tilt orientation $\boldsymbol{WYMM_{1,2}}$ are also zero in the observed conjugate design. For the exact definition of the pinion to be generated, the ratio of roll between generating gear and work gear during the roll is still missing. From Equations 11 and 12 in Chapter 1 ("Basics of Gear Theory, Part 2," July 2015 *Gear Technology*) the ratio can be computed with:

$$\boldsymbol{UDIF_{1,2}} = \sin\gamma_1 = 0.348187 \tag{39}$$

$$\boldsymbol{UTEI_{1,2}} = Z_1 / Z_W = 0.764706 \tag{40}$$

All bold-printed values calculated in this section are input values for a bevel gear cutting simulation program whose functionality was discussed in the previous section (August 2015 issue). The machine settings of this section are summarizesd in Table 4.

Simulation of the Gear Cutting Process and Tooth Contact Analysis of the Face Hobbed Spiral Bevel Gearset Example

For the tooth contact analysis results of the gearset generated in a continuous cutting process, (face hobbing) applies basically the same as explained for the face milled example in the previous section (August 2015 issue). The Ease-Offs for coast and drive side are perfectly conjugate, the motion graphs are zero and the contact lines extend over the entire active flank area (Fig. 5). Also, in case of the face hobbed example, large unused stripes can be observed towards the root of the pinion. The explanations given in the previous section apply here as well; a positive profile shift $X_1 = 0.5$ would be sufficient to achieve a better and more effective profile contact ratio.

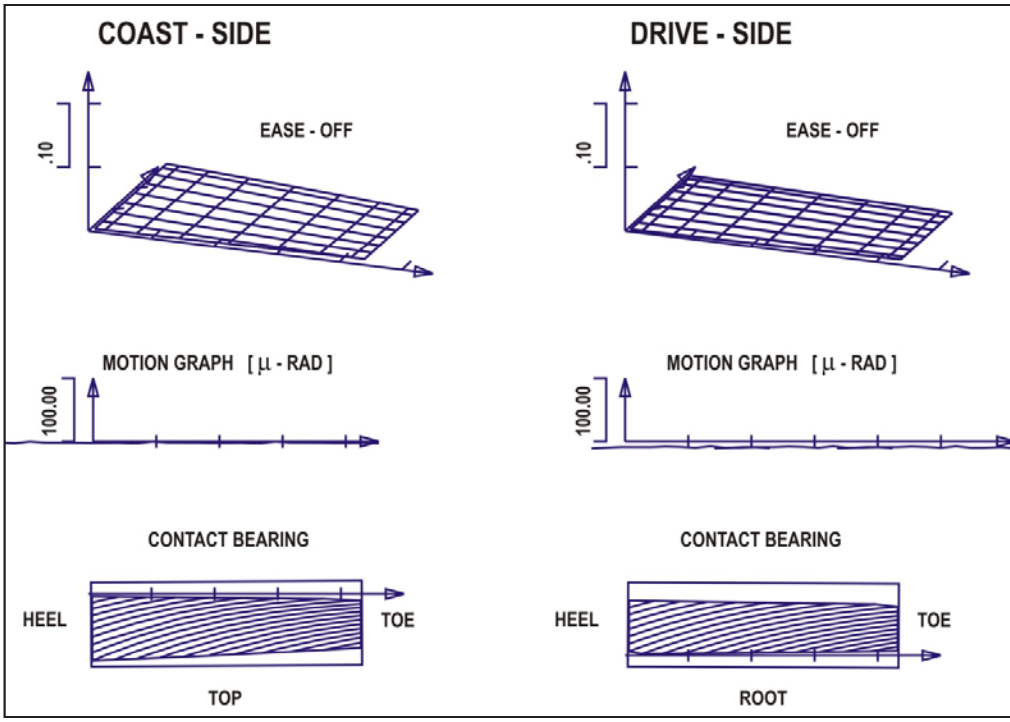

Figure 5 Graphical results of roll simulation (TCA) of a face hobbed gear pair.

References

1. Stadtfeld, H.J. *Handbook of Bevel and Hypoid Gears - Calculation, Manufacturing and Optimization,* Rochester Institute of Technology, Rochester, NY, March 1993.
2. Stadtfeld, H.J. "The Ultimate Motion Graph," *Journal of Mechanical Design*, Vol. 122, September 2000.
3. Weck, M., B. Neupert, H. Schriefer and H.J. Stadtfeld. "Das Lauf- und Beanspruchungsverhalten bogenverzahnter Kegelradgetriebe," *Reports of the 21st to 28th Annual Conference Gear and Transmission Research,* 1980 to 1987, WZL-RWTH Aachen.
4. Krumme, W. *Klingelnberg Spiralkegelraeder, Berechnung, Herstellung und Einbau,* Springer Publishing, Berlin/Heidelberg/New York, 1967.
5. Wildhaber, E. "Skew Hypoid Gears," *American Machinist,* 1946.

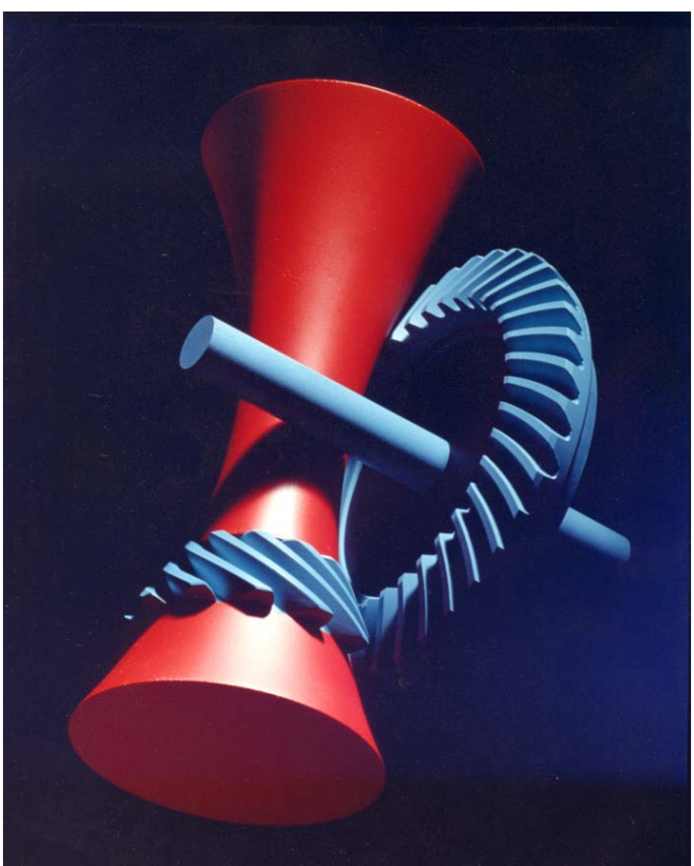

Figure 6 Hyperbolic pitch element of a gearset with hypoid offset (hypoid gears).

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.

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Gear Tooth Surface Roughness of Helical Gears Manufactured by a Form Milling Cutter

Mattias Svahn, Lars Vedmar, Carin Andersson

Manufacturing involute gears using form grinding or form milling wheels are beneficial to hobs in some special cases, such as small scale production and, the obvious, manufacture of internal gears. To manufacture involute gears correctly the form wheel must be purpose-designed, and in this paper the geometry of the form wheel is determined through inverse calculation. A mathematical model is presented where it is possible to determine the machined gear tooth surface in three dimensions, manufactured by this tool, taking the finite number of cutting edges into account. The model is validated by comparing calculated results with the observed results of a gear manufactured by an indexable insert milling cutter.

Introduction

The dominant and most cost-effective manufacturing method for large scale production of involute gears is hobbing. Nevertheless, form grinding wheels and form milling cutters can be beneficial compared to hobs in some special cases, viz. cheap tooling in rapid prototyping and small scale production, the ability to manufacture internal gears, gear integrated components can be machined complete in one machine and one set-up using multitasking CNC-machine and thereby reducing total lead time and cost. In addition, a new type of form milling cutter has been introduced to the market with indexable carbide inserts which prolong tool life and are capable of operating at higher cutting data, leading to higher productivity.

These tools are not universal, unlike true generating methods such as hobbing and shaping, and therefore must be matched to the gear to cut. When machining spur gears, one can choose from a selection of standard cutters for each module, where each cutter will, at the cost of small geometrical errors to the tooth form, cut a range of gear-tooth numbers. According to Dudley (Ref. 1), these cutters are sometimes used in practice to machine helical gears of small helical angles by matching the cutter to the virtual number of spur gear teeth. However, to machine helical gears correctly, the milling cutter must be purpose designed.

Previous work on machining helical profiles states two problems: 1) the direct problem — to determine the geometry of the manufactured helical profile given the tool geometry, and 2) the inverse problem — to determine the tool geometry that correctly machines the helical profile. One example of solving the direct problem in gear manufacturing is presented by Ishibashi et al. (Ref. 2), who used an element removal method to determine the manufactured gear tooth with given tool geometry. If interference occurred, corrections were made to the tool profile. To solve the inverse problem, the helical profile to machine and the kinematic relation between the workpiece and tool must be specified in advance. This is presented in previous work for helical drill flute machining using a CAD/CAM approach (Refs. 3–4), for helical gear manufacturing by Xiao et al. (Ref. 5) using a contact point method and by Häussler (Ref. 6) using differential geometry. These works derived the tool geometry that correctly machines the helical profile, but did not define the cutting edges to the tool. Thereby no consideration was made of the machined surface topography. Shih and Chen (Ref. 7) investigated form grinding of helical gears with flank form correction via modifications to the machine tool axis controls and by modification to the tool profile form, using B-splines.

This paper, conversely, focuses on the manufactured tooth surface topography machined by both form milling cutters and form grinding discs where the tool geometry is obtained through inverse calculation. Using a milling cutter, the gear tooth can be finished-cut or rough-cut. If finished-cut, the achieved tooth surface topography is of interest as to how the gear will perform in operation. If the gear is rough-cut instead, additional grinding stock will be left on the involute flank in the milling process to account for feed marks and possible manufacturing errors to be removed in a subsequent refining operation. If the machined surface can be predicted in advance, it opens up for optimization of the manufacturing process, such as minimizing the required amount of grinding stock and choosing process data. The machined tooth surface topography achieved after hobbing is presented by Vedmar (Ref. 8) using parametric differential functions for highest accuracy; this approach will also be used here. The optimal designs of form milling cutters and form grinding wheels are presented and the paper concludes with an experimental verification using a form milling

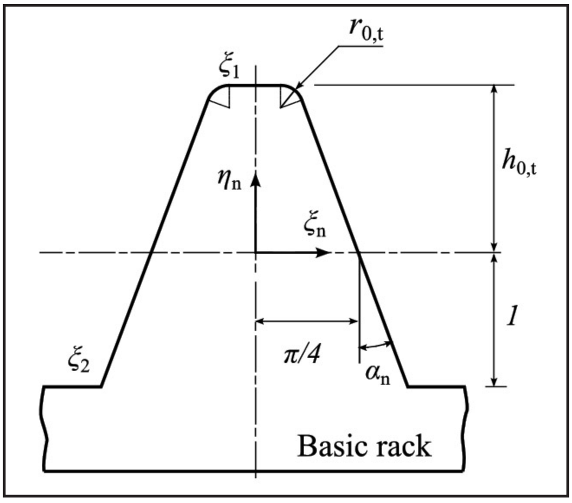

Figure 1 Basic rack.

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cutter with carbide inserts.

Geometry of the Tool

One of the intentions in this report is to determine the geometry of a disc-type form tool that should be able to manufacture an involute helical gear correctly. This is achieved through inverse calculation by invoking the geometry of the gear being manufctured and the kinetic relation between workpiece and tool. The geometry of an involute gear can be described through conjugate action with its basic member, in this case the basic rack. Presupposing a gear blank with the outer diameter $2R_{tip}$, and rolling the basic rack with the normal module m_n over the pitch circle $R_t = m_n z/2/cos\beta$, the complete gear tooth geometry is determined. The basic rack is described in the normal plane by Vedmar (Ref. 8) using the coordinates ξ_n and η_n (Fig 1). The design of basic racks is standardized for cylindrical gears; see, for example, DIN 867 (Ref. 9).

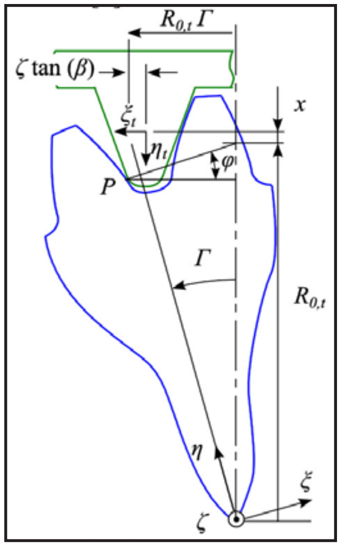

Figure 2 Helical gear conjugated to its basic rack.

The basic rack forms the gear tooth in the transverse plane; in this plane the coordinates describing the basic rack are:

$$\xi_t = \frac{\xi_n}{\cos\beta} \qquad \eta_t = \eta_n \tag{1}$$

In Figure 2 a helical gear is in contact with the basic rack at point P. At any contact, the rack and the gear have a common surface normal, and this normal must be directed through the pitch point. This gives the geometric relation:

$$\Gamma(\xi_n, \zeta) = \frac{-\dfrac{\xi_n}{\cos\beta} + (\eta_n - x)\cot\varphi + \zeta\tan\beta}{R_{0,t}} \tag{2}$$

and from the rack coordinates we have:

$$\cot\varphi = -\frac{d\eta_t}{d\xi_t} = -\frac{d\eta_n}{d\xi_n}\cos\beta \tag{3}$$

Here, the coordinate ξ_n is chosen as the parameter. By division with the normal module m_n the ideal gear tooth surface is described by the non-dimensional parameters:

$$r = \begin{pmatrix} \xi(\xi_n, \zeta) \\ \eta(\xi_n, \zeta) \\ \zeta \end{pmatrix} = \begin{pmatrix} R_{0,t}\sin(\Gamma) - \dfrac{\eta_n - x}{\sin(\varphi)}\cos(\Gamma - \varphi) \\ R_{0,t}\cos(\Gamma) + \dfrac{\eta_n - x}{\sin(\varphi)}\sin(\Gamma - \varphi) \\ \zeta \end{pmatrix} \tag{4}$$

where $\eta(\xi_n, 0)$ divides the tooth space into two equally symmetric parts. The normal to the gear tooth surface will be needed to determine the point of contact between the tool and the gear tooth surface, and to measure the distance from the ideal smooth tooth surface to the machined surface.

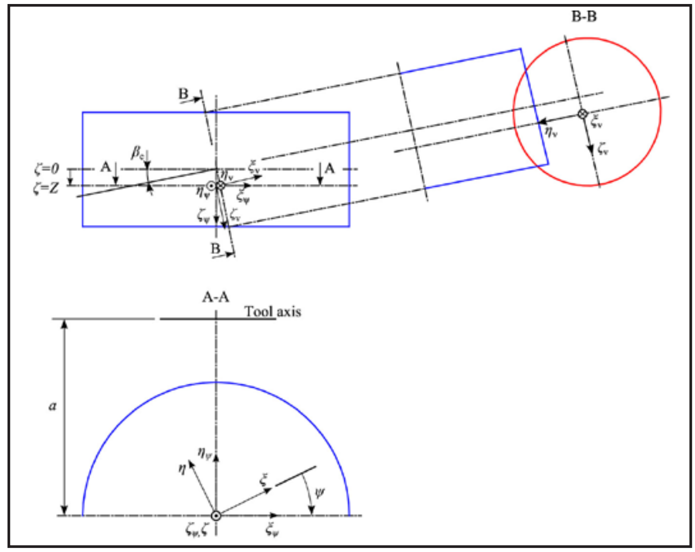

Figure 3 Form wheel and helical gear.

$$n = \begin{pmatrix} n_\xi \\ n_\eta \\ n_\zeta \end{pmatrix} = \frac{\partial r}{\partial \xi_n} \times \frac{\partial r}{\partial \zeta} = \begin{pmatrix} \dfrac{\partial \eta}{\partial \xi_n} \\ -\dfrac{\partial \xi}{\partial \xi_n} \\ \dfrac{\partial \xi}{\partial \xi_n}\dfrac{\partial \eta}{\partial \zeta} - \dfrac{\partial \eta}{\partial \xi_n}\dfrac{\partial \xi}{\partial \zeta} \end{pmatrix} \tag{5}$$

Now the complete geometry of the helical gear tooth is described in detail. To determine the profile of the form wheel tool, which should be able to manufacture this gear correctly, the tool axis is positioned at the center distance a, and at the angle β_c to the transverse plane of the gear (Fig. 3). If a point P_v on the tool is to generate a point P_g on the gear, these must be the same point in space — i.e. $P_v = P_g = P$. In addition, the normal of the gear tooth surface must coincide with the normal to the tool surface in such a point. The point P_g belongs to the gear tooth surface and is described in the gear coordinate system O_g by $r(\xi_n, \zeta)$, and the surface normal by $n(\xi_n, \zeta)$. The same point and surface normal is found in the tool coordinate system O_v by:

$$r_v = \begin{pmatrix} \xi_v \\ \eta_v \\ \zeta_v \end{pmatrix} = \begin{pmatrix} \xi_\psi\cos\beta_c - \zeta_\psi\sin\beta_c \\ a - \eta_\psi \\ \xi_\psi\sin\beta_c + \zeta_\psi\cos\beta_c \end{pmatrix}; \text{where} \begin{cases} \xi_\psi = \xi(\xi_n, 0)\cos\psi - \eta(\xi_n, 0)\sin\psi \\ \xi_\psi = \xi(\xi_n, 0)\sin\psi + \eta(\xi_n, 0)\cos\psi \\ \zeta_\psi = -Z \end{cases} \tag{6}$$

and

$$n_v = \begin{pmatrix} n_{v,\xi} \\ n_{v,\eta} \\ n_{v,\zeta} \end{pmatrix} = \begin{pmatrix} n_{\psi,\xi}\cos\beta_c - n_{\psi,\zeta}\sin\beta_c \\ -\eta_{\psi,n} \\ n_{\psi,\xi}\sin\beta_c + n_{\psi,\zeta}\cos\beta_c \end{pmatrix}; \text{where} \begin{cases} n_{\psi,\xi} = n_\xi(\xi_n, 0)\cos\psi - n_\eta(\xi_n, 0)\sin\psi \\ n_{\psi,\xi} = n_\xi(\xi_n, 0)\sin\psi + n_\eta(\xi_n, 0)\cos\psi \\ n_{\psi,\zeta} = n_\zeta \end{cases} \tag{7}$$

The gear tooth surface is here described in the transverse plane at $\zeta = 0$ in Equation 4. The gear profile at any other section, $\zeta \neq 0$, is found by pure rotation in O_g by the angle.

$$\psi(\zeta) = \zeta\frac{\sin\beta}{z/2} \tag{8}$$

In Figure 4 the disc tool is shown with the contact point P described in the coordinate system O_v. The tool is a rotational symmetric surface, thus the resultant of the components $n_{v,\eta}$ and $n_{v,\zeta}$ of the normal vector n_v must be directed through the rotational center. In conjunction with the point P:s coordinates, for which $tan\ \gamma = \zeta_{v,P}/\eta_{v,P}$, the relation is obtained:

$$\tan\gamma = \frac{\zeta_{v,P}}{\eta_{v,P}} = \frac{n_{v,\zeta}}{n_{v,\eta}} \tag{9}$$

Rewriting to suit numerical calculations this relation will be:

$$E(\xi_n,\zeta) = \eta_{v,P}(\xi_n,\zeta)\, n_{v,\zeta}(\xi_n,\zeta) - \zeta_{v,P}(\xi_n,\zeta)\, n_{v,\eta}(\xi_n,\zeta) = 0 \tag{10}$$

For given ξ_n, the corresponding ζ value is obtained by solving Equation 10; here, Newton-Raphson's method is used.

$$\zeta_{i+1} = \zeta_i - \frac{E(\xi_n,\zeta)}{\frac{\partial E(\xi_n,\zeta)}{\partial\zeta}} \tag{11}$$

$$\frac{\partial E(\xi_n,\zeta)}{\partial\zeta} = \frac{\partial\eta_{v,P}(\xi_n,\zeta)}{\partial\zeta} n_{v,\zeta}(\xi_n,\zeta) + \eta_{v,P}(\xi_n,\zeta)\frac{\partial n_{v,\zeta}(\xi_n,\zeta)}{\partial\zeta} - \frac{\partial\zeta_{v,P}(\xi_n,\zeta)}{\partial\zeta} n_{v,\eta}(\xi_n,\zeta) - \zeta_{v,P}(\xi_n,\zeta)\frac{\partial n_{v,\eta}(\xi_n,\zeta)}{\partial\zeta} \tag{12}$$

A convergent solution gives the point of contact. By varying ξ_n ($\xi_1 \le \xi_n \le \xi_2$) all contacts between the gear and the tool are found. The line of contact is found by connecting these points. The tool axis is perpendicular to the gear axis for spur gears, hence the line of contact will be a coplanar curve and located in the transverse plane of the gear. However, for helical gears, the contact line will be a three-dimensional curve. The contact lines are shown in Figure 5 for a disc tool with the outer radius R_c, for a spur gear and a helical gear, $\beta = 20°$.

With the contact line known, the cross-section of the form tool can be determined. The axial and radial coordinates of the disc cutter:

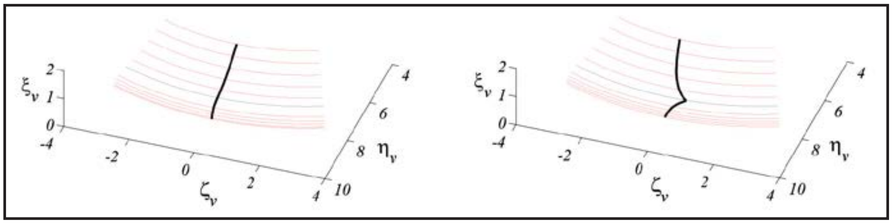

Figure 5 Contact lines.

$$\xi_c = \xi_v(\xi_n,\zeta) \qquad \eta_c = \sqrt{\eta_v^2 + \zeta_v^2} \tag{13}$$

are revolved around the rotational axis a rotation angle ϕ to describe the disc tool

$$\xi_\phi = \xi_c \qquad \eta_\phi = \eta_c \cos\phi \qquad \zeta_\phi = \eta_c \sin\phi \tag{14}$$

A form milling wheel possesses a finite number of cutting teeth n. To avoid interference in the milling process, these cutting teeth must be relieved to allow only the cutting face to remove material. The cutting faces are described by planes intersecting the cutting teeth, perpendicular to the rotational axis, where the cutting edges are the boundaries of these faces. To describe a milling cutter, the complete wheel is gashed to the desired number of cutting teeth. The i:th cutting plane is then described by:

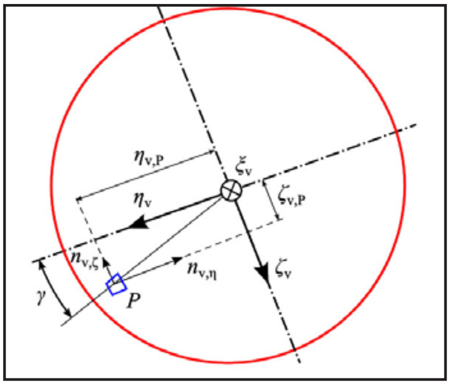

Figure 4 Form wheel.

$$\xi_{\phi,i} = \xi_c \qquad \eta_{\phi,i} = \eta_c \cos(\phi + (i-1)\Delta\phi) \qquad \zeta_{\phi,i} = \eta_c \sin(\phi + (i-1)\Delta\phi) \tag{15}$$

where $\Delta\phi = 2\pi/n$ is the equiangular increment between the cutting faces.

For a form grinding wheel, there are no defined cutting edges. The surface grinding the gear tooth is the outer boundary of the form wheel. The form grinding process can then be described by a form milling process with a sufficient number of cutting planes, so that the number of planes of the milling cutter does not influence the tooth surface topography. Then a milling cutter with many cutting faces is approximately equivalent to a grinding wheel.

Milling Process

The form wheel is now positioned to machine the gear. Like before, the tool is positioned at the center distance a and the rotational axis is set at the angle β_c to the transverse plane of the gear. It is not evident how the angle β_c should be chosen since the helical angle of a helical gear varies with the radius according to the relation $r_i\, cot\ \beta_i = \text{constant}$. It is here assumed that the angle β_c coincides with the helical angle β of the gear at the pitch radius R_t. The form wheel can be positioned at another angle $\beta_c \ne \beta$, as long as the angle β_c corresponds to a radius on the gear tooth. However, the geometry of the form wheel must be determined at the same angle β_c as previously to machine the helical profile correctly.

The form wheel is rotated with the angular velocity ω_c to machine the gear here in the negative ϕ direction. Climb milling is achieved by moving the gear blank the distance $Z = -\ S_0\phi/(2\pi)$ at the angular displacement of ϕ, where $S = S_0 m_n$ is the feed rate in distance-per-revolution. To achieve conventional milling, the feed is in the reversed direction, i.e. —$Z = S_0\phi/(2\pi)$.

Here the center of the cutting plane $i = 1$, ($\xi_{\phi,1} = 0$, $\eta_{\phi,1} = \eta_c$) is assumed to be located so it coincides with the center point of the gear ($\xi = \zeta = 0$ and $Z = 0$). In the mathematical model, the form wheel is now rotated backwards and the gear blank moves the distance Z and rotates $\psi(Z)$ so that the form wheel is outside the range of the gear blank. The form wheel then starts to machine the gear blank over the whole width. That means as no radial feed is present, the form wheel starts to machine the gear at full depth.

As the gear blank is fed the distance Z, the coordinates of the i:th cutting edge of the form wheel can be determined in the transverse plane of the gear. Simultaneously and continuously, the gear is rotated the angle $\psi(Z)$. The i:th cutting edge can then be represented in a coordinate system that coincides with that of the gear.

Table 1 Numerical example	
Gear	
Number of teeth	$z = 27$
Normal module	$m_n = 5\,mm$
Normal pressure angle	$\alpha_n = 20°$
Tip radius	$R_{0,tip} = z/2/\cos\beta + x + 1$
Helical angle	$\beta = 25.8°$
Addendum	$h_{0,t} = h_t/m_n = 1.25$
Addendum correction	$x = -0.1$
Rack fillet radius	$r_{0,t} = r_t/m_n = 0.2$
Form Cutter	
Number of cutting teeth	$n = 7$
Feed per revolution	$S_0 = S/m_n = 2.1/5 = 0.42$

$$r_{Si} = \begin{pmatrix} \xi_{Si}(\xi_{n,c},\phi) \\ \eta_{Si}(\xi_{n,c},\phi) \\ \zeta_{Si}(\xi_{n,c},\phi) \end{pmatrix} = \begin{pmatrix} \zeta_\psi \cos\psi + \eta_\psi \sin\psi \\ -\xi_\psi \sin\psi + \eta_\psi \cos\psi \\ \zeta_\psi + Z \end{pmatrix}; \text{where} \begin{cases} \xi_\psi = \xi_{\phi,i}\cos\beta_c + \zeta_{\phi,i}\sin\beta_c \\ \eta_\psi = a - \eta_{\phi,i} \\ \zeta_\psi = -\xi_{\phi,i}\sin\beta_c + \zeta_{\phi,i}\cos\beta_c \end{cases} \quad (16)$$

The Machined Surface

The machined tooth surface, that is, the surface after all material is removed, is now to be determined. By using a milling cutter with finite number of cutting teeth n that is fed by the feed rate S_0, the machined surface will deviate from the ideal smooth geometry. The distance $h_0 = h/m_n$ between these two surfaces is measured in the normal direction from the ideal tooth surface to the machined surface. From a specific point on the gear tooth, the distance h_0 to the i:th cutting edge is found:

$$r_{Si}(\xi_{n,c},\phi) = r(\xi_n,\zeta) - h_0 \frac{n(\xi_n,\zeta)}{|n|} \quad (17)$$

where $r(\xi_n,\zeta)$ is the coordinate of the ideal tooth surface and $n(\xi_n,\zeta)$ is the normal to this surface. The distance h_0 is measured in the normal direction from the ideal tooth surface and, in this formulation, measured positive in the direction into the gear blank material. In component form Equation 17 is expressed as:

$$\begin{aligned} f_\xi(\xi_{n,c},\phi,h_0) &= \xi_{Si}(\xi_{n,c},\phi) + h_0 \frac{n_\xi(\xi_n,\zeta)}{|n|} - \xi(\xi_n,\zeta) = 0 \\ f_\eta(\xi_{n,c},\phi,h_0) &= \eta_{Si}(\xi_{n,c},\phi) + h_0 \frac{n_\eta(\xi_n,\zeta)}{|n|} - \eta(\xi_n,\zeta) = 0 \\ f_\zeta(\xi_{n,c},\phi,h_0) &= \zeta_{Si}(\xi_{n,c},\phi) + h_0 \frac{n_\zeta(\xi_n,\zeta)}{|n|} - \zeta(\xi_n,\zeta) = 0 \end{aligned} \quad (18)$$

This set of equations contains three unknowns, namely, $\xi_{n,c}$, ϕ and h_0. To find a solution, Newton-Raphson's method is employed. In matrix form, a solution is found by:

$$\begin{pmatrix} \xi_{n,c,k+1} \\ \phi_{k+1} \\ h_{0,k+1} \end{pmatrix} = \begin{pmatrix} \xi_{n,c,k} \\ \phi_k \\ h_{0,k} \end{pmatrix} - M^{-1} \begin{pmatrix} f_\xi(\xi_{n,c,k},\phi_k,h_{0,k}) \\ f_\eta(\xi_{n,c,k},\phi_k,h_{0,k}) \\ f_\zeta(\xi_{n,c,k},\phi_k,h_{0,k}) \end{pmatrix} \quad (19)$$

where

$$M = \begin{pmatrix} \frac{\partial f_\xi}{\partial \xi_{n,c}} & \frac{\partial f_\xi}{\partial \phi} & \frac{\partial f_\xi}{\partial h_0} \\ \frac{\partial f_\eta}{\partial \xi_{n,c}} & \frac{\partial f_\eta}{\partial \phi} & \frac{\partial f_\eta}{\partial h_0} \\ \frac{\partial f_\zeta}{\partial \xi_{n,c}} & \frac{\partial f_\zeta}{\partial \phi} & \frac{\partial f_\zeta}{\partial h_0} \end{pmatrix} = \begin{pmatrix} \frac{\partial \xi_{Si}}{\partial \xi_{n,c}} & \frac{\partial \xi_{Si}}{\partial \phi} & \frac{\partial n_\xi}{\partial n} \\ \frac{\partial \eta_{Si}}{\partial \xi_{n,c}} & \frac{\partial \eta_{Si}}{\partial \phi} & \frac{\partial n_\eta}{\partial n} \\ \frac{\partial \zeta_{Si}}{\partial \xi_{n,c}} & \frac{\partial \zeta_{Si}}{\partial \phi} & \frac{\partial n_\xi}{\partial n} \end{pmatrix} \quad (20)$$

Reaching a convergent solution the distance from the ideal surface to the surface machined by the i:th cutting edge is known.

Table 2 Radial run-out of tooth tips							
Cutting tooth number	1	2	3	4	5	6	7
Radial run-out [mm]	51.958	51.946	51.969	51.982	51.975	51.961	51.956
Deviation [μm]	-24	-36	-13	0	-7	-21	-26

To find the finished machined surface, the surface after all material to be removed is cut, the maximum h_0 of all n cutting edges is to be found.

$$h_0(\xi_n,\zeta) = \max(h_0(\xi_{n,c},\phi,i)) \quad (21)$$

In the machining process, all cutting teeth do not have the possibility to machine the surface at all positions. To make the calculations faster, only the cutting teeth facing the gear blank need to be considered.

Numerical Example and Validation

Table 1 shows the specifications of the gear and the milling cutter used in this example. The geometry of the milling cutter used in the simulation software is based on the mathematical model, whereas the indexable milling cutter used in experiments is determined using the software *PTM/GH–Precision Tool Manufacturing/Gear Hob.*

To verify the model, an actual gear is cut using an indexable insert milling cutter in a Höfler HF600. Before machining, the milling cutter was control measured for radial run-out at tooth tips. These values are given in Table 2, showing the maximum deviation of 36 μm between the cutting teeth. This run-out error is too large for the calculated results from the simulation model to agree with the observed machined surface topography. Thus, deviations must be considered in the model. To account for both axial and radial deviations, Δa_i and Δr_i, of the i:th cutting tooth, Equation 15 is modified accordingly:

$$\begin{aligned} \xi_{\phi,i} &= \xi_c + \Delta a_i \\ \eta_{\phi,i} &= (\eta_c + \Delta r_i)\cos(\phi + (i-1)\Delta\phi) \\ \zeta_{\phi,i} &= (\eta_c + \Delta r_i)\sin(\phi + (i-1)\Delta\phi) \end{aligned} \quad (22)$$

To compare the machined surface with the computed tooth surface from the simulation model, one tooth of the gear was cut

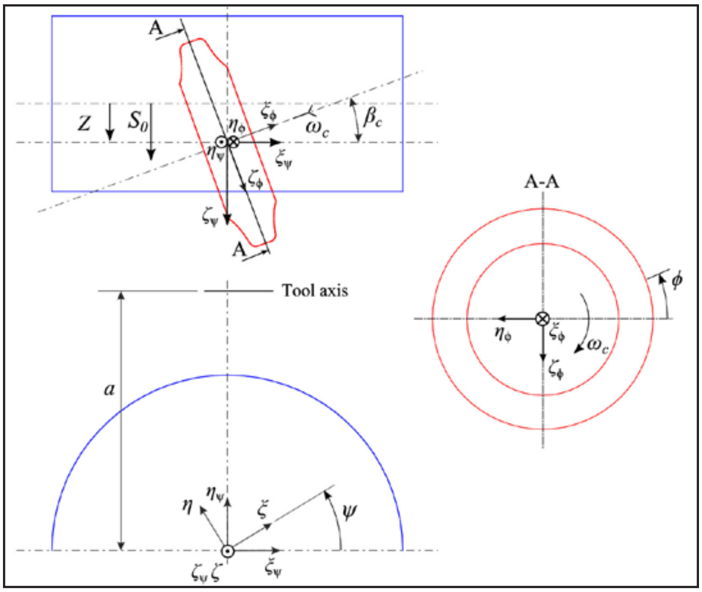

Figure 6 Form wheel machines helical gear.

out and a width of approximately 10 mm was scanned using a computer controlled optical microscope, Alicona Infinite Focus. The magnification used on the optical microscope was 20×, with a vertical resolution (height) of 25 *nm* and a lateral resolution (in-plane) of 3 µm.

The same area was calculated using the simulation model and the results are presented in Figure 7. In these figures, measurements along the three lines over the width are extracted, i.e. — lines a, b and c. The roughness profiles for these three lines are presented in Figure 8. The feed rate was set to $S = 2.1\ mm/rev$ in the axial direction of the gear, and the milling cutter having $n = 7$ cutting teeth. Thus, the distance between the feed ridges of the feed marks should be approximately $s = S/n/\cos\beta = 2.1\ \text{mm}/7/\cos 25.8° \approx 0.33\ \text{mm}$. This is not the case in the results shown in Figure 8. Although all cutting teeth remove material in the milling process, the finished gear tooth is actually formed by only one cutting tooth due to the radial run-out error of the cutter, i.e. $s = S/\cos\beta = 2.1\ \text{mm}/\cos 25.8° \approx 2.33\ \text{mm}$.

Conclusion

This paper presents a mathematical model for determining the tooth surface topography machined by a form wheel, i.e. for both form grinding wheels and form milling cutters. The geometry of the form wheel is determined through inverse calculation and the form wheel is able to manufacture helical gears correctly. Due to the finite number of cutting teeth of the milling cutter, the cut surface will deviate from the ideal smooth tooth surface. With this model the machine surface is predicted. To be able to predict the machined tooth surface topography is of great industrial interest as it opens up the manufacturing process for optimizations such as choosing process data and the required amount of grinding stock. In the prescribed mathematical model, the machined surface in both the fillet and involute region is determined.

The model is validated by milling a helical gear using an indexable insert milling cutter. This type of cutter could cause positional errors of the cutting teeth that are not present for conventional high speed steel milling cutters; such errors are axial and radial positional errors. The mathematical model is modified to account for these types of positional errors to the cutting teeth. Measurements of the positional errors of the used indexable milling cutter were used as input to the simulation model, resulting in very good agreement of the surface roughness achieved of the milled gear and the calculated roughness from the mathematical model.

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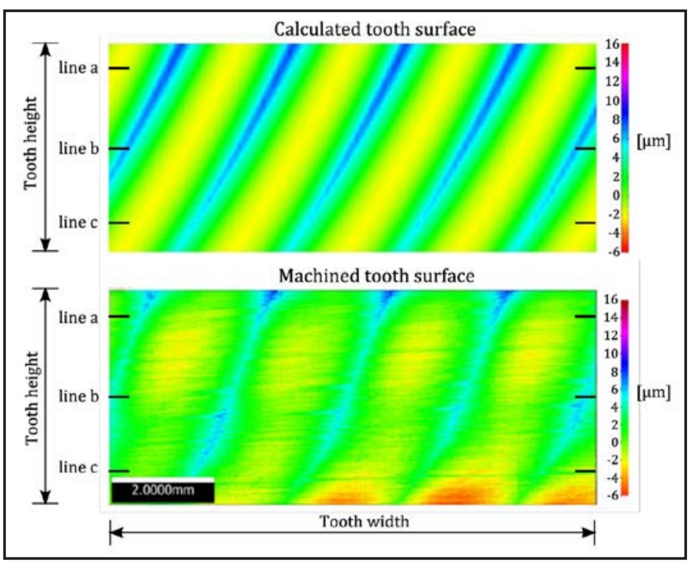

Figure 7 Comparison between the calculated and the machined tooth surface topography.

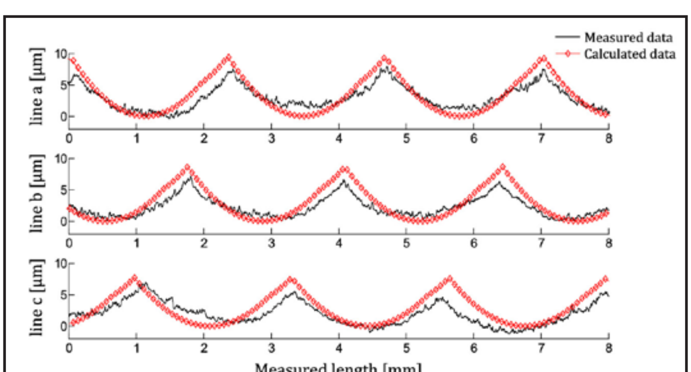

Figure 8 Comparison of line measurements between the calculated and the machined.

References

1. Dudley, D.W. *Gear Handbook, The design, Manufacture, and Application of Gears*, 1962, Mc Graw-Hill.
2. Ishibashi, A. and H. Yoshino. "Design and Manufacture of Gear Cutting Tools and Gears with an Arbitrary profile," *JSME International Journal*, 30, 1987, 1159-1166.
3. Ehrmann, K.F. "Grinding wheel profile definition for the manufacture of drill flutes," *Annals of the CIRP*. 39, 1990, 153-156.
4. Steth, D.S and S. Malkin. "CAD/CAM for Geometry and Process Analysis of Helical Groove Machining," *CIRP*, 39, 1990, 129-132.
5. Xiao, D.C. and D. Lee. "A Contact Point Method for the Design of Form Cutters for Helical Gears," *ASME Journal of Engineering for Industry*, 1994, 116, 387-391.
6. Häussler, U. "Generalistere Berechnung räumlicher Verzahnungen und ihre Anwendung auf Wälzfräserherstellung und Wälzfräsen," (In German), Ph. D. thesis, 1999, Universität Stuttgart.
7. Shih, Y-P and S-D Chen. "Free-Form Flank Correction in Helical Gear Grinding Using a Five-Axis Computer Numerical Control Gear Profile Grinding Machine," *ASME Journal of Manufacturing Science and Engineering*, 2012, 134, 041006-1– 041006-13.
8. Vedmar, L. "A Parametric Analysis of the Gear Surface Roughness after Hobbing," *ASME Journal of Mechanical Design*, 132, 2010, 111004-1–111004-8.
9. DIN 867 (1986). Basic Rack Tooth Profiles for involute teeth of Cylindrical Gear for General Engineering and Heavy Engineering.

Carin Andersson is a Professor at the Division of Production and Materials in the Department of Mechanical Engineering, Lund University, Sweden.

Mattias Svahn is a Ph. D student at the Division of Machine Elements in the Department of Mechanical Engineering, Lund University, Sweden.

Lars Vedmar is an Associate Professor at the Division of Machine Elements in the Department of Mechanical Engineering, Lund University, Sweden.

Local Simulation of the Specific Material Removal Rate for Generating Gear Grinding

Christian Brecher, Fritz Klocke, Markus Brumm, Florian Hübner

Generating gear grinding is one of the most important finishing processes for small and medium-sized gears, its process design often determined by practical knowledge. Therefore a manufacturing simulation with the capability to calculate key values for the process—such as the specific material removal rate—is developed here. Indeed, this paper presents first results of a model for a local analysis of the value. Additionally, an empirical formula—based on a multiple regression model for a global value describing the process—is provided.

Introduction

The hard fine finishing process is generally the last step in the manufacture of cylindrical gears. The most established processes are the generating gear grinding and discontinuous profile grinding (Ref. 1). Similar to conventional grinding processes—e.g., external cylindrical grinding or surface grinding—the process design for grinding tooth flanks is based on characteristic values that can be determined for a particular process due to its geometrical conditions. Among these characteristic values are the volume of cut material V'_w, the un-deformed chip thickness h_{cu} and the specific material removal rate Q'_w (Refs 2–3).

Figure 1 shows the processes of surface-peripheral-traverse grinding, profile gear grinding and generating gear grinding. While the contact between tool and workpiece is considered constant for one stroke with the conventional grinding process of surface-peripheral-traverse grinding and profile gear grinding, the contact varies for generating gear grinding.

For conventional fine finishing processes, these values can be calculated analytically from geometrical and kinematic data with little effort (Ref. 4). Calculating these characteristic values for gear grinding processes is significantly more elaborate and has not to date been standardized (Refs. 2–3; 5). This is due to the significantly more complex geometry of tool and gear for both continuous generating gear grinding as well as discontinuous profile grinding. For generating gear grinding, the calculation is made particularly difficult by the more complex kinematic relations. At this writing, there is no standardized calculating methodology to generate characteristic values for continuous generating gear grinding, nor for discontinuous profile grinding, on which basis the grinding process can be designed (Refs. 2-3 and 6).

State of the Art

Gear grinding processes are among the kinematically and geometrically most complex grinding processes, with high requirements for accuracy in dimension as well as in parts' properties of the surface zone (Refs. 1, (6–7). Therefore, designing the processes poses a considerable challenge; generally, the design process is supported by using characteristic values, since a design based entirely on empirical studies is time- and cost-consuming. Characteristic values are generated in order to determine cause-and-effect relationships of a characteristic function that do not depend on the chosen grinding process. In this way different processes and their conduct can be compared to one another (Ref. 7) and an optimal manufacturing strategy for a specific part can be chosen. One of these characteristic values is the specific material removal rate Q'_w, which cannot be determined metrologically. This value can be represented by models or determined indirectly by analyzing empirically determined correlations to measurable characteristics or damages (e.g. grinding burns) of the part (Refs. 2–3). This characteristic value is explained and defined in the following sections—initially for conventional grinding processes and subsequently for gear grinding processes as well.

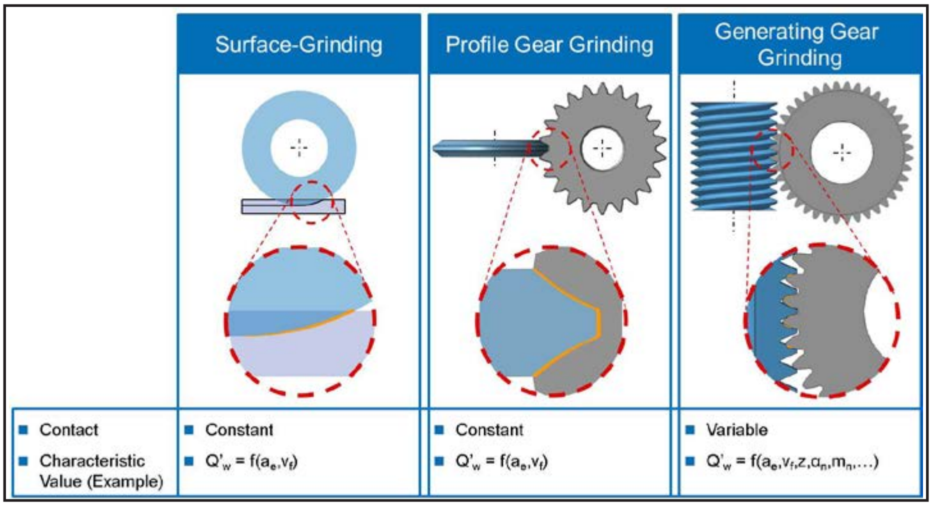

Figure 1 Comparison of conventional grinding processes with gear grinding processes

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Specific Material Removal Rate for Conventional Grinding Processes

As the part geometry and process kinematics are easy to follow, surface-peripheral-traverse grinding is chosen as an example for calculating the specific material removal rate for conventional grinding processes. The process is applied for grinding large surfaces and its schematic is depicted in Figure 2. The grinding wheel is advanced radially along the feed

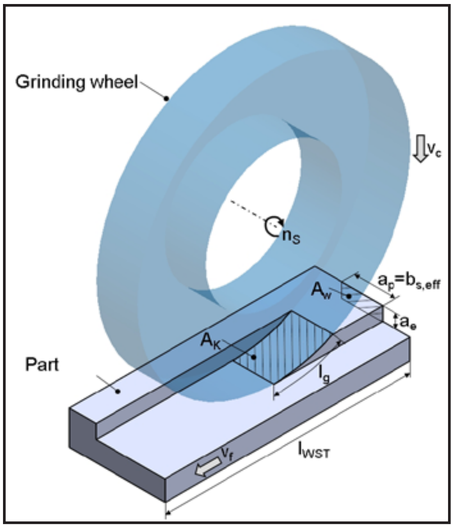

Figure 2 Characteristic values for surface-peripheral-traverse-grinding (7), (3)

a_e and perpendicularly to the worktable in order to grind the desired stock.

The tool is typically fed axially by the contact width a_p outside the part. The contact width correlates to the effective grinding wheel width $b_{s,eff}$ due to the process. Generally the worktable with the clamped part is moved with the feed velocity v_f. The grinding wheel rotates with the set number of rotations n_s — which results in circumferential velocity v_s. Should v_s and v_f align, the process is referred to as climb grinding; if not, as conventional grinding (Ref. 7).

According to Equation 1, the material removal rate can be referenced to the grinding wheel width in order to compare different processes with respect to their productivity (Refs. 6-7).

$$Q'_w = a_e \cdot v_f \tag{1}$$

Besides geometrical characteristic values, grinding forces, power and energy can be consulted for assessing and designing grinding processes (Ref. 7). Werner (Refs. 8–9) developed an initial calculating methodology for determining the normal force F'_n that is based both on the presented characteristic value chip cross-section A_{cu} and the kinematic number of cutting edges n_{kin} (Eq. 2).

$$F'_n = \int_0^{l_k} k \cdot A_{cu}(l) \cdot N_{kin}(l) dl \tag{2}$$

In addition to forces, grinding temperatures play a decisive role in assessing and designing processes. Until now, few studies have been conducted that examined the change and influence of grinding temperatures. However, the influence on the structure by inducing energy into the part is an essential quality criterion for functionality (Ref. 10).

According to Stimpel (Ref. 3), it applies to all presented characteristic values for ideal contacts, and that the contact geometry:

- shows stationary behavior during the course of the process (except for start and end of contact)
- can be considered constant for the contact width a_p of the tool

Specific Material Removal Rate for Gear Grinding Processes

Generally, characteristic values used for gear grinding processes mainly conform to characteristic values of conventional grinding processes. Calculating the characteristic values is based on similar formulas which parameters are adapted to the particular process by geometrical considerations (Refs. 2-3, 6). This approximation, however, is hardly — or not at all — admissible, due to the presented requirements of a contact geometry that is temporally stationary, as well as constant along the contact width.

For continuous generating gear grinding, a temporally constant behavior of the contact between tool and part is not a factor. Defining the contact width a_p proves to be more of a challenge for continuous generating gear grinding than for conventional grinding or profile gear grinding processes, since, due to the complex kinematics, the contacting conditions cannot be described in simple terms (Ref. 6). As the resulting velocities of the profile are neither local nor temporally constant, nor can the contact width be constant (Ref. 11). Theoretically, the contact width conforms with the width of the chip cross-section, which is perpendicular to the resulting feed velocity (Refs. 4 and 6). The contact width, however, is temporally inconstant, thus the characteristic values for these processes vary along the profile and the tooth width.

Despite these restraints, formulas have been developed based on the algorithms of conventional grinding processes, with which help the specific material removal rate for continuous generating gear grinding can be calculated in approximation (Refs. 2 and 6). Based on geometric considerations, Türich generated formulas for an average specific material removal rate (Eq. 3) as well as for calculating Q'_w locally (Eq. 4).

$$Q'_{w,m} = \frac{v_f \cdot z \cdot a_e \cdot \sin\alpha_n \cdot \cos\beta \cdot (d_a^2 - d_{Ff}^2)}{2 \cdot d_b \cdot \cos\gamma_0} \tag{3}$$

$$Q'_{w,lok} = \frac{2 \cdot v_f \cdot \pi \cdot \Delta s \cdot \sin\alpha_n \cdot \cos\beta \cdot \sqrt{d_f^2 - d_b^2}}{d_0 \cdot \sqrt{1 - \left(\frac{2 \cdot \Delta s \cdot \sin\alpha_n - d_0}{d_0}\right)^2}} \tag{4}$$

Further algorithms for calculating the specific material removal rate have been established by Schriefer (Ref. 6). A general formula (Eq. 5), as well as an extended formula (Eq. 6), have been developed. Both approaches — according to Schriefer and Türich — provide significantly differing results. For all presented approaches, the scope of application is limited, as the formulas have not been explicitly defined for an application to gear flanks; root grinding processes are not covered.

$$Q'_w = a_w \cdot v_{res} \cdot \sin\alpha_n \tag{5}$$

$$Q'_w = a_w \cdot \sin\alpha_n \cdot \frac{f_{res} \cdot n_0}{\cos\beta} \tag{6}$$

The desired stock — as well as the motion of the tool for generating the final slot geometry — has been greatly simplified for the presented formulas. Furthermore, a limited regard to influences on the specific material removal rate has been paid in these approaches. Therefore no standardized approach for determining one or more characteristic values for the process design of continuous generating gear grinding and discontinuous profile grinding yet exists.

Objective and Approach

The state of the art shows that significant differences exist between determining characteristic values for conventional grinding processes and gear grinding processes. And yet the characteristic values — as established for conventional grinding processes — are transferred to generating and profile gear grinding. But in many cases this is not effective, so that designing the process has required expert knowledge or an extensive series of tests (Refs. 1-3; 6).

For the approaches presented here, the stock conditions are especially simplified and the contact conditions for continuous generating gear grinding are disregarded. It therefore becomes an objective of the project to develop a methodology that allows determining characteristic values for generating and profile grinding processes. This methodology is to lead to a manageable formula that supports the design process that can provide results to a machine operator within a reasonably short time. Furthermore, a local analysis of the characteristic values has to be developed for a detailed analysis of critical process designs.

In the following sections, a local approach for calculating the specific material removal rate is presented. This model analyzes a single process in detail for optimizing the process design; thus the local approach needs a time-consuming simulation of the process.

An approach for determining the specific material removal rate based on a regression model follows. This approach provides an empirical formula without having to use the previous local approach, making it much easier to handle and less time-consuming.

Local Approach for Calculating the Specific Material Removal Rate for Generating Gear Grinding

From the state of the art it can be gathered that a number of approaches exist to define and determine characteristic values for processes. Existing approaches for defining characteristic values for continuous generation grinding use approximate calculations that rely on kinematic and geometrical values. Schriefer approximated the generating gear grinding process by using a limited number of external grinding processes and derives characteristic values (Refs. 5-6). Türich and Stimpel calculate a theoretical contacting plane and derive approximation formulas as well (Eqs. 29), only in part regarding the conditions of engagement (Eqs. 2-3). Therefore these calculation approaches cannot be applied without restrictions.

Stimpel developed a first numerical approach that allows the calculation of characteristic values for generating gear grinding (Ref. 3). However, it calls for a detailed knowledge of the algorithms or the possession of the developed program. Therefore this approach is not generally available.

In recent years, a model has been developed with the assistance of the WZL Gear Research Circle and the DFG (German Research Foundation) in order to analyze gear grinding processes (Ref. 11). An overview of this model is presented (Fig. 3). For this model, the used tool and the given slot geometry is approximated by a triangular mesh. Both geometries can be calculated by the program or imported from external data.

Additionally, the machine kinematics can be represented by choosing the respective process — generating or profile gear grinding — beforehand. For internally calculating tool, part and kinematics, the geometrical values for unambiguously describing the parts are necessary. Furthermore, the grinding stock, cutting velocity and axial feeds can be specified. By using this approach, it is possible to set up a batch operation in order to calculate a high number of different gear designs automatically, with the help of the model within a short period of time.

As a result, the model provides the finished part as well as the contacting geometry for the rolling positions during the process (Fig. 4). Ideal contacting geometries are calculated that are analyzed for discrete rolling positions. With that, it is possible to reproduce root finishing alongside flank finishing. From the calculated contacting geometry, process parameters such as the characteristic value of the local contracting volume $V_{k,lok}$ or the contact thickness $h_{k,lok}$ can be

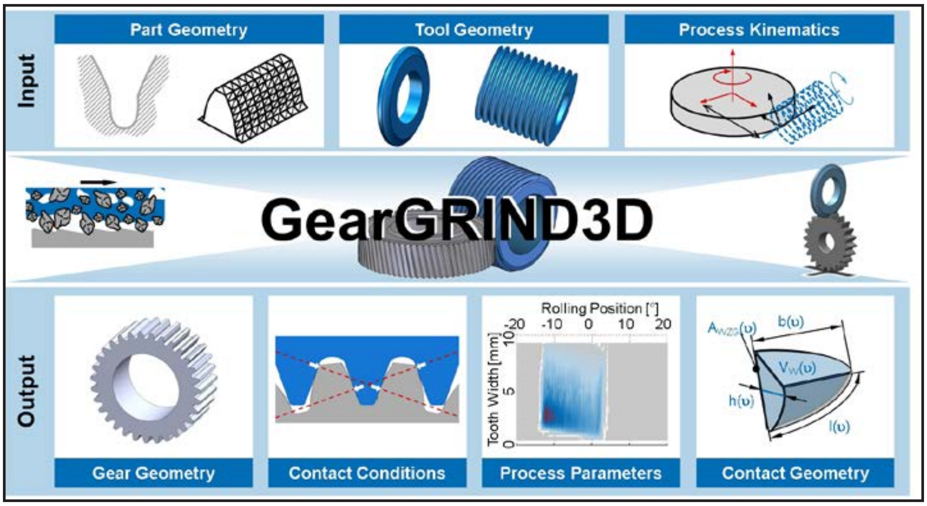

Figure 3 Scope of the manufacturing analysis GearGRIND3D

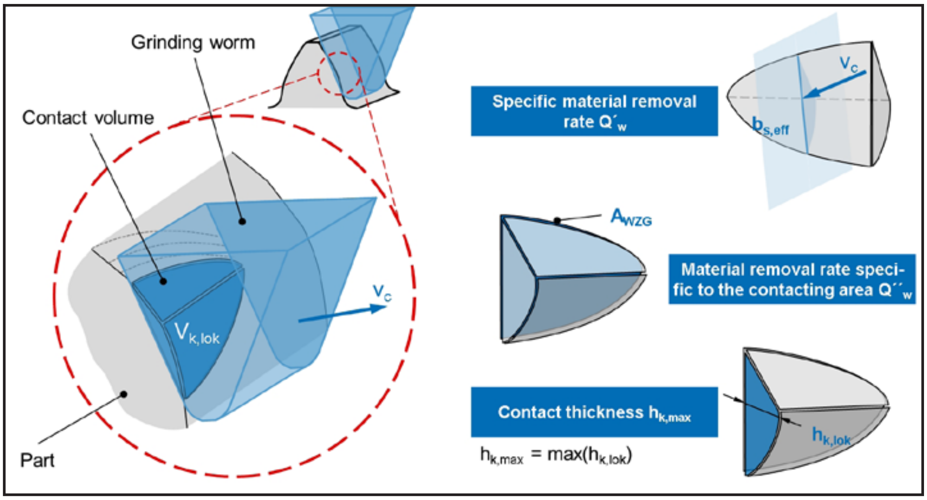

Figure 4 Numerical approach for a local calculation of the specific material removal rate

determined.

Besides the specific material removal rate Q'_w, Salje (Ref. 4) defines the material removal rate specific to the contacting area Q''_w as a further characteristic value, since the contacting conditions between grinding tool and workpiece cannot be considered constant, as is the case for the generating gear grinding process. For this the volume is divided by a common contacting plane between tool and part. This value can be calculated by means of the presented methodology as well (Fig. 4, center/right). The following discussion is limited to the calculation of the specific material removal rate Q'_w:

Since besides the contacting geometry, the direction of the resulting cutting velocity is known for any rolling position, the contacting geometry can be characterized by a plane that is perpendicular to the cutting velocity in the center of gravity of the contacting volume (Fig. 4, top/right). Thus the effective width of the grinding worm $b_{s,eff}$ can be determined for a discrete rolling position of a continuous grinding process. If the volume $V_{k,lok}$ is divided by the effective width of the grinding wheel and the increment of time Δt, in which the contacting volume is cut, the specific material removal rate according to Equation 7 results. The increment of time Δt is determined by the given increment of the rolling angle Δv, the ratio i, as well as the number of revolutions of the tool n_0, (Eq. 8).

$$Q'_{w,lok} = \frac{V_k}{b_{s,eff} \cdot \Delta t} \tag{7}$$

$$\Delta t = \frac{\Delta \nu \cdot i}{2 \cdot \pi \cdot n_0} \tag{8}$$

Thus the specific material removal rate can be calculated locally on the flank for discrete rolling positions with the help of the methodology implemented in *GearGrind3D*.

An example for the displayed results is given (Fig. 5). On the left, the data of the grinding worm and process parameters are listed. For this calculation, a helical gear applied in a wind turbine serves as example.

The vertical axis represents the axial position of the grinding worm, the horizontal axis the position on the profile of the workpiece. The leading flank is ground from the tip to the root, the other flank in the opposite direction.

For the leading flank, the maximum value of the specific material removal rate occurs at the tip during the beginning of the process. The maximum for the entire grinding process occurs at the trailing flank, also at the beginning of the process at the tip of the simulated tooth. In general, Q'_w has higher values at the beginning of the process and during the manufacturing of the tip. The reason for this is found in the curvature of the involute that leads to a higher removed volume at the tip.

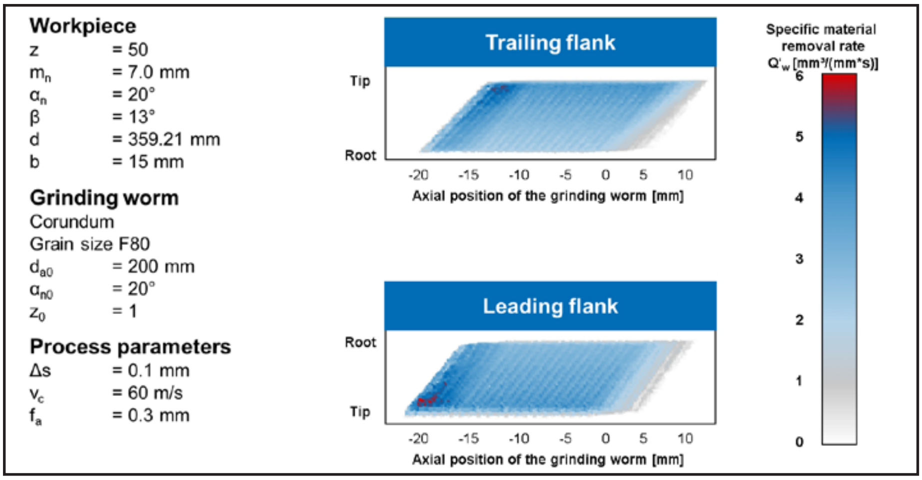

Figure 5 Local calculation of the specific material removal rate

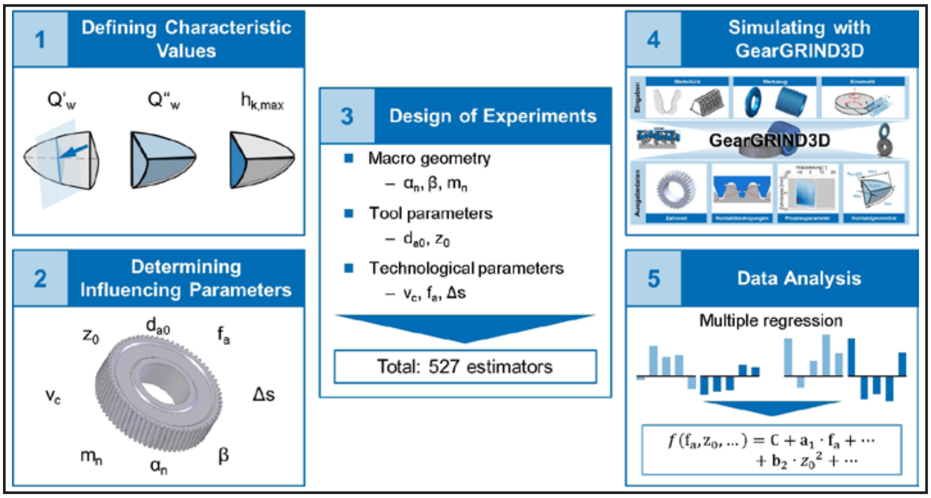

Figure 6 Empirical approach for a global calculation of the specific material removal rate

Global Approach for Calculating Specific Material Removal Rate for Generating Gear Grinding

Besides the presented simulative approach, a preferably simple formula for determining a mean specific material removal rate is to be developed. It can be determined with the help of the previously presented approach, since, due to its flexibility, it can be applied to any generating and profile grinding process. So it is possible to calculate a multitude of variants with the help of the numeric approach *GearGrind3D*. Based on the results, a regression model can be generated that provides a formula for the desired characteristic value.

Figure 6 shows the necessary steps for setting up an empirical model. As a first step, the general calculation of the specific material removal rate is defined. Subsequently, relevant influencing parameters are determined. This occurs on the basis of previous formulas and regarding the process parameters of generating gear grinding. According to Schriefer, Türich and Stimpel, influencing factors on the characteristic value of the specific material removal rate Q'_w are the grinding worm outside diameter d_{a0}, number of threads z_0, cutting velocity v_c, axial feed f_a, grinding stock Δs, pressure angle α_n, normal module m_n and helix angle β.

Subsequently, by using a DoE approach, the number of variants that must be examined is reduced, allowing the simulation to be conducted within a reasonable time. If the investigations had been conducted on a full factorial scale, it would result in $4^8 = 65{,}536$ estimators; the effort would lead to a calculating time of several weeks. On the other hand, parameters cannot be varied independently from one another, since not every combination leads to an operational gear. Variations of the module m_n, pressure angle α_n and helix angle β make the automated design of trial gears especially more difficult. Therefore, as a first step the process parameters f_a, Δs and v_c — as well as the tool parameters d_{a0} and z_0 — are varied with the help of a D-optimal design of experiment (Fig. 6, left). By applying a D-optimal design of experiment the number of estimators can be reduced from $4^5 = 1{,}024$ to 31 trials. In order to vary m_n, β and α_n as well, the design of experiment is applied to 17 example gears. It is therefore assured that all examined 527 trial points are operational gears for which the specific material removal rate Q'_w can be calculated by means of the model presented previously in this paper.

The evaluation of the data occurs with the help of a multiple regression analysis. For this, a quadratic transfer function for the individual factors is determined in advance; thus the regression analysis is conducted by means of a quadratic basic function. Interdependencies between the individual factors are left disregarded in order to limit the complexity of the approach. The result is a lower coefficient of determination R^2 as well as the prognosis factor Q^2 than if the interdependencies had been considered. A lower coefficient of determination signifies a higher variance of the values — or that there is no relation between the values. A Q^2 that is too small means that the model will change for new tests. An able model for describing the influences is given — if Q^2 as well as R^2 are above 0.9.

By introducing a transformation of the target values, R^2 and Q^2 can be further improved. This so-called Power or Box Cox Transformation is an established instrument and generally used for taking the logarithm of wear characteristics. The results of the regression analysis are Equations 9 and 10:

$$Q'_w = e^x \tag{9}$$

$$x = 10.278 + 0.275 - z_0 - 0.006 \cdot d_{a0} + 0.018 \cdot v_c - 12.275 \cdot f_a^2 + 12.058 \cdot f_a - 22.5 \cdot \pi \cdot \Delta s^2 + 12.371 \cdot \Delta s - 0.069 \cdot m_n^2 + 0.911 \cdot m_n + 0.001 \cdot \beta^2 - 0.003 \cdot \beta \tag{10}$$

The coefficient of determination R^2 for the conducted analyses is 0.934. The value for Q^2 is with 0.933 on the same level. Thus, a good correlation between the formula and the simulation can be determined for examining the specific material removal rate.

Summary and Outlook

Due to the limited number of scientific investigations, gear grinding processes are currently designed and optimized based on experience. For this reason, the transferal of characteristic values — as they have been applied to conventional grinding processes for many years onto continuous generation grinding and discontinuous profile grinding — is pursued. However, no standardized methods or formulas which are able to calculate these characteristic values exist. Therefore, investigations have been initiated aimed at developing a standardized methodology for determining the specific material removal rate Q'_w. This methodology is supposed to calculate Q'_w locally, as well as by means of a manageable formula."

The specific material removal rate is calculated locally with the help of the process simulation program *GearGRIND3D* for continuous generating gear grinding. Subsequently a design of experiments is defined and a regression model is set up for the characteristic value. Finally, the formula for attaining the specific material removal rate Q'_w is presented. The quality of the presented formula regarding the spread of the values and the robustness regarding additional testing points is good.

Since the presented characteristic values cannot be recorded metrologically, the determined values and formulas must be verified by other means. Furthermore, there are no boundary values that would lead to part, tool or machine damage if transgressed. These values can be determined by grinding trials, for instance, in which an occurrence of grinding burns is the matter of investigation. If an influence of the surface zone due to process conditions should appear for a certain amount of the characteristic value, a boundary value can be found that would lead to flank damage if transgressed. Another option for defining boundary values is the investigation of the grinding worm's wear that has to be correlated to the determined characteristic value.

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References

1. Bausch, T. Innovative Zahnradfertigung: Verfahren und Maschinen zur kostengünstigen Herstellung von Stirnrädern mit hoher Qualität. 3rd ed.: Expert Verlag, Renningen-Malmsheim, 2006.
2. Türich, A. Werkzeugprofilgenerierung beim Wälzschleifen. Dissertation, Universität Hannover, 2002.
3. Stimpel, F. Technologische Kenngrößen für das kontinuierliche Wälzschleifen von Evolventenverzahnungen. Dissertation, Universität Hannover, 2009.
4. Saljé, E.: Begriffe der Schleif- und Konditioniertechnik: Vulkan-Verl, Essen, 1991.
5. Meijboom, L. Erhöhung der Wirtschaftlichkeit beim Wälzschleifen durch verbesserung des Zerspanvorganges. Dissertation, RWTH Aachen, 1979.
6. Schriefer, H; W. Thyssen, W. Wirz, G. Scacchi and M. Gretler. Reishauer Wälzschleifen: Eigenverlag Reishauer, Walisellen, 2008.
7. Klocke, F. and W. König. *Fertigungsverfahren 2: Schleifen, Honen, Läppen*, Springer, Berlin, New York, 2005.
8. Werner, G. "Kinematik und Mechanik des Schleifprozesses," Dissertation, RWTH Aachen, 1971.
9. Werner, G. Konzept und Technologische Grundlagen zur Adaptiven Prozessoptimierung des Außenrundschleifens, Habilitation, RWTH Aachen, 1973.
10. Fritz Klocke; Markus Brumm; Jan Reimann, 2013: Modeling of Surface Zone Influences in Generating Gear Grinding. Procedia CIRP 8(2013):21–26.
11. Brecher C; Brumm M; Hübner F: Manufacturing simulation for generating-gear grinding of large-module gears. In: Höhn B. International Conference on Gears: Europe invites the world. VDI Berichte 2199, VDI Verlag, München, 2013.

Prof. Dr.-Ing. Christian Brecher has since 2004 served as Ordinary Professor for Machine Tools at the Laboratory for Machine Tools and Production Engineering (WZL) of the RWTH Aachen, as well as director of the Department for Production Machines at the Fraunhofer Institute for Production Technology IPT. Upon receipt of his engineering degree he began his career as a research assistant and later as team leader in the Department for Machine Investigation and Evaluation at the WZL. From 1999–2001 Brecher worked as a senior engineer with responsibility for machine tools and director (2001–2003) for development and construction at the DS Technologie Werkzeugmaschinenbau GmbH, Mönchengladbach. Brecher has received numerous honors and awards, the Springorum Commemorative Coin and the Borchers Medal of the RWTH Aachen among them.

Markus Brumm, a RWTH graduate with a degree in mechanical engineering, began his career in 2005 as a research assistant in gear investigation at the Laboratory for Machine Tools and Production Engineering (WZL) of the RWTH Aachen. He subsequently became that group's team leader in 2010.

Prof. Dr.-Ing. Dr.-Ing. E.h. h.c. Dr. h.c. Fritz Klocke studied manufacturing engineering at the TU Berlin, was a research fellow there at the Institute for Machine Tools and manufacturing Technology until 1981, and then as head engineer until 1984, receiving his engineering doctorate in 1982. Klocke worked in industry from 1984 until 1994 at Ernst Winter & Sohn in Hamburg. On January 1, 1995 he was called to the RWTH Aachen as Professor of Manufacturing Engineering Technology and has since then been Chair of Manufacturing Technology, co-director of the WZL Laboratory for Machine Tools & Production Engineering at the RWTH Aachen and head of the Fraunhofer Institute for Production Technology IPT in Aachen. Klocke was awarded the Otto-Kienzle Memorial Coin in 1985 by the Manufacturing Engineering University Group. The title,"Dr.-Ing. E.H," was bestowed upon Klocke by the University of Hannover in 2006 for his outstanding achievements in science, his efforts in the industrial implementation of a broad range of manufacturing techniques, and for his commitment to numerous scientific committees. The title "Dr. h. c." was awarded him in 2009 by the University of Thessaloniki and in 2010 by Keio University in Tokio for his achievements in production science, his engagement in international cooperation, and his benefits as a teacher and supervising tutor of student engineers.

Dipl.-Ing. Florian Hübner has since 2012 served at Aachen University of Technology, Germany as Team Leader and Research Assistant—Group Gear Design and Manufacturing Simulation—focusing on manufacturing simulation for generating gear grinding. Previously—i.e., 2005 – 2012—Hübner devoted his attention to the study of mechanical engineering, also at Aachen.

ITAMCO

CELEBRATES ITS 60TH ANNIVERSARY

Founded in 1955, the Northern Indiana-based manufacturer has grown from a single 4000 sq. ft. plant to two facilities that encompass a total of 485,000 sq. ft. ITAMCO delivers precision-machined components to OEMs worldwide in mining, off-highway vehicles, marine, and aviation. The company specializes in precision gear manufacturing and their capabilities range from mining gearing to production runs of CBN-ground transmission gears.

"I believe the success of ITAMCO is due to uncommon perseverance and a true spirit of innovation. Embracing technology while holding to solid and proven principles has given us an atmosphere that is creative, yet built upon a foundation that can be relied upon," said Gary Neidig, president of ITAMCO.

ITAMCO's spirit of innovation makes the company adaptable to the technology that enables it to provide better quality, better lead times and better pricing. In 2011, the company installed one of the largest gear grinders on the market in its climate-controlled grinding facility. The Niles ZP 40 gear grinder has taken hours out of the grinding process, saving production costs for ITAMCO's customers. ITAMCO produces gears that meet the standards of their most demanding customers, including NASA and the Department of Defense. The grinding area with nine CNC-grinding machines is just one component of a company that includes precision machining tools, large press parts, 60-foot high bays, and 80-ton cranes.

"We're one of the few US facilities that can do it all, from cutting to finishing," said David Neidig, business development for ITAMCO.

While acknowledging the company will always offer subtractive manufacturing like gear grinding, ITAMCO believes that additive manufacturing, often called 3D printing, is the future of their business. To that end, they have developed an additive manufacturing strategy titled: "Strategic Technology Initiative for Additive Manufacturing." Their drive to bring additive manufacturing to their plant floor was enhanced when they won a funding award from the National Additive Manufacturing Innovation Institute in July 2015. ITAMCO's IT development team will be working with Johnson & Johnson, the University of Pittsburgh and the University of Notre Dame to develop an additive manufacturing CAD application.

In addition, the technology team at ITAMCO has released over 65 mobile device apps for machinists; designed and markets iBlue, the first industrial Bluetooth transmitter; and developed an award-winning application Google Glass application for machine tools.

ITAMCO is a privately held company that has maintained the principles of its founders, Donald and Noble Neidig.

"My uncle and father believed in a cause larger than themselves, and were willing to make sacrifices in order to build for the future of others," said Gary Neidig.

In 2013, ITAMCO partnered with the Plymouth, Indiana School Corporation and Ivy Tech Community College to launch the ITAMCO Manufacturing Center on the Plymouth High School's campus. Students enrolled in the Precision Tool Manufacturing course at the center will receive credits toward high school graduation and college credits from Ivy Tech. ITAMCO donated $100,000 worth of equipment in addition to technical assistance for the program and recently donated an additional CNC precision machine tool to the large inventory of precision machining tools. ITAMCO's goal is to help combat the skills gap in the technical trades by being an active participant developing the local workforce.

ITAMCO is also preserving natural habitats for future generations. The company has turned 750 acres of forest next to one of their facilities into a nature preserve. They also began the Woodland Restoration Project in 1997 with the planting of 300 acres of hardwood forest.

Martin Boelter

APPOINTED CHIEF OPERATING OFFICER OF KLINGELNBERG

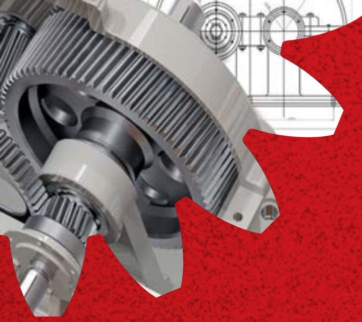
Klingelnberg recently announced the appointment of **Martin Boelter** as chief operating officer. Boelter will assume responsibility for the production and logistics divisions within the Klingelnberg Group. A four-member senior management team is now once again at the helm at Klingelnberg.

In his capacity as the new chief operating officer (COO), Boelter is now part of the senior management in the group, together with Jan Klingelnberg (CEO), Christoph Küster (CFO) and Dr. Hartmuth Müller (CTO). Due to this reinforcement, resources are now available to accelerate growth on the international stage and further strengthen its market position.

"We are delighted to have gained a highly experienced manager in Martin Boelter," said Jan Klingelnberg, who also serves as chairman of the supervisory board at Klingelnberg GmbH. "His knowledge and experience will drive our company's continued growth."

Boelter, who studied mechanical engineering at Munich Technical University, was most recently employed as COO in the Sterling SIHI Group.

"I like having the opportunity to build upon a valuable his-



tory," Boelter said. "What I find particularly exciting about Klingelnberg is the combination of corporate values that are part of the daily experience: The stability of a traditional family-run business with deep roots in the region on the one hand – and the international presence and dynamism of a global market leader on the other. Against this backdrop, I am enthusiastically looking forward to working together with the company to meet the challenges of the coming years."

In his previous management positions, Boelter always attached great importance to working closely with employees in all growth and development processes to ensure that everyone could find ways to achieve success together.

Governor Charles D. Baker

VISITS ADCOLE TO RECOGNIZE PRODUCT DEVELOPMENT

Governor **Charles D. Baker, Jr.** recently visited Adcole Corporation and was accompanied by Jay Ash, secretary of housing and economic development for the commonwealth and several team members. The purpose of his visit was to recognize Adcole's product development and commitment to quality which formed the basis of a state grant for $95,000 to train local employees in more efficient and LEAN manufacturing techniques.

Founded in 1957, Adcole manufactures precision measuring machines that are used worldwide by leading automobile manufacturers and suppliers for controlling the quality of camshafts, crankshafts, and pistons. Adcole gages let manufacturers achieve the submicron tolerances required to meet the growing demand for high performance, fuel efficient engines.

Adcole's Aerospace division manufactures sun sensors that provide mission-critical positioning and control. In addition to being deployed on every GPS satellite orbiting the earth, they stabilized and guided NASA's New Horizons spacecraft which recently passed within 8,000 miles of Pluto's surface after a 9-1/2 year, 3 billion mile journey.

"We are proud of our industrious people, history, and leading edge products and believe Adcole Corporation represents the very best of Massachusetts high-tech manufacturers," said J. Brooks Reece, president of Adcole.

Mahr Federal

ACQUIRES ENGINEERING SYNTHESIS DESIGN INC.

The Mahr Group recently acquired Engineering Synthesis Design Inc. (ESDI), headquartered in Tucson, AZ.

Over the past two years, Mahr has completed product developments of the MarSurf WM 100, MarSurf LD130/260 Aspheric and MarForm MFU 200 Aspheric 3D solutions for measuring contour and roughness parameters on aspheres and freeform optics. Furthermore, a prototype of the Tilted-Wave-Interferometer MarSurf TWI 60 was presented to the market. The MarSurf TWI 60 was one of the three finalists of SPIE's (International Society for Optics and Photonics) 2015 PRISM Awards, and winner of the German AMA (Association for Sensors and Measurement) 2014 Innovation award.

The Mahr Group has now broadened its technology base by adding the leading-edge surface and wavefront metrology from ESDI. According to Mahr, ESDI – with its Dimetior and Intellium product series – complements the Mahr product portfolio.

Hans Grass

APPOINTED VICE PRESIDENT OF STAR SU'S MACHINE TOOL DIVISION

Star SU recently appointed **Hans Grass** as vice president of its machine tool division.

Grass brings 43 years of experience in the machine tool industry, including thirty nine years in management roles – most recently (for 10 years) as vice president of engineering for Bourn & Koch. Prior to his last position, Grass managed the machine tool operation of American Pfauter as vice president of engineering and manufacturing for 18 years after various management positions at Pfauter. After the Gleason/Pfauter merger in 1996, starting in 2000, Grass managed the sales and service of all European Gleason operations for the North American market as director of distributed products. Grass also served as president for Index Corporation USA from 1998 and 2000.

Grass has gained in-depth expertise of gear manufacturing machine tools as well as milling, turning, grinding and other machine tools.

Grass was educated in Germany with a Pfauter machine tool apprenticeship program, complemented by three years of engineering studies.

Darian Ditzler

RETURNS TO LUREN PRECISION AS MACHINE TOOL SALES MANAGER

Luren Precision Chicago recently announced the return of **Darian Ditzler** as their machine tool sales manager.

Ditzler started with Luren Precision in January of 2011 and has coordinated and attended many different trade shows, including multiple IMTS and Gear Expo shows. As a good ambassador for Luren in the U.S. market, Ditzler has visited many factories in the U.S., Canada and abroad, presenting Luren's products and understanding how Luren can continue to grow in North America.

Solar Atmospheres

INSTALLS RECORD-SIZED HORIZONTAL HIGH VACUUM FURNACE

Solar Atmospheres of Western Pennsylvania recently announced the installation of the largest horizontal high vacuum furnace ever constructed at their Hermitage facility. The furnace will be engineered and manufactured by its sister company, Solar Manufacturing, Inc.

The entire investment for Solar Atmospheres will be on the order of $8 million, including the cost of this large furnace, a new 20,000 square foot building addition and utilities to operate this large system.

"We will all be very busy over the next year, not only preparing a site to expand our current facility by another 20,000 square feet to house this newest piece of equipment, but also assembling and building the new equipment on-site," said Robert Hill, president of Solar Atmospheres Western Pennsylvania. "All of our employees are eagerly anticipating the day that we commission one of the most unique vacuum furnaces in the world."

This car-bottom type furnace Model HCB-84576-2EQ will have a work-zone that measures 7×48 feet and will be capable

of handling loads up to 150,000 pounds at 2400oF. Dual US patented loading cars are provided for loading/unloading from both ends of this furnace with its 48-inch long hot zone.

The vacuum chamber is being manufactured by Youngberg Industries, Inc. of Rockford, IL. and will incorporate three 48-inch diameter vacuum ports as well as six 24-inch diameter ports for gas cooling inlet and outlet. Autoclave type locking doors are included at both ends of the furnace.

"This is the largest horizontal high vacuum chamber they have ever manufactured," said Tom Larson, CEO of Youngberg Industries.

The programs for the engineering and construction phases have been initiated with key orders placed for major system components. The ultimate goal is to have installation and testing completed by the first quarter of 2016.

Heiko Machine Tools

CHOSEN TO SELL CESAR GALDABINI PRODUCTS

Heiko Machine Tools of Canton, MI recently announced that it has been chosen by Cesar Galdabini SPA of Milan, Italy, as the sales and marketing representatives for their straightening and rounding machines in the North American Market. Galdabini produces manual and automatic straighteners for all sizes and types of bars, tubes, and shafts as well as special shapes like gun barrels and steering racks. The smallest of the automatic straighteners are sized from .12 inches diameter by 6 inches length while the large machines handle more than 52 inches diameter by 43 feet length.

Galdabini also makes machines for rounding of numerous types of rings such as synchro rings, gear blanks and bearing races up to large ring gears for wind power planetary systems. Laser inspection developed by Galdabini can be integrated into any of the machines for unparalleled quality while full automation designed and built in house makes for unmatched productivity.

James Petiprin

NAMED REGIONAL SALES MANAGER OF EMAG

EMAG recently introduced **James Petiprin** as the new regional sales manager representing Michigan and Ohio, as well as eastern Pennsylvania and New York. Petiprin has over 15 years experience in the machine tool and automation market.

Petiprin earned his Bachelor's of

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Science from Central Michigan University and has held several positions in the manufacturing industry. Most recently he represented Swedish conveyor company Ewab as a business engineer.

Contour Hardening Mexico Heat Treating Facility

COMPLETES ISO/TS CERTIFICATION

Contour Hardening, Inc. recently announced the ISO/TS certification of its heat treating service facility in Silao, Guanajuato, Mexico. The company's U.S. heat treating facility has been certified since 2004.

The rapid expansion of vehicle and related component manufacturing in Mexico has resulted in a local deficit of TS-certified suppliers in general, and induction heat treating process service providers specifically. With its new TS certification, Contour Hardening will have in-country capabilities to deliver direct-to-line parts, components and assemblies that meet the industry's mandated heat treating standards.

"Because we were one of the first ISO certified heat treating operations in the U.S. and were among the first HT process service providers to achieve ISO/TS certification as well, we are uniquely suited to immediately serve the needs of a wide range of customers in Mexico," said John Storm, president and CEO of Contour Hardening. "We've already solved the technical problems that will hinder others and have formed solid, long-standing relationships with all major OEMs and their tier-one and tier-two suppliers. We've also processed more than 12 million parts in our Mexico facility alone."

Patented Micropulse induction heat treating equipment is built to ISO standards. Today, the company's Micropulse equipment continues to process parts for virtually every major automotive manufacturer in the world.

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Michael Goldstein
1840 Jarvis Ave., Elk Grove Village, Cook County, IL 60008-2440

Editor (Name and complete mailing address)
Michael Goldstein
1840 Jarvis Ave., Elk Grove Village, Cook County, IL 60008-2440

Managing Editor (Name and complete mailing address)
Michael Goldstein
1840 Jarvis Ave., Elk Grove Village, Cook County, IL 60008-2440

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Michael Goldstein	1840 Jarvis Ave.
	Elk Grove Village, Cook County, IL 60008-2440

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Gear Technology, the Journal of Gear Manufacturing		AUGUST 2015	
15. Extent and Nature of Circulation		**Average No. Copies Each Issue During Preceding 12 Months**	**No. Copies of Single Issue Published Nearest to Filing Date**
a. Total Number of Copies (Net press run)		11,747	11,688
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f. Total Distribution (Sum of 15c and e)		11,517	11,248
g. Copies not Distributed (See Instructions to Publishers #4, (page #3))		230	440
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a. Requested and Paid Electronic Copies	2,753	2,603
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17. Publication of Statement of Ownership for a Requester Publication is required and will be printed in the September/October 2015 issue of this publication.

18. Signature and Title of Editor, Publisher, Business Manager, or Owner: Michael Goldstein — Date: 9/28/15

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October 26-29. The Quality Show. Donald E. Stephens Convention Center, Rosemont, IL. The Quality Show is the only tradeshow focused exclusively on quality technology, equipment and products. The event is produced by BNP Media, one of the country's leading business-to-business media companies serving industry professionals across 50+ industries through magazines, custom media, e-newsletters, webinars, events and market research. For more information, visit *www.qualityshow.com*.

October 27-29. Modern Furnace Brazing School. Brazing Engineering Center, Wall Colmonoy Aerobraze Division, Cincinnati, OH. The late Robert Peaslee's tradition continues with the return of the brazing school. The Brazing Engineering Center provides engineering services and training, as well as offering new practical experience on the shop floor. For over 60 years, Wall Colmonoy engineers have gained practical experience on actual problems in brazing plants around the world. Knowledge and practical application will be taught by industry-leading brazing experts. In 1950, Peaslee developed the first nickel-based brazing filler metal, Nicrobraz. Modern Furnace Brazing School will allow you to apply workable solutions to your brazing needs. For more information or to register, contact *brazingschool@wallcolmonoy.com*.

October 27-29 and November 3-5. Discover 2015. Mazak Corporate Headquarters, Florence, KY. Mazak Corporation encourages those involved in the metalworking industry to attend its Discover 2015 technology and education event. Here, the machine tool builder plans to spotlight new technologies and trends that will change how part manufacturers operate, including unconventional ways to drive operational efficiency via additive manufacturing, CNC technology and the Industrial Internet of Things (IIoT) concept. Additive manufacturing is creating a shift in the way engineers and designers think about product development. The company will also offer a series of seminars that will teach attendees the latest metalworking tools, trends and techniques for improved productivity and profitability. For more information, visit *www.MazakUSA.com/DISCOVER2015*.

October 27-30. PTC Asia 2015. Shanghai New International Expo Center, Shanghai. PTC Asia is the largest annual industrial event in power transmission and control in Asia and the second largest in the world. In the exhibition, the debut of new products will illustrate the integration and development of Industry 4.0, highlighting the utilization of eco-friendly materials as an optimal solution to achieving industrial high efficiency and energy conservation. The expo will boast over 90,000 sq. m and 80,000 visitors. Over 15 industries will be included, but PTC will focus on the rail transportation, petrochemical, mining machinery, wind power and food and medicine packing industries in particular. PTC will also be providing over 12 seminars as well as matchmaking services between businesses and potential buyers. Occurring alongside PTC ASIA will be six other expos: ComVac Asia, Industrial Supply Asia, Cold Chain Asia, Heavy Machinery Asia, Battery and Energy Storage Asia and CeMat Asia. Combined the seven shows will take up 17 halls of space. Visit *www.ptc-asia.com/EN/*.

October 27-29. The Assembly Show 2015. Donald E. Stephens Convention Center, Rosemont, IL. Focused exclusively on assembly technology, equipment and products, visitors will find the latest advances in custom automated assembly solutions, robotics, screwdriving, adhesives, dispensing, plastics assembly, conveyors, fasteners, packaging, workstations, welding, vision systems and more. The target audience includes corporate management, manufacturing engineers, design engineers and purchasing personnel. Entering its third year, the Assembly Show continues to grow. The expo floor has been expanded and exhibit hours have been extended. The show will feature 20 educational showcase theaters, almost double the number they had in 2014. There will also be three pre-show workshops for in-depth lessons and hands-on training. Visit *www.theassemblyshow.com*.

October 28-30. Dynamic Systems and Control 2015. Hilton Columbus, Columbus, OH. The Dynamic Systems and Control Conference is the showcase technical forum of the ASME Dynamic Systems and Control Division. It provides a focused and intimate setting for dissemination and discussion of the state of the art in dynamic systems and control research, with a mechanical engineering focus. The 2015 DSCC Technical Program will consist of sessions in all of the usual areas of interest to the Division. In addition, the conference will feature specific technical tracks that uniquely identify this particular DSCC. The location of the conference, in the heart of the Manufacturing and Automotive industries, makes these two areas especially appropriate for special tracks. Other special tracks will include *Interplay between Biology/Ecology/Life Sciences and Engineering* and *Information Technology in Mechanical and Aerospace Engineering*. The program will include contributed sessions, invited sessions, tutorial sessions, special sessions, workshops and exhibits. Visit *www.asmeconferences.org/DSCC2015/*.

November 3-5. 2015 Detailed Gear Design - Beyond Simple Service Factors. Hyatt Place, Las Vegas, NV. This AGMA course explores all factors that go into good gear design, including life cycle, load, torque, tooth optimization, and evaluating consequences. Students should have a good understanding of basic gear theory and nomenclature. The course is designed for gear engineers, gear designers, application engineers, and others who are responsible for interpreting gear design or who want to better understand all aspects of gear design. AGMA members: $1,395 for first registrant from a company, $1,195 for additional registrants. Non-members: $1,895 for first registrant, $1,695 for additional registrants. Visit *www.agma.org*.

November 4-5. Advanced Engineering UK 2015. NEC, Birmingham UK. Integrating multiple show exhibit zones with the UK's largest free-to-attend engineering conference program, Advanced Engineering is where the supply chain meets with visiting engineering and procurement decision makers from OEMs and top tier organizations spanning: aerospace; automotive; motorsport; marine, civil engineering, and more. Whether you are a visitor or an exhibitor, Advanced Engineering will not only provide you with a business forum and supply chain showcase for your own sector, but will also introduce you to new opportunities in industries using related technologies and services. For more information, visit *www.advancedengineeringuk.com*.

November 13-19. 2015 International Mechanical Engineering Congress & Exposition. George R. Brown Convention Center, Houston, TX. ASME's International Mechanical Engineering Congress and Exposition (IMECE) is the largest interdisciplinary mechanical engineering conference in the world. IMECE plays a significant role in stimulating innovation from basic discovery to translational application. It fosters new collaborations that engage stakeholders and partners not only from academia, but also from national laboratories, industry, research settings, and funding bodies. Visit *www.asmeconferences.org*.

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4

What is your primary JOB FUNCTION (check ONLY one)

- ❑ Corporate Executive (B)
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- ❑ 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)

____

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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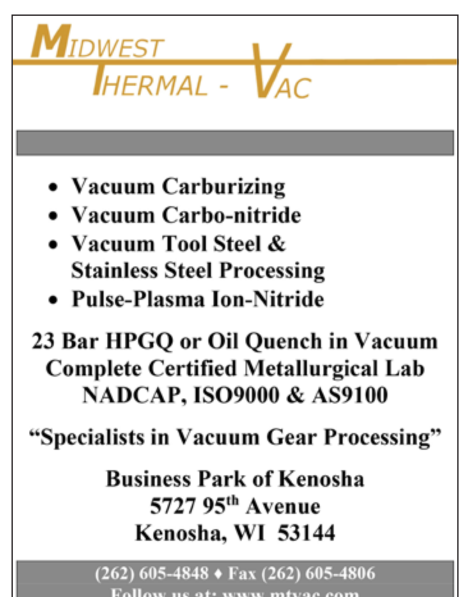
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The Watch That Does Everything, *Plus Tells Time*

Franck Muller's Aeternitas Mega 4 gives new meaning to the word 'complicated'

Erik Schmidt, Assistant Editor

There's a silly ongoing joke in the 2002 family film Spy Kids 2 (a movie that I'm admittedly not very proud I've seen, but hey, I was 12 at the time) involving a super advanced secret agent watch that does everything but tell time.

Well, Franck Muller's Aeternitas Mega 4 is exactly like that — except it tells time, too.

The Aeternitas — named after the divine personification of eternity in ancient Roman religion — has been proclaimed the "pinnacle of success in the art of watch-making in terms of complexity." That name is certainly appropriate, because if you attempt to count all the watch's components you'll be toiling away at your abacus until the end of days.

Luckily, the good folks over at Franck Muller counted for you: 1,483.

That's a ton of horsepower. Pop the hood of this bad boy and find and endless mass of teeny tiny metal mechanisms — most of which are gears — whirling and churning and spinning about like a steampunk wonderland.

According to Franck Muller, "the basic movement has a Cintrée Curvex shape. It's an automatic movement with a micro-rotor placed at 6 o'clock and visible through the open-back. It has a grand tourbillon with a balance wheel with adjustment screws in platinum and no index.

"It has a Breguet spiral and a Franck Muller conception escapement. The movement is equipped with a double barrel: the first barrel guarantees a power reserve of about three days; the second barrel provides energy for the Sonnerie. Each barrel has its own power reserve displayed on the dial."

If nothing else, this watch seems to be a perfect example of what people can accomplish when they have too much time on their hands (see what I did there?). See, nothing that the Aeternitas does is *necessary* — but it's definitely *impressive*, in the most superfluous way possible.

Let's start with the alarm. Your watch probably makes some sort beeping or ringing noise, right? How quaint. When the Aeternitas's Grand Sonnerie strikes the hour, it chimes the same notes as the clock tower of the Westminster cathedral.

Alright, but what about the date, you may wonder? So happy you asked. The Aeternitas "has a perpetual calendar that indicates the day, the date and the month. It takes into account the length of each month and doesn't require any manual intervention. This mechanism also takes into account the leap years, but it needs to be adjusted three times in a row every 100 years."

If that wasn't enough, the watch (I'm not even sure if it's fair to call it that anymore) also displays the moon phases on the dial. The error is "only 6.8 seconds per lunar month, which represents a deviation of only one day every 1,000 years, whereas in a traditional system the error is of one day every four years."

Oh yeah, *and* it displays the time — in *two* time zones. It seems to me Danny Trejo's inventor character in *Spy Kids* needs to go back to the drawing board.

All in all, the Aeternitas has 36 complications.

With 99 rubies thrown in for good measure.

And it costs $2.7 million.

Before you break out your abacus again and start bashing your head against it, let me crunch the numbers for you: That comes out to roughly $72,000 per complication (something tells me that the Aeternitas won't be featured on too many Christmas lists this year).

When Franck Muller began the long, unwieldly and pointless task of creating the Aeternitas, the primary aim was to produce a watch that was "extremely complex."

Well boys, go ahead and give yourselves a pat on the back.

It's about time.

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