

# gear

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## IMTS 2018

### BOOTH PREVIEWS

#### BEVEL GEARS

- PROTOTYPES AND SMALL BATCHES

#### GEARBOX REPAIR



# FFG Modul H200

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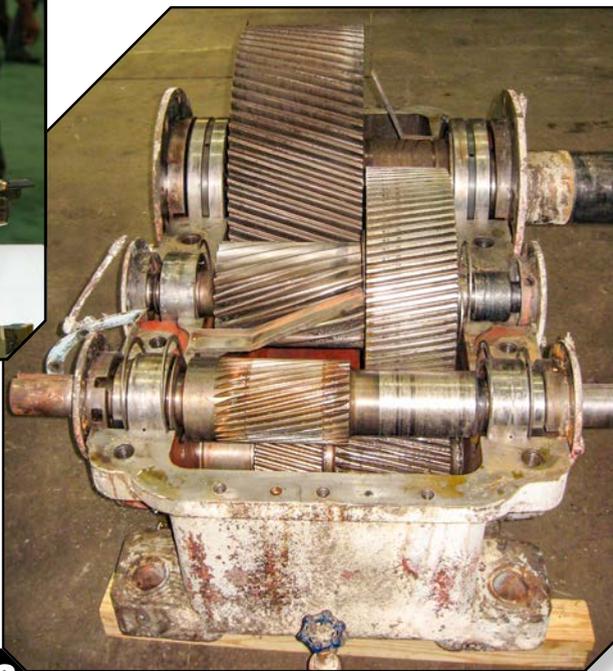
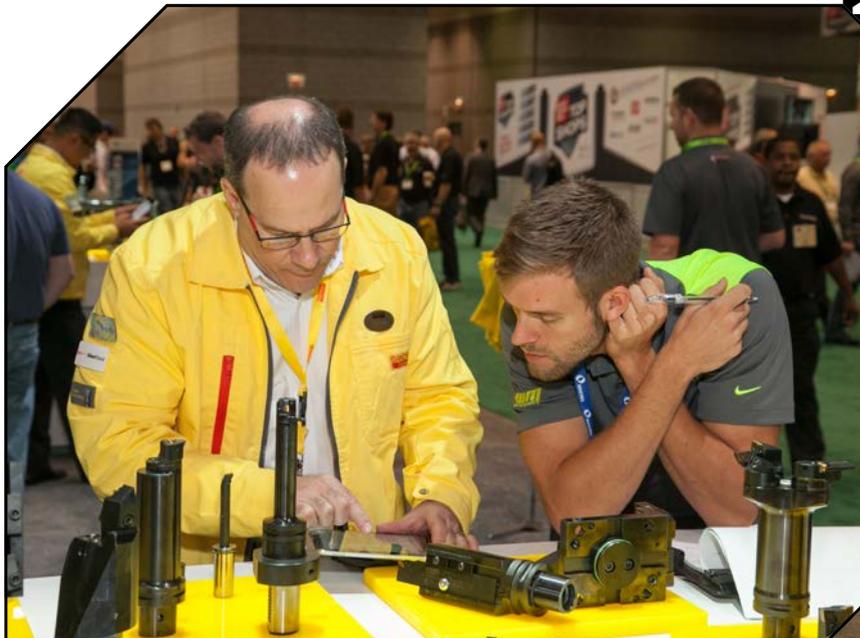


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Cover image by David Ropinski

# Gear Technology and Automation Systems.



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# LIEBHERR

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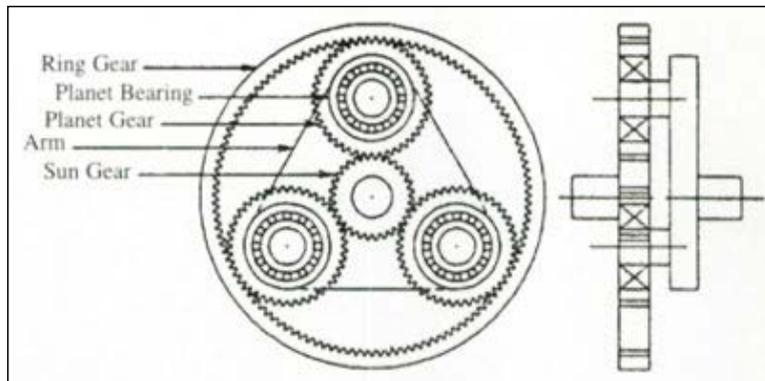
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**Event Spotlight: Gear Dynamics and Gear Noise Short Course**

The Gear Dynamics and Gear Noise Short Course will be offered this year on the Ohio State campus from September 17 to 20, 2018. It has been offered for over 38 years and is considered extremely valuable for gear designers and noise specialists who encounter gear noise and transmission design problems. For additional information, visit [www.geartechnology.com/news/8698/Gear\\_Dynamics\\_and\\_Gear\\_Noise\\_Short\\_Course\\_2018/](http://www.geartechnology.com/news/8698/Gear_Dynamics_and_Gear_Noise_Short_Course_2018/)



**Gear Talk with Chuck**

Charles Schultz looks at planetary gears in recent blog entries such as "A Wheel Inside a Wheel," "Suns and Planets," and "Inside Information" Learn more at [www.geartechnology.com/blog/](http://www.geartechnology.com/blog/).

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# Take the Time: Invest in Knowledge

**If your manufacturing operation is like most, you're pretty busy these days.** And it's not just you. Everybody is making parts as fast as they can.

According to the Institute for Supply Management, the manufacturing sector continues its growth trajectory. The institute's Purchasing Managers Index (PMI) registered 58.1% in July, representing 23 consecutive months of growth.

Similarly, the AMT and U.S. Cutting Tool Institute report that January through May cutting tool consumption was up more than 10% compared to last year. So despite supply chain issues, tariff concerns and global trade wars, the majority of you are still making gears, transmissions and machinery.

More importantly, it appears that many of you are anticipating that growth will continue. You're investing in technology—namely machine tools—to enable your production to continue to increase. According to AMT, January through May machine tool consumption was up more than 26% compared to last year.

It's reassuring that you're continuing to invest this way. And while you're at it, you should be investing in more than just iron. You should also be investing in knowledge.

One of the best ways you can do so is by attending IMTS. The show takes place September 10-15 at Chicago's McCormick Place. This unique opportunity only comes once every two years. You get the chance to see all of the latest manufacturing technology available—not just for gears, but for nearly every aspect of your manufacturing operation.

More than 2,400 exhibitors will display more than 15,000 machine tools and occupy more than 1.3 million square feet of show floor space.

That's a lot of ground to cover, so not only do I urge you to come, but I also urge you to bring as many people from your company as you possibly can. IMTS isn't just for executives. It's for engineers, machinists and everybody else at your company who needs to understand manufacturing technology.

A show like this gives you the chance to talk to the salesmen and executives at your supplier companies, but it also lets you make connections with the engineers and technicians who install and maintain equipment like yours all over the world. If you make the effort, you can gain powerful insights from the people who have already solved manufacturing problems like the ones you face every day in your shop.



**Publisher & Editor-in-Chief**  
Michael Goldstein

In just a few days at IMTS, you can accomplish more than you would almost anywhere else. By investing a little time and energy, you can better understand how to invest your money. You can identify the machine tools and other technology that will help you the most in the coming years.

I know you're busy. I also know you have serious concerns about the future. But ensuring your future success is what IMTS is all about. Don't skip the opportunity.

**Michael Goldstein**, *Publisher & Editor-in-Chief*

P.S. Don't forget to stop by the *Gear Technology* booth (#237314 in the North Hall) when you come to IMTS. See our editors in action as they interview experts from around the world, learn more about the GT LIBRARY at [geartechnology.com](http://geartechnology.com) and renew your subscription. Most of all, just stop by and say hi. We'd love to learn how you're dealing with growth in this era of uncertainty.

# Forest City Gear

## EXPANDS QUALITY CAPABILITIES WITH DIGITAL MAGNIFICATION TECHNOLOGY

Forest City Gear has added an EVO Cam advanced full-HD digital microscope to its Quality Assurance Lab to greatly speed and simplify the visual inspection of precision parts.

The EVO Cam provides the operator with a particularly large 30:1 optical zoom and magnification up to 300x to display even the most minute workpiece details in ultra-sharp full-HD 1080p / 60fps live video. As compared to the traditional stereoscopes typically used for visual parts inspection, the EVO Cam offers the Forest City Gear operator a much faster and more accurate way to detect for burrs, tears and other surface finish anomalies that might exist in workpieces after machining.

“It’s a particularly useful tool for the fine pitch, high precision gears we excel at producing for demanding aerospace applications,” says Quality Assurance Manager John Young. “It’s also been invaluable for inspection of some of the gears we’ve produced for the Mars Rover 2020 program, where we’re striving for perfection.”

EVO Cam is well suited for fast visual inspection of gears, since it gives operators the ability to view the entire



workpiece, or the smallest detail, at the touch of a button. It also has a 360° rotating viewer capability to reveal an angled all-round view of the part.

It’s just one of many technologies that Forest City Gear has at its disposal in a Quality Assurance Lab that is among the most advanced in the industry.

### For more information:

Forest City Gear  
Phone: (815) 623-2168  
[www.forestcitygear.com](http://www.forestcitygear.com)

# KISSsoft

## IMPLEMENTS BEVEL AND HYPOID GEAR CALCULATIONS

In the ISO Committee, the scuffing load capacity calculation for bevel and hypoid gears is currently in draft form, and has been implemented so in *KISSsoft*. This method is mainly applicable for hypoid

gears, and it also takes into account effects such as the running in of GL5 oils.

The backlash (as the tooth thickness allowance) according to ISO, Gleason and Klingelnberg is now available for bevel gears, which is especially helpful in the bevel gear design process, because the manufacturing principle is not yet defined in some cases.

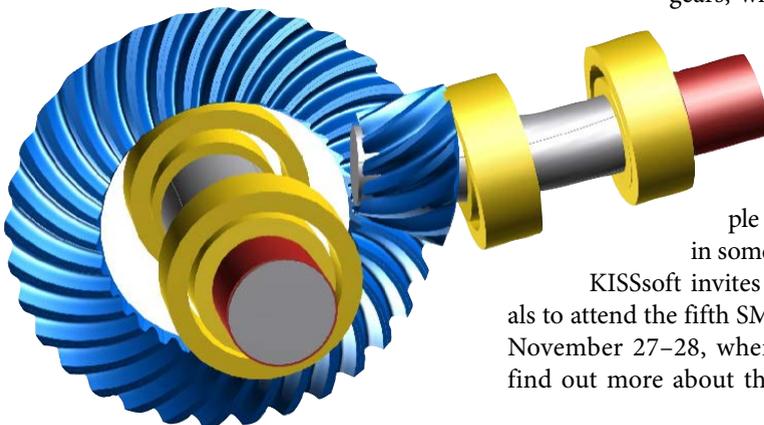
KISSsoft invites gear professionals to attend the fifth SMK in Rapperswil November 27–28, where attendees can find out more about this topic. Among

others, Dr. Joachim Thomas from ZG Hypoid GmbH, Frederik Mieth from the Technical University Dresden and Jürg Langhart from KISSsoft AG will give presentations on bevel gears.

In addition, there are still places open for the advanced training gear design and optimization course in taking place September 25–28. Visit the website below for details.

### For more information:

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The L.S. Starrett Company has introduced a range of Digital Electronic Indicators conforming to true AGD (American Gage Design) Group 1 dimensions, providing the ability to replace traditional mechanical indicating applications in the smallest AGD size specification class. Starrett 2700 Electronic Indicators are the first digital

gages to match true AGD Group 1 dimensions (1.70"/ 43mm diameter).

Starrett 2700 Indicators feature a 1.70" diameter, 270 degree rotating bezel, allowing different user viewing preferences. The gages are available in two displays - a single LCD Numeric IQ model (the largest of its class) with low battery warning and programmable ratios, or a



Numeric/ Analog AD model showing the two displays simultaneously.

Gages feature a .400" (10 mm) travel, accuracy of  $\pm 0.0001$ " (0.002 mm) on the F2715 models and accuracy of  $\pm 0.0002$ " (0.004 mm) on the F2714 models. The gages can store and view 200 readings internally. Stored readings can be downloaded with included software and a USB style cable. Starrett 2700 Digital Indicators have a CR2032 cell long-life battery that can last up to 3,000 hours under typical use. Gages are output-compatible for SPC documentation via cable or wirelessly using a Starrett DataSure® Data Collection device.

These indicators are Made In America, have a 3/8" (.375") stem with 4-48 thread and are available in four models based on display readout format and resolutions. Switchable resolutions are .001/ .0005/ .0001/ .00005 or .001/ .0005/ .0001 in inch. In metric readouts, switchable resolutions are 0.02/ 0.01/ 0.002/ 0.001 or 0.02/ 0.01/ 0.002 mm. Gage functions are easy-to-operate and include: Absolute True Position, Travel Reverse, TIR, Tolerance Settings, Floating Zero, In/mm conversion, three Hold functions (max/ min/ freeze) and Auto Off.

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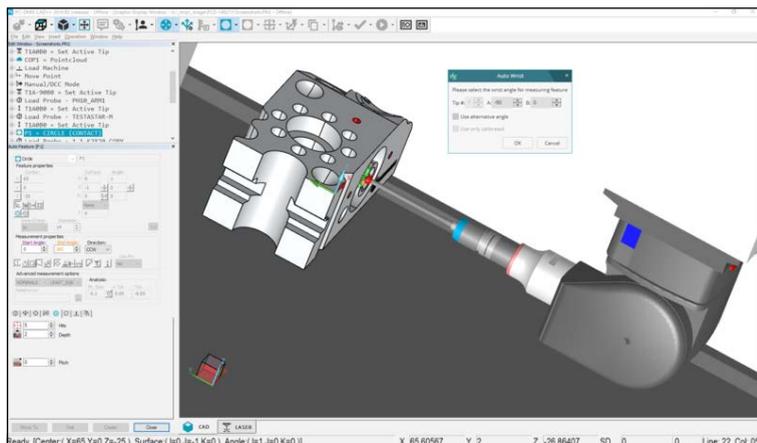
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# Hexagon Manufacturing Intelligence

LAUNCHES LATEST EDITION OF MEASUREMENT SOFTWARE

Hexagon's Manufacturing Intelligence division has launched *PC-DMIS 2018 R2*, the latest edition of its measurement software. This is the second of two major releases scheduled for *PC-DMIS* in 2018, with continued



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service pack updates to ensure maximum reliability of the platform.

*PC-DMIS 2018 R2* introduces a new reporting workflow, making it easier than ever to create customized reports with simple drag and drop and an intuitive slideshow-style interface. A new QuickPath tool expands on existing QuickFeature functionality to simplify feature creation with a safe path *PC-DMIS 2018 R2* also introduces the ability to add run charts from qs-STAT into the *PC-DMIS* report. Improved Probe Utility allows users to mark favorite tip configurations, create required tip angles by simply clicking on CAD, and buy replacements with Shopping Cart tools; a new e-Store is coming soon to [hexagonmi.com](http://hexagonmi.com). Improvements in the use of lasers, specifically for path creation and offline programming, are also featured in the new release.

"*PC-DMIS 2018 R2* continues the recent trend towards maximizing productivity in the three major metrology tasks: creation, execution, and collaboration," said Ken Woodbine, product line manager for metrology software at Hexagon Manufacturing Intelligence. "Creating measurement routines is even simpler and more intuitive with the addition of both QuickPath for adding motion in 'walk up and measure' applications and the offline path visualization and simulation for laser probes. Execution is also streamlined with improvements to our Inspect module, making it easier to control access to routines, and for operators to search and find routines and reports."

**For more information:**  
Hexagon Manufacturing Intelligence  
Phone: (401) 866-2000  
[www.hexagon.com](http://www.hexagon.com)

# Sandvik Coromant

## OFFERS TWO NEW CERAMIC INSERT GRADES

Sandvik Coromant has introduced two new ceramic insert grades that are capable of performing high-speed, high-security turning operations on components made from demanding HRSA (heat resistant super alloy) materials. The CC6220 and CC6230 ceramic grades have been developed to machine demanding materials where whisker ceramics and SiAlONs fall short. Their ability to handle higher cutting speeds contributes to reduced cost per component, while inherent machining security ensures that quality is not compromised to help manufacturers produce high quality parts, time after time.

There is growing demand for aerospace engine parts that can withstand extreme temperatures beyond the capability of those made from Inconel and other high-performance super alloys. Although these powder metallurgic materials can be tailored to handle substantially higher temperatures, they are more difficult to machine than common HRSAs.

“CC6220 and CC6230 excel when turning demanding materials in intermediate stage machining,” says Rolf Olofsson, product management turning at Sandvik Coromant. “They take productivity to a new level in comparison with whisker ceramics and SiAlONs, in terms of both cutting speeds and feeds. Moreover, repeatable quality is assured.”

Along with productivity improvements of more than 50% over whisker ceramics and SiAlONs, CC6220 and CC6230 offer long tool life in challenging HRSAs, and thereby lower cost per part.

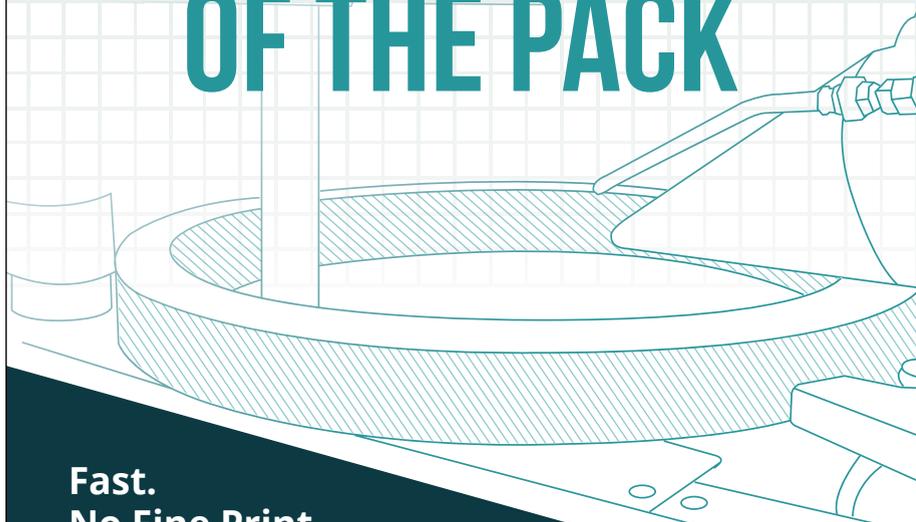
One of the most common applications to benefit is expected to be the turning of turbine discs. In a customer example machining a low-pressure turbine (LPT) disc made from Rene material (42-45 HRc) as part of the intermediate stage machining process, a CC6220 RPGX insert was deployed to perform pocketing and CC6230 RPGX inserts for rough-turning operation at cutting speeds as high as 400 m/min (1380 sfm). The process achieved a metal removal rate (MRR) of 80 cm<sup>3</sup>/min (5 inch<sup>3</sup>/min).

### For more information:

Sandvik Coromant  
Phone: (800) 726-3845  
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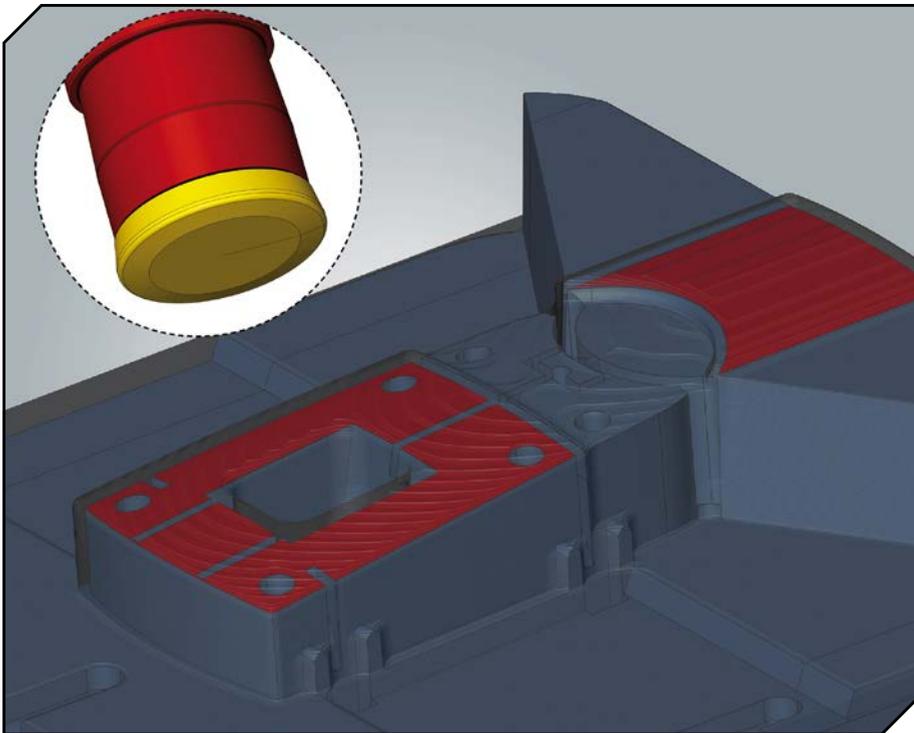
# Open Mind Technologies

RELEASES LATEST VERSION OF HYPERMILL SOFTWARE

Open Mind Technologies AG, a developer of CAD/CAM software solutions, has introduced *HyperMill 2018.2*, the latest version of its advanced, comprehensive CAM software. *HyperMill 2018.2* offers a range of enhancements and new features for 3D Shape Z-level Finishing and 3D Optimized Roughing, greater CAD functionality and more.

For reduced programming times and improved milling, 3D Z-level Shape Finishing, available in *HyperCAD-S*, has two new features. "Automatic face extension" can be used during CAM programming to automatically extend the selected milling surfaces, eliminating manual CAD work and resulting in cleaner corner cuts. Also, 3D Z-level Shape Finishing now has the ability to support conical barrel cutters in addition to general and tangential cutters.

During 3D Optimized Roughing, multiple allowances are now recognized and accounted for when using free tool



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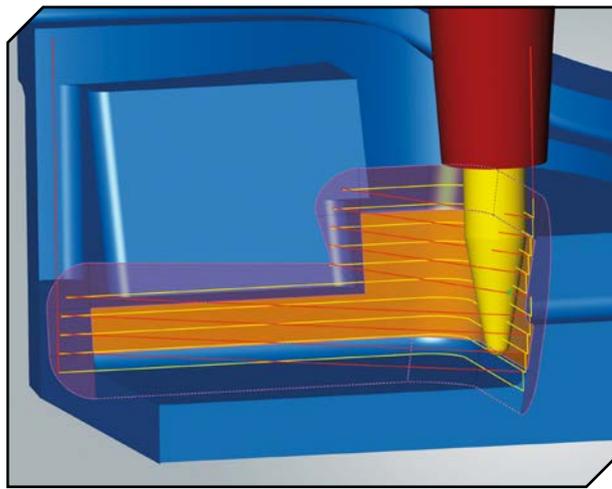
geometries, resulting in easier programming and a high level of flexibility for defining special tools. *HyperMill 2018.2* can define different allowances and adapt the machining process accordingly. High-feed cutters have a special cutting geometry that is easy to define using tool management, and *HyperMill 2018.2* uses the free geometries of the cutting tool edge for calculation, simulation and collision checking.

“Keeping the *HyperMill* suite at the forefront of CAM technology, we are pleased to offer our customers improved CAM strategies and enhanced CAD tools for even greater machining productivity through our new release of *HyperMill 2018.2*,” said Alan Levine, managing director of Open Mind Technologies USA, Inc.

New *HyperMill 2018.2* functionality also includes several enhancements to its *HyperCAD-S* module, including the ability to measure and record the distances between two shapes such as face models, solids, meshes or stock. In addition, for easy changes to milling boundaries and turning contours, *HyperMill 2018.2* offers a ‘V sketch’ command that assigns geometric constraints to 2D contours. When individual contours are changed, the sketch is automatically updated using their dependencies.

The electrode module, which provides quick designing of die-sinking electrodes, offers a new Virtual Electrode function for securely creating electrode copies which are checked for collisions, and can be assigned new technology values or the values of the master electrodes. For easier analysis, the reference system and eroding position for each electrode copy are included in a report.

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Walter Surface Technologies, the global industry leader in surface treatment technologies, recently introduced the Surfox 305, a patented electrochemical MIG and TIG weld cleaning system that is now safer, faster, and more user-friendly.

The Surfox 305 works fast to remove heat tint from the heat-affected zone of MIG, TIG, and spot welds on stainless steel and aluminum making it the most versatile weld cleaning system to date. It cleans the surface without disrupting passivation on stainless steel or altering the surface finish, and its dynamic current control protects the surface against micro-pitting. With an integrated tank and flow-through system, the Surfox 305 delivers the electrolyte solution directly to the workpiece to minimize the risk of spillage or cross-contamination.

“Resisting corrosion is a natural property of stainless steel due to the presence of the passive chromium oxide layer on



the surface, but this layer is compromised from the heat caused by welding,” says Jonathan Douville, senior product manager - Surfox, Finishing & Tooling. “Surfox 305 can safely, quickly, and effectively remove the heat tints caused by welding to help restore the corrosion resistance of stainless steel.”

Designed to streamline weld cleaning operations and minimize downtime, the Surfox 305 offers unsurpassed ease of use and functionality. Its exclusive quick-change brush system allows users to change out accessories easily, and its brushes are designed to clean large and hard-to-reach areas. Other industry-leading features of the Surfox 305 include an AC mode for cleaning and marking, a DC mode for polishing and etching, and a built-in vapor dispersion system.

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# IMTS 2018: A Field Guide

## Chicago Preps for the Next Manufacturing Technology Extravaganza

Matthew Jaster, Senior Editor

The International Manufacturing Technology Show is once again upon us. Soon, Chicago will be overrun with grinding, inspection, automation, robotics and metalworking technologies that could potentially change the way your shop conducts business overnight. It's a pretty big deal in the manufacturing sector. We recently caught up with Peter Eelman, vice president of exhibitions and communications for AMT, to discuss IMTS 2018.

### Then & Now: A Digital Revolution

Eelman compared his very first IMTS trade show experience to the upcoming show.

"It was 1980 and it was the biggest and most amazing trade show I had ever seen," Eelman said. "From a technology standpoint, the emphasis in 1980 was on digital manufacturing, but at a completely different level than today."

Eelman continued, "Back then it was strictly moving from CNC to DNC (direct numerical control); moving from the old world into the digital world of controls. Now, when we talk about digital transformation we're talking about every facet of manufacturing from part design to finished piece. It's truly an exciting time to be involved in manufacturing."

### What's New & Relevant?

Eelman promises much more in the area of additive manufacturing. "We have gone in four years from additive being a demonstrated technology to finding a home in the emerging technology center. We've now formed a pavilion and 35,000 square feet of the show will be additive manufacturers including companies that will be introducing unique metal processing capabilities. The change in the size and scope of this technology is dramatic," Eelman said.

"This really is a sea change for manufacturing. It won't be overnight, but it will definitely impact the way we think about making parts now and in

the future. Not only 3D printing, but the entire manufacturing process; start to finish. We're seeing at the moment that almost every company is working in the digital realm and trying to make their part processes more efficient," he added.

With the Internet it's hard to have any surprises anymore, but Eelman believes attendees will see some product introductions in 3D-printing that are a great leap forward for the industry.

"We're talking real metals and things that you can use. 3D printing started with things like key chains and now we're demonstrating at the show that so much more is coming. What manufacturers traditionally make is going to be

made differently in the future," Eelman said.

The underlining theme for the 2018 show is digital transformation. "This is a foundation of additive manufacturing, but it's also the foundation for the future of every manufacturing plant. We're examining the connection between everything in the factory from design to finished product. Where can you gain efficiencies on the shop floor and become a more nimble and flexible manufacturer? Products that used to take weeks or months to produce can now be made in hours and sometimes minutes. This is where we're heading as an industry," Eelman added.



## Bigger, Better and Still Expanding

Eelman said the original reason AMT collaborated with Hannover Fairs was to expand the scope of IMTS. "IMTS started as a general machine tool show and then it moved beyond that into factory automation. Today, we're basically building a one-stop shop concept. The breadth of manufacturing that is now covered when you add the Hannover Fairs pieces with the IMTS pieces, there's not a person at manufacturing facility that would not benefit from attending the show," he said.

Here's a brief rundown of the co-located shows that complement the metalworking solutions at IMTS 2018:

**Integrated Automation, Motion & Drives:** The two leading trade shows Industrial Automation and MDA will be combined to create a new annual event: Integrated Automation, Motion & Drives (IAMD) USA. IAMD USA will present the complete spectrum of industrial

automation, IT, power transmission and fluid power technology.

**Surface Technology USA:** This event will cover the entire spectrum of industrial surface treatment and finishing; from cleaning and pre-treatment to coatings, paint finishes, and electroplating.

**ComVac USA:** Highlights the latest product developments, technology, and plant & system components for all areas of compressed air and vacuum.

**Industrial Supply USA:** Covers the entire spectrum of industrial

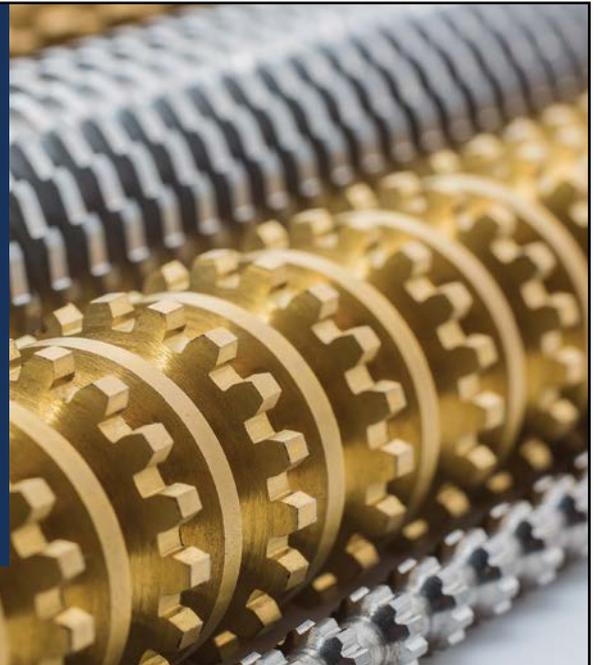
subcontracting and lightweight construction. This is the event where you will find supply solutions across the entire industrial value chain.

## Get Educated

A variety of technical conferences and educational sessions will be available throughout the week — more than 70 sessions covering areas like manufacturing process innovations, alternative/additive manufacturing, plant operations, quality/inspection/metrology and



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systems integration/Industry4.0/IIoT.

“You can spend an entire day learning more about additive manufacturing or drop-by a few conferences on digital manufacturing throughout the week,” Eelman said. “There are plenty of educational opportunities available to everyone. It’s best to start at the website and dig through the sessions that are available.”

Some notable conference topics include:

*Beginners Guide to IIoT/Industry 4.0*

(2:15 on Monday, September 10, Room W194-A)

*Trends in Manufacturing*

(2:15 on Tuesday, September 11, Room W196-B)

*High-Performance Grinding of Nickel-Based Superalloys*

(10:00 on Wednesday, September 12, Room W193-B)

*How Automation & Optimization can Maximize Shop Floor Capabilities*

(9:00 on Thursday, September 13, Room W192-C)

*The Next Step: Taking 3D Printing from Prototyping to the Production Floor*

(3:15 on Thursday, September 13, Room W193-B)

### Bring the Kids

The Smartforce Student Summit aims to introduce students and teachers from elementary through post-secondary schools to exciting, high-tech careers in manufacturing. Companies such as ABB Robotics, Carl Zeiss, Fanuc America, Festo-Didactic, Haas Automation, Heidenhain, Mastercam, Mitutoyo, and Siemens, will have hands-on challenges for students and Learning Labs for teachers as well as advanced students focused on areas such as additive manufacturing, metrology, collaborative robotics, IIoT and more.

“Our Student Summit is by far the largest singular event to expose the manufacturing industry to students here in the United States,” Eelman said. “We had almost 17,000 students in 2016. We’ll have more this time around.”

### The Health of the Manufacturing Trade Show

The trade show itself is evolving in different ways, according to Eelman. “Big trade shows have gotten bigger — EMO in Europe and IMTS here in the states. These big events open your mind and help the technology move forward. I think with the smaller trade shows you’re seeing a bigger appetite for education. We recently collaborated with SME on the Smart Manufacturing Experience. The whole point was to learn about smart manufacturing. The big trade show is still an event — and it’s doing quite well — while the regional and small trade shows are more about showing the application and presenting educational benefits to attendees.”

### Chicago: A U.S. Manufacturing Hub

On the topic of moving future shows to other areas of the country, Eelman says it just doesn’t make sense. “Chicago is cost-competitive with most other cities and is actually cheaper and more affordable in some respect,” Eelman said. “One of the main reasons for keeping IMTS in Chicago is our audience. There’s no better centralized location for manufacturing. It’s easy to get here — for both our domestic and international attendees. It’s so easy, in fact, that moving it any other place in the United States doesn’t make much economic sense.”



## A Clean Slate

The reason each IMTS feels different and original has to do with a little ceremony AMT's internal staff performs at the end of every show. "We tear everything up and start all over again," said Eelman. "We don't get caught up in traditions or what may have worked in previous shows. I believe this is why we've grown so much while other shows have not. This will not be a repeat of the 2016 show. This way we're able to see trends as they come and keep the whole concept of IMTS new and innovative."

## Make Friends with the Website

Is it your first time heading to the show this September? Eelman believes every attendee should get familiar with the resources available on the website prior to making the trip.

"You can register your preferences on the IMTS website and the area of interests that matter most to you and your organization," Eelman said. "This technology allows you to manage your visit as opposed to the visit managing you."

This is really why AMT puts a premium on the website so they can clearly determine what it is the attendees are looking for and where they can go to find it. Planning, according to Eelman, is the way to go.

"It's key that you have a game plan for the show. Make a schedule and stick to it at the beginning of the week. Then you

have the freedom to walk around and see the rest of the show later," Eelman added.

## Economic Impact

There's always a question about the state of manufacturing heading into IMTS. This year, there is much more optimism and excitement than in the past. AMT members have been collecting data and talking with exhibitors leading up to the 2018 show.

"U.S. manufacturing is extremely strong. Our forecasting department

believes manufacturing (everything from automotive to aerospace) is currently in great shape," Eelman said. "There are plenty of orders. There are backlogs. There is an excellent forecast from now until the end of 2019 and beyond."

## Don't Miss Out

And there you have it. Just like that we're about to come together again in the Second City and celebrate manufacturing technology. You can probably come up with a dozen excuses why you won't



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be able to attend this year, but you might want to reconsider.

“In a few years major process changes in manufacturing will take place and having your head down is not a good way to stay in business,” Eelman said. “If you’re not aware of what’s happening in manufacturing today, you can fall behind much more quickly than you would have in the past.” 

**For more information:**  
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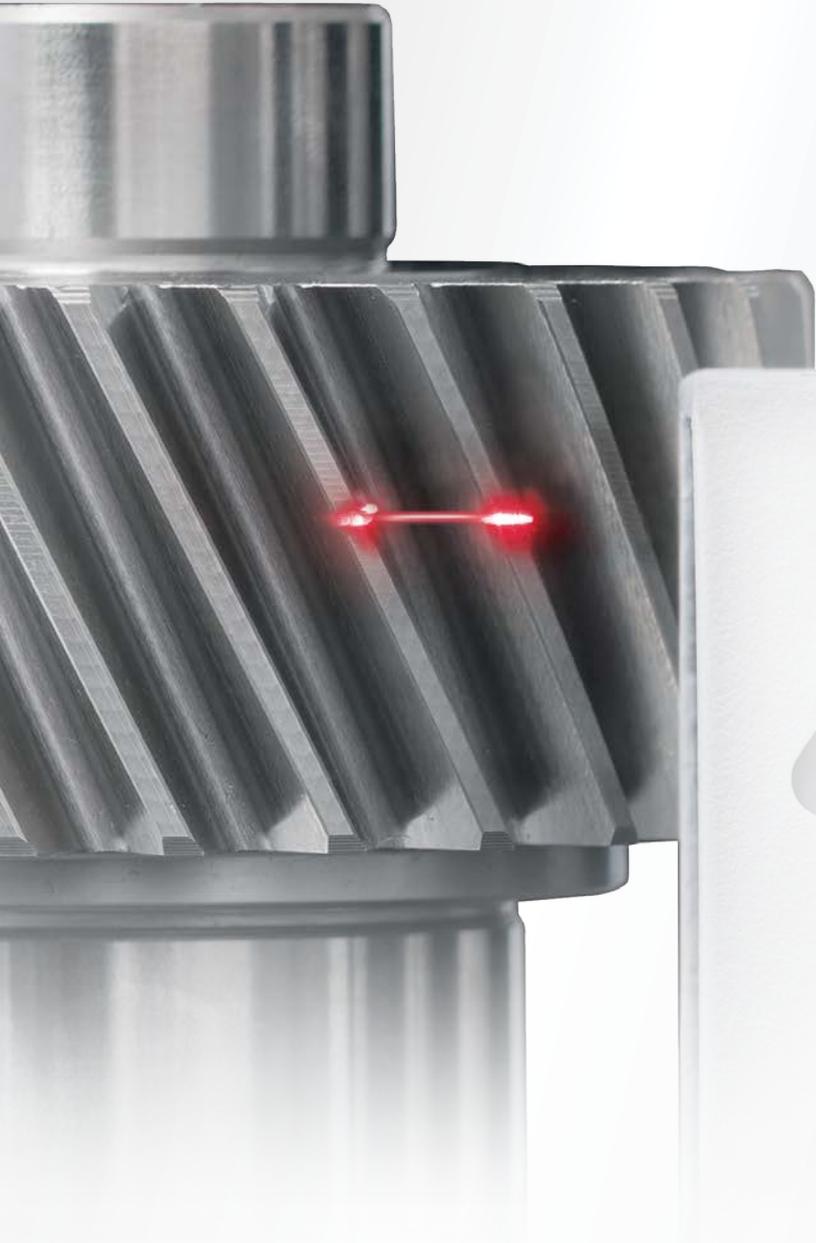
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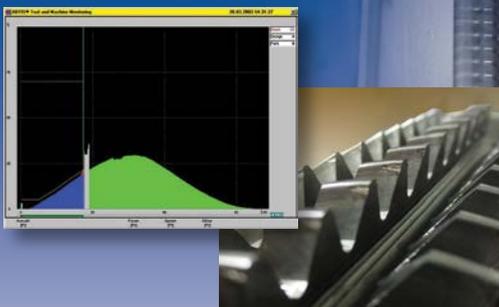
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# IMTS 2018 Booth Previews

## Affolter Technologies North Hall, Booth 237223

Affolter Technologies, in partnership with its U.S. representative, Rotec Tools, will showcase their innovative gear hobbing center AF110 plus at IMTS 2018.

The AF110 plus is the most advanced machine offered by Affolter Technologies. It convinces with its versatility, precision, power, rigidity and ease of use. The AF110 plus has eight axes, a cutter-spindle speed of up to 12,000 rpm capable to make gears with a maximum DP17 and minimum of DP1270. Different automation systems for part loading and unloading are available, such as universal grippers, drum loader or robot loading as well as options such as deburring, dry cutting, centering microscope and oil mist aspiration.

“The loader system AF71 with two grippers ensures 24 hours automatic production,” Vincent Affolter, managing director of Affolter Technologies, said. “While a gear is in the hobbing process, the other gripper already reaches out for the next part to load.”

The AF110 plus can cut spur, helical, frontal, bevel, and crown gears.

Worm Screw Power Skiving, a cutting-edge technology developed by the Affolter engineers, is available as an option. The idea behind it: Unlike in worm hobbing, where the hob turns much faster than the workpiece, the Affolter engineers inverted the process.

“The workpiece turns extremely fast, with two new spindles up to 12,000 rpm, while the cutter turns much slower. Only highly advanced machines can reach such speeds and at the same time provide the necessary stiffness,” Affolter said.

WSPS allows manufacturers to finish a high-precision worm in only 6 seconds — four times faster than the traditional worm hobbing.

“Manufacturers of a high volume of worms will greatly benefit from this new process and improve their productivity significantly,” Affolter said.

The WSPS technology focuses on small worms with a module up to 17 DP.

“The Affolter gear hobbing machines offer customers a

production machine with high precision and efficiency,”

Ivo Straessle, president of Rotec Tools, said. “The simplicity of these machines is remarkable. The user-friendly controls with step-by-step and easy-to-follow functions will simplify the gear-making process. With a relatively small investment, customers can keep know-how and technology in-house.”

### For more information:

Affolter Technologies  
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## American Broach & Machine North Hall, Booth 237020

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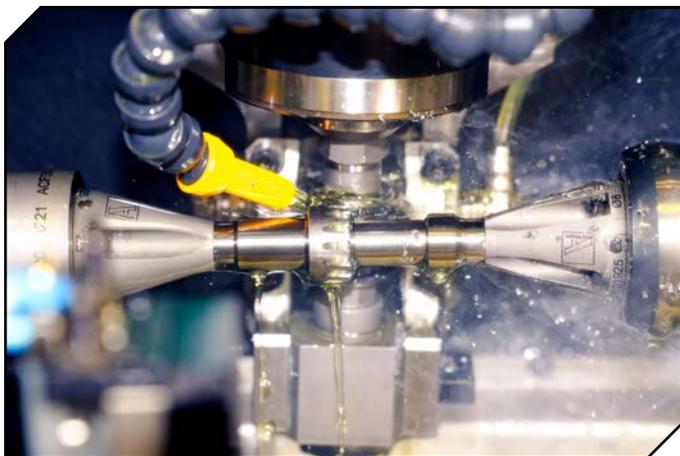
## Bourn & Koch

### North Hall, Booth 236854

The global manufacturing community is invited to receive a behind-the-scenes look into how precision machine tools are being built, right here in America, during the Bourn & Koch “Made in America” open house on Wednesday, Sept. 12 and Friday, Sept. 14, 2018.

Tours will be held in Rockford at 10 am and 2 pm both days of the open house. Included in the tours will be a display of select original prints from Blanchard, Fellows, Springfield, DeVlieg, Bullard, Barber Coleman and many other brands which Bourn & Koch, as an OEM for 35 American machine tool brands, is curating.

Full factory tours during the event include the 130,000 square foot shop floor where Bourn & Koch remanufactures classic American machine tools to OEM specifications and also builds brand new Springfield vertical grinders, Blanchard rotary grinders, Bourn & Koch gear hobbers, Fellows shapers and DeVlieg milling machines with the latest technology and designs. A highlight of the tour will be demonstrations of a newly redesigned and reengineered Blanchard 22AD-42 rotary surface grinder.





Resident historian, engineer, and Bourn & Koch co-founder, Loyd Koch, will be greeting visitors during the two-day Rockford event. Light refreshments and beverages will be served. RSVP to Tyler Free at Bourn & Koch: [tfree@bourn-koch.com](mailto:tfree@bourn-koch.com).

Bourn & Koch is located in Rockford, Illinois' industrial zone, which is approximately 90 miles from McCormick Place. For those who cannot attend the open house during IMTS, other tour dates are available by appointment request.

Bourn & Koch will simultaneously be exhibiting at IMTS 2018. The company will be showcasing their full line of machine tool solutions including the Springfield VBG vertical grinder, a fully automated Fellows 10-4 gear shaper, Bourn & Koch 100H-T turning and hobbing center and Blanchard 8AD-12 surface grinder. The Springfield VBG offers precision grinding down to 0.0001" as well as integrated vertical turning for single-step production and in-process inspection.

The remanufactured Fellows 10-4 integrates patented electronic crowning and taper technology, BKI-S-HMI and Easy Automate enclosure for standard 3-axis (or optional 6-axis) CNC gear shaping with Fanuc Oi control. The Fellows 10-4 is an affordable way for job shops to introduce high-quality gear manufacturing to their operations. New to the machine is electronic helical guide capability. The machine will be demonstrated with a Halter robot for auto-loading.

The Bourn & Koch 100H-T gear hobber with seven-station turning turret is capable of turning, boring and hobbing up to AGMA Class-13 gears in one setup to save floor space, reduce overall cycle times and increase workpiece accuracy. Shipped with patent-pending adjustable hob arbor spacers and BKI-H-HMI, the machine allows easy setup, programming and manufacturing by novice operators.

The Blanchard 8AD-12 surface grinder is an iconic machine tool, producing the characteristic "Blanchard Grind" synonymous with quality ground parts. Like the Blanchard 22AD-42 being demonstrated at the "Made in America" Rockford open house, the smaller Blanchard 8AD-12 in the Bourn & Koch booth at IMTS has been reimagined and reengineered to meet today's manufacturing challenges.

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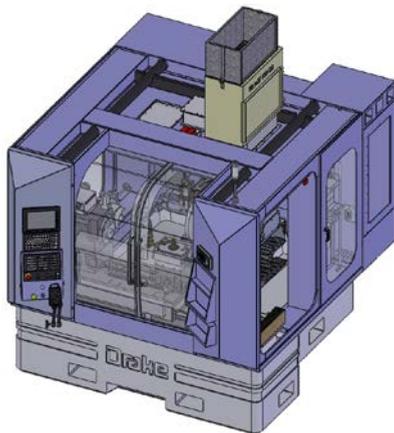
## Drake Manufacturing

North Hall, Booth 236927

At IMTS 2018, Drake Manufacturing will introduce its newest machine tool, the GS:DS dual spindle grinder, further expanding Drake's premium line of thread grinders and milling machines. The dual spindle machine, complete with automation, will be demonstrated throughout the week in Drake's booth.

The GS:DS combines the grinding capabilities of two machines into one. Depending on application, the machine can be equipped with two external grind spindles, two internal grind spindles or one of each. This not only eliminates changeover, but also reduces takt time while maintaining tight tolerances. A programmable B-axis allows for the

wheel to grind both straight and taper sections in one set-up providing excellent concentricity.



There will be technical presentations offered throughout the show on thread grinding and latest Drake Technologies. Innovation has become a primary focus for Drake as it continues to invest in R&D. While advanced registration is preferred, attendees can also register for these presentations in the Drake booth.

Drake's team of engineers, sales and technical support specialists will be available all week to discuss solutions for your

thread grinding requirements. Don't miss this opportunity to talk threads with the best in the industry! If you prefer to schedule an IMTS appointment, please contact [marketing@drakemfg.com](mailto:marketing@drakemfg.com).

### For more information:

Drake Manufacturing  
Phone: (330) 847-7291  
[www.drakemfg.com](http://www.drakemfg.com)

## DTR Corp.

North Hall, Booth 237017

DTR offers a full line of gear cutting tools, including hobs, carbide hobs, shaper cutters, milling cutters, chamfering and deburring tools, broaches and master gears.

### For more information:

DTR Corporation  
Phone: (847) 375-8892  
[www.dtrtool.com](http://www.dtrtool.com)

## DVS Technology Group

North Hall, Booth 236744

From soft to hard fine machining, from small to large series production, the companies belonging to the DVS Technology Group will be exhibiting trend-setting machine and tool systems for turning, gearing, grinding and gear

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# REISHAUER

Gear Grinding Technology

honing applications at the IMTS 2018.



Pittler T&S will be presenting the gearing center SkiveLine for the first time in the United States at IMTS. Based on the tried-and-trusted Pittler vertical series, the new platform has been oriented towards Pittler Skiving gear-cutting technology. The SkiveLine provides maximum productivity for the complete machining of components with a diameter of up to 16 inches. Pittler Skiving is a technology used for manufacturing inner and outer gearing in small, medium-sized and large series. The SkiveLine offers enormous potential for meeting the quality and productivity requirements of new drive concepts such as those used in electro-mobility. The hollow wheels of planetary gears are already being series produced completely in two clampings in Europe, with upstream or downstream turning, milling or deburring processes. The machine has been designed both for the gearing of non-hardened (soft) and hardened components. Users can choose between dry machining with compressed air cooling, wet machining or a combination of the two.



The SkiveLine has also been optimized for fully automatic series production: The work chambers of up to two gear centers are automatically supplied with tools via the automation cell, thus minimizing space and investment requirements compared with robot loading. Pittler Skiving also means that Pittler supplies the tools and clamps from a single source.

Praewema Antriebstechnik GmbH will be at the DVS booth and is using

IMTS to present new developments for outer gearing. VarioCrossHoning, a special oscillation method during honing, makes it possible to reduce surface roughness even further and thus further increase the surface quality of components with external gearing. The method can be marveled together with the new, larger honing head with a diameter of 15.75 inch for components with a maximum diameter of 8.7 inch.

Praewema will be presenting a manufacturing solution for the highly efficient production of face crown gearing on claw clutch components to trade visitors at IMTS. Praewema's WPSLV 2-2 has a double spindle and stands out through maximum thermal and dynamic stability, which creates the basis for extremely smooth running of the fly-cutting tool. The rotating milling cutter with only one direction of cutting from the inner to the outer diameter prevents the formation of undesirable burr in the groove of the inner diameter, saving the user complex reworking. The burr at the outer diameter is removed during the milling process using integrated deburring operations which have no effect on the cycle time. In addition, both tooth flanks can be made crowned, which has a positive effect on claw clutch function. Following machining, the components have a code engraved which helps the user trace all the relevant data for component production for years.

DVS Tooling GmbH will be presenting a comprehensive spectrum of tools for Praewema gear honing for both internal and external gearing at IMTS. The dressing tool VSD SF is new in the range. In this case, the letters SF stand for "super-finishing" and refer to the extremely good surface quality. To do justice to these requirements in series production as well, the tools used must be coordinated accordingly. With the VSD SF, DVS Tooling has managed not only to offer tools with extremely tight production tolerances, but also surfaces of  $Rz < 1 \mu\text{m}$  for external gearing.

A further DVS Tooling highlight will be the diamond dressing gear wheels which the company finishes using its own DVS LaserCut method. The diamond wheels from DVS Tooling GmbH thus stand out with great cutting properties, excellent pitch quality and a long

service life.

DVS Tooling has also developed new tool and dressing solutions for the honing process for internal gearing developed by Praewema. Used in conjunction with the Praewema technology, these raise the standard for the surface quality of transmission components with internal gearing to a whole new level.

Buderus Schleiftechnik presents DVS UGrind for the small and medium-sized series production of shaft and chuck parts. The heart of the machine is the flexible multi-function machine head, which is used for grinding, hard-turning and measuring processes in one clamping and without interruption. DVS UGrind's UCee user interface reduces setup time for these processes. Intuitive user guidance allows machining programs to be created quickly and easily even without in-depth programming knowledge being necessary.

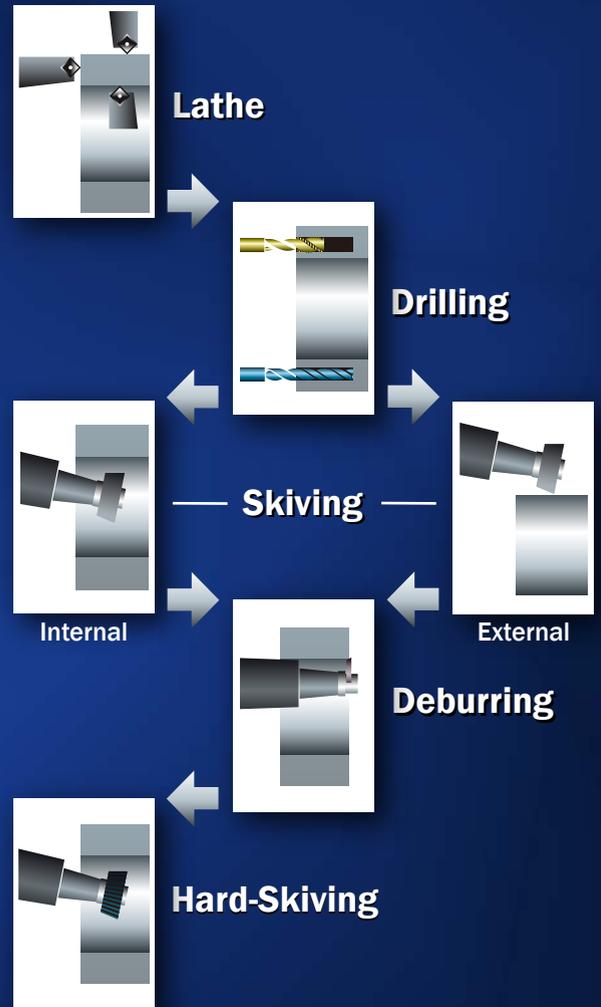
Productivity-reducing machining steps such as continual measurement and repeated feeding until the required final dimension has been achieved after clamping are still part of everyday life in small to mid-size workshops. The DVS UGrind makes these steps unnecessary, because the measuring probe integrated in the multi-function head monitors and controls the machining process without the operator having to intervene.

The DVS UGrind can be extended by the ULoad automation cell for fully automated series production. With the aid of a flexible pivoting gripper, the shaft or chuck parts of up to 5 inches in diameter are guided quickly and precisely into the work chamber. Thanks to its own controller, the automation cell works independently and can even be connected to UGrind machines that are already in operation.

Naxos-Diskus Schleifmittelwerke GmbH will also have several innovations on display at the IMTS booth. One highlight is the new Airmento bonding for cold-pressed CBN grinding discs for double-sided face grinding. The newly developed binding stands out thanks to its optimized bonding strength, temperature resistance and enhanced damping behavior during grinding. Correspondingly longer tool service lives, improved conditioning ability as well as higher supply and feed rates for optimized material

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#### For more information:

DVS Technology America, Inc.  
Phone: (734) 656-2080  
[www.dvs-technology.com](http://www.dvs-technology.com)

## EMAG

### South Hall, Booth 339436

EMAG will showcase the VL 3 DUO, a compact machine used for the production of gear wheels at IMTS.

When EMAG launched the new TrackMotion automation system in 2015, it quickly became apparent that it not only focused on transporting parts, but on the perfect combination of machine tool, raw parts storage facility and a standard automation solution to create a highly efficient production line.

The consistent adjustment of the automation to the modular machines from its internal production makes it possible to create manufacturing systems using a modular kit.



EMAG is now unveiling another world first, a direct development of the modular machines in combination with the TrackMotion automation system — the VL 3 DUO.

When you first see the machine, you'll immediately notice how compact it is. "We need just 13 m<sup>2</sup> (140 sq ft) to install the complete VL 3 DUO," explained Andreas Frank, product manager for modular standard machines at EMAG. "For a twin-spindle vertical pick-up turning machine, that is a fantastic size. Even if the machine is combined with a raw parts storage facility and the TrackMotion automation system, the dimensions for a complete manufacturing system for chucked parts up to 150 mm (2 in.) is almost laughably small. That makes the VL 3 DUO one of the most compact and efficient systems available from EMAG."

With its parts ranging up to 150 mm (2 in.) in diameter, the VL 3 DUO is ideal for the manufacturing of gearbox

components, for example, machining blanks for gear wheel production. "Gearbox components such as gear wheels must be manufactured in very large quantities. The standard production process is always the same: in OP 10 and OP 20, both sides of the gear wheel blank are machined by a turning process and the surfaces are prepared; the gear cutting process follows in OP 30 and deburring takes place in OP 40," Frank explained. "The VL 3 DUO is, of course, primarily focused on the first process in this machining chain, in other words OP 10 and OP 20, which can be implemented perfectly with our system."



The VL 3 DUO can be fitted with EMAG's TrackMotion automation system as an option. The automation system consists of three central parts, the track (i.e. the rails) on which the TransLift NC gripper runs and the raw parts storage facility. The entire system is very compact and runs directly behind the machining areas of the VL 3 DUO. The TrackMotion always focuses on the individual component. Each transport process only moves a single component which allows for significant benefits for component management. The increased mobility of the TransLift, including the Z-axis, means that stackable pallets can be used on the raw parts storage facility, making it possible for the raw and finished parts to be stacked with minimal space requirements. In addition, the TransLift is also used as a changer between the two machining operations. This means that the TrackMotion automation system provides everything required for compact manufacturing on the VL 3 DUO: an extensive parts storage area that accommodates up to 400 parts and a fast, flexible parts transport system between the various manufacturing stations.

Like every modular machine, the VL 3 DUO has its own parts buffer and a

pick-up spindle in each machining area. The TrackMotion automation system loads the individual part pallets on the parts buffer as they shuttle between the loading position near the machining area and the rear section of the machine. From there, the working spindle takes the raw part, transports it into the relevant machining area and places the part back onto the appropriate pallet after it has been machined. Immediately next to it, the subsequent part is waiting to be picked up by the spindle, so that only a few seconds pass until the next part is being machined.

The machining areas are arranged in a mirror constellation and each has its own working spindle which, with a rating of up to 18.1 kW and torque of up to 142 Nm, has plenty of power for high speed, precision machining.

In addition, each machining area has a tool turret with twelve tool positions which can be fitted with turning tools or driven tools. "The turrets can also be fitted with an additional Y-axis to extend the range of uses of the machine even further," Frank explained.

The VL 3 DUO adds a highly productive, compact manufacturing system for large-scale production to EMAG's modular machine family.



"Its real strength can be seen when it is connected to other machines in the modular machine family," Frank continued. "Let's look at the example of gear wheel production mentioned above."

If we supplement the VL 3 DUO with the VL 4 H, the modular gear hobbing machine from EMAG Koepfer, and a VLC 100 CC or VLC 100 RC, the vertical chamfering and deburring machines, we create a manufacturing system for gear wheels which is completely linked using the TrackMotion automation system, with a very small footprint. The whole thing is made possible by the standard structure of the modular machines, the integrated automation system and the fact that the transfer height between the machines is always identical — it's simply brilliant! In other words, almost as simple as using building blocks."

**For more information:**

EMAG L.L.C.  
Phone: (248) 477-7440  
[www.emag.com](http://www.emag.com)

**Emuge Corp.**

**West Hall, Booth 431536**

At IMTS this year, Emuge Corp. will showcase its comprehensive line of clamping solutions. Emuge's workholding division specializes in providing highly accurate, almost maintenance-free customized solutions for

applications from low volume job shops to high volume automotive production environments. ([www.emuge.com/products/precision-workholding](http://www.emuge.com/products/precision-workholding))



"Our workholding group stays close to our customers to learn about their unique challenges and production environments. Doing so helps us develop the best solutions for their applications," David Jones, precision workholding manager at Emuge Corp., said.

The precision workholding lineup on display will include:

With its expanding-bush design, Emuge's System SG is used in many machining operations such as hobbing, shaping and shaving for gear production, as well as milling and inspection. The

System SG's large surface area contact with the workpiece provides a clamping solution which is very rigid, accurate and repeatable.

The high precision System SP is used not only to clamp workpieces but also to clamp tools. By applying an axial force, the clamping sleeves move in the direction of the force and expand radially. This eliminates the clearance between clamping sleeve and body and between clamping sleeve and workpiece. System SP achieves concentricity of < 0.002 mm (corresponding to < 0.0001 inch).

For workpieces that have a short clamping base or for diameters with a very large tolerance, System SZ is the best choice. By applying an axial force, a slitted collet is radially expanded by a cone. Simultaneously an axial movement occurs, clamping the workpiece.

When the eccentricity between pitch circle and seating bore is very small, diaphragm clamping System SM is ideal. It allows clamping of the gear wheel at the pitch circle for machining the seating bore. The gear wheel is clamped in both axial and radial directions.

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  - Shaper Cutters
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  - Chamfering and Deburring Tools
  - Broaches
  - Master Gears

We can produce virtually any tool you need for auto, aerospace, wind, mining, construction and other industrial gears.

Every tool is precision-made utilizing high speed steel, premium powder metal or carbide and the latest in coatings, to achieve superior cutting and long life. DTR uses top of the line equipment including Reischauer CNC grinders and Klingelberg CNC sharpeners and inspection equipment.

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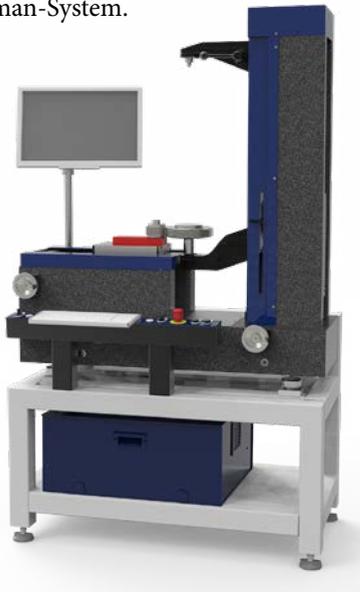
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Phone: (508) 595-3600  
[www.emuge.com](http://www.emuge.com)

### **Euro-Tech Corporation** **West Hall, Booth 432453**

Euro-Tech will be presenting the products of a few of the companies they distribute in North America for.



One example is Mytec-Hydraclamp's new Perman-System, which will be introduced at IMTS 2018. In recent years Mytec-Hydraclamp customers were looking for more loading clearance combined with high accuracy and stability due to the introduction of Industry 4.0, the networking of machines and factory automation. To meet that need they developed the hydra-mechanical-based Perman-System.



The mechanical clamping tool is directly actuated with the drawbar of the machine or permanent with springs while the hydra-mechanical clamping tool is actuated directly by the hydraulic system of the machine.

The technical advantages are high loading clearance, a runout accuracy of < 0,005 mm (0,0002"), high gripping force, pull-back function (axial clamping force) and modular design with an interchangeable collet (quick change).

At IMTS 2018, Frenco will also introduce the ZWP 30 for large gears, shafts and worms at Euro-Tech's booth. The ZWP 30 can work with workpieces up to 500 mm in diameter and features a high precise granite base, an ergonomic arrangement of controls, and widely adjustable height with a 30 mm opening path. There's also an optional fixture for worms.

**For more information:**

Euro-Tech Corporation  
Phone: (262) 781-6777  
[www.eurotechcorp.com](http://www.eurotechcorp.com)

### **Felsomat USA** **North Hall, Booth 237030**

Felsomat is a manufacturer of high precision machine tools and automation systems used in high volume automotive parts manufacturing. We specialize in gear manufacturing for automotive transmissions, cam manufacturing and assembly for engines and high performance machine tool loading systems for a wide range of automotive components.

**For more information:**

Felsomat USA  
Phone: (847) 995-1086  
[www.felsomat.com](http://www.felsomat.com)

### **Frenco GmbH** **West Hall, Booth 432453**

See Euro-Tech.

### **German Machine Tools of America**

#### **North Hall, Booth 237054**

German Machine Tools of America, founded in 1991 as the U.S. subsidiary of Profilator GmbH in Wuppertal, Germany and based in Ann Arbor, Michigan, today represents various lines of German machine tools and metal fabricating equipment, including gear cutting and honing, parts washing systems, special machine tools, tooling, laser welding, surface grinding and deburring machines, multi-spindle lathes, multi-station vertical turning machinery and more.

**For more information:**

German Machine Tools of America  
Phone: (734) 973-7800  
[www.gmtamerica.com](http://www.gmtamerica.com)

### **Gleason Corporation** **North Hall, Booth 237000**

At IMTS 2018, Gleason will demonstrate smart innovations in advanced gear manufacturing at their booth, covering a wide array of processes for the complete

production and inspection of all types of bevel and cylindrical gears. Highlights include hobbing with integrated chamfer cutting solutions, hard finishing of gears by Power Skiving, bevel gear grinding with integrated, fast automation and revolutionary multi-sensor metrology incorporating laser scanning for in-process inspection. These new developments are accompanied by the latest flexible workholding solutions and cutting tool technologies, like the new bevel gear cutting system Pentac Mono or new dressing tools for grinding and honing applications.

There will also be live demonstrations of the open software architecture of the new GEMS Gear Engineering and Production System that seamlessly integrates with the latest version of KISSsoft Gear and Transmission Design Software. Gleason's vision and current solutions for the factory of the future will be on display throughout all exhibits including tool-to-machine communication, Gleason Fingerprint for predictive maintenance and the introduction of augmented reality into maintenance and service.

**For more information:**

Gleason Corporation  
Phone: (585) 473-1000  
[www.gleason.com](http://www.gleason.com)

### **Kapp-Niles** **North Hall, Booth 237024**

The Kapp-Niles group specializes in the manufacture of gear grinding machines, including both profile grinding and generating grinding. In addition, Kapp-Niles manufactures dressing tools and grinding wheels for their machines. The Kapp-Niles Metrology division offers dedicated gear inspection equipment as well as a range of gages and other measuring tools.

**For more information:**

Kapp-Niles  
Phone: (303) 447 1130  
[www.kapp-niles.com](http://www.kapp-niles.com)

### **Klingelberg** **North Hall, Booth 236817**

With its closed loop system for cylindrical gears, a hybrid solution for optical measurement and a digital identification system for tools, Klingelberg is now engaged in three areas of innovation. The solutions provider will showcase these innovations at IMTS 2018.



Klingelberg is presenting the system provider's greatest innovations at the largest trade show for manufacturing technology in North America and will showcase what is possible these days in terms of digitalization in production. On that account, the mechanical engineering company is bringing the cylindrical gear generating grinding machine Speed Viper 300 with KOENIG Automation, the P 40 precision measuring center (into which the innovative optical measuring technology, Klingelberg Optical Metrology, will first come into use) and SmartTooling digital tool management to the stage. Each of these machines and solutions represent the newest in state of the art technology and work together in a cyber-physical production system in which every step in the value chain is described by a digital twin. Therefore, Klingelberg is setting benchmarks for production in the Industry 4.0 era. In June 2018, the trade magazine MM Maschinenmarkt just awarded the company the Best of Industry Award in the Industry 4.0 category.

A winner of the iF-Design Award, the Höfler cylindrical gear generating grinding machine Speed Viper was developed by Klingelberg with a very particular focus on high-production generation grinding in the large-scale series. To do this, the development team has further tested the boundaries of that which is technologically possible in productivity. With a cutting speed range of 100 meters/second, the Speed Viper 300 — which will be exhibited at the trade show — achieves extremely high productivity.



In doing so, the Speed Viper platform is optimally designed for the Industry 4.0 manufacturing environment. This most recent development makes it possible to connect cylindrical gear machines directly to the measuring devices. This technology is already being used successfully in bevel gear manufacturing. By transferring the closed loop concept established by Klingelberg to the world of cylindrical gears, the mechanical engineering company has made another systematic step toward digitalization in gear manufacturing. Due to a wide variety of associated applications and software, Klingelberg is implementing central production control using its cyber-physical production system, which will standardize rating results on different machines and even in different plants.

Klingelberg will have a measuring machine designed for these types of closed loop processes live at IMTS. The P 40 represents future-proof quality management of gears and it showcases Klingelberg's new, ergonomically optimized design. The fully automatic CNC-controlled precision measuring center is conceptualized as a compact unit for the workpiece diameter range up to 400 mm. The machine and software concept is optimized for the measurement of complex drive components using a technology that replaces up to six conventional measuring devices: gear measurement, general coordinate measurement, form and position measurement, roughness measurement, contour measurement and optical measurement. Maximum measuring and reproduction accuracies are guaranteed — the P series represents a widely used standard in the industry. The P 40 that Klingelberg is presenting at the IMTS is equipped with a unique feature.



Klingelberg has equipped a P 40 with the new optical measuring technology for the first time specially for the trade show. Klingelberg Optical Metrology is a smart combination of tactile and optical measurement. It combines the benefit of quick measured value logging using an optical sensor, with the flexibility and the extremely high accuracy of the tactile 3D Nanoscan sensor system. In this way, the hybrid system distinguishes itself through its extremely rapid changeover from the tactile to the optical system and is designed so that the optical sensors can be adapted in a number of ways. In addition to this combination, optical measured value logging alone is also possible, of course. The measuring result then takes the form of a high-resolution 3D point cloud, which can be further processed and evaluated as a CAD file. The optical measurement is a new, extremely efficient option for the precision measuring centers of the P 26, P 40, P 65, P 100 and P 100L series. At the IMTS, visitors can see the advantages of the P 40 demonstrated live.

With SmartTooling, Klingelberg is introducing a digital identification system for tools and clamping tools and is consistently further incorporating the bevel gear cutting machine into the Industry 4.0 subject area. With a look toward an extensive cyber-physical production system, it is a case of designing processes which are currently still carried out manually to be more efficient using software support and of establishing the basis for automation. SmartTooling facilitates traceability, and

with it, a 360 degrees view of the production equipment. The additional data that is currently available also provides a good basis for the identification of optimization potential in process improvement. The goal is to support customers both in reducing costs and in increasing production quality.

**For more information:**  
Klingelberg America Inc.  
Phone: (734) 470-6278  
[www.klingelberg.com](http://www.klingelberg.com)

## Koepfer America/Helios Gear Products

### North Hall, Booth 236906

Visit the Koepfer America / Helios Gear Products booth 236906 at IMTS to see and learn about the latest in gear manufacturing solutions with integrated automation. Located at the Gear Pavilion in the North Building, this exhibit will feature Koepfer CNC hobbing and automation technology, CNC hob and cutter sharpening technology, and the latest Monnier + Zahner (“MZ”) CNC hobbing and automation technology. You can also learn about world-leading automated gear deburring and chamfering solutions, worm milling machines, cutting tools, and hard finishing solutions.

**For more information:**  
Koepfer America  
Phone: (847) 931-4121  
[koepferamerica.com](http://koepferamerica.com)

## Leistritz

### North Hall, Booth 237052

Leistritz has developed internal whirling, a process to cut long internal threads without tilting the tool at helix angle. The method utilizes the bore to support the carbide or CBN cutting tool for extremely accurate profiles and overall geometries. This special purpose machine, model LWN-120-IW has high frequency oscillation to cut threads with high helix angles and/or multiple starts. .

**For more information:**  
Leistritz  
Phone: (201) 934-8262  
[www.leistritzcorp.com](http://www.leistritzcorp.com)

## Liebherr

### North Hall, Booth 236914

Liebherr Automation Systems will demonstrate its new PHS Allround pallet handling system, designed to enable a broad range of shops to engage in flexible production in combination with 4- and 5-axis machining centers, at IMTS

2018. The new modular concept, available in three capacities, can handle loads up to three tons, is extremely flexible and can be individually configured and expanded. This corresponds to pallet sizes of 500×500 mm to 1000×1000 mm. Users can introduce flexible production systems with manageable investment and expand them when necessary.



The customer is able to combine pre-configured modules as needed to match production handling needs: the storage locations can be arranged in a circular pattern, with one or more machines, or in a line.

According to Liebherr, this extremely space-efficient system fits in almost every production floor. The user can easily expand a production system with the Allround, spreading investment over different expansion stages. It is no problem to start with one or two machines and increase this number to five, for example, as production changes.

For all Liebherr pallet handling systems (RLS, PHS Pro and PHS Allround), Liebherr offers a new cell control with simple operation as its priority. The new graphically-guided interface concentrates functions on the main computer in a user-friendly manner, and if required also allows full production control. This includes resource planning, cutting tools and NC data management plus also interfaces to the ERP systems.



Liebherr will also demonstrate its

gear skiving process on its LK series machines based on the tried-and-tested components of the corresponding large hobbing machines but equipped with greater rigidity and more powerful spindles. A gear skiving machine requires a table with a direct drive owing to the high workpiece speeds required. This drive works with an automatic control that constantly has the optimal parameters. The complex clamping fixture, which links the workpiece and the machine, is designed by Liebherr.

As skiving is a highly dynamic process, the machine is supplied on a “turn-key” basis with individual clamping fixtures for each workpiece, precise rigidity and contour accuracy.

“This overall view is an important part for the production success,” explains Siegfried Schmidt, team leader in development and design of skiving. “A complex process such as skiving has many specific obstacles, which we overcome with very specific mathematical solutions.”

With its skiving3 program, Liebherr not only provides the LK 300 or 500 skiving machine, but a whole process, including machine, tools and technology for gear production. This integrated approach from Liebherr has already been tried and tested in practice. For many customers, the process of skiving is new, and therefore the operators of the machines need comprehensive training and assistance. On top of that, the tool design is a very complex issue

Skiving3 is especially popular for internal gearing with medium size and quantity as it is much faster than shaping and more economical than broaching. In situations where gear skiving is not possible or appropriate, owing to interfering contours or quantities that are too low, Liebherr still offers technological alternatives with gear shaping and gear hobbing.

The newly developed LHGe@rTec control system also contains the mathematical formulas for pressure angle corrections. This way, quality improvements can be easily achieved via the kinematics of the machine.

The optional tool changer, which can be used to change between roughing and finishing tools, for example, is new. Liebherr offers a ringloader as a standard option for the workpiece changing

device; other automation solutions, such as belts and robots, can also be realized upon request.

**For more information:**

Liebherr Gear Technology and Automation Systems  
 Phone: (734) 429-7225  
[www.liebherr.com](http://www.liebherr.com)

**Luren Precision  
 North Hall, Booth 237058**

Luren offers machine tools for manufacturing gears, including the new LVC-100 CNC Spiral Bevel Gear Cutting machine. In addition, for over 20 years, Luren has been offering a wide variety of custom and standard gear cutting tools.

**For more information:**

Luren Precision  
 Phone: (847) 882-1388  
[www.lurenusa.com](http://www.lurenusa.com)

**Mahr  
 East Hall, Booth 135608**

Mahr Inc. will highlight the new MarSurf contour drive (CD) series of surface finish and contour measurement systems, the MarSurf CM series of Optical 3D surface metrology systems and Micromar series of digital

micrometers at IMTS 2018.

Attendees can visit the Mahr booth and take a photo with the Joe Gibbs Racing No. 18 M&Ms Toyota Camry driven by Kyle Busch. Those that post images to Twitter with #MahrWins will be entered to win official Joe Gibbs Racing memorabilia. Joe Gibbs Racing engineers leverage Mahr precision measurement tools to ensure the highest quality and performance for their NASCAR Cup Series championship drivers.

The MarSurf CD series takes contour measurement to never before seen levels of speed, flexibility and precision, allowing users to improve the manufacturing quality of workpieces with faster throughput, higher accuracy and flexibility for a broader range of workpieces. The MarSurf CD allows for the measurement of the shape of a surface, often referred to as the contour or form, and provides dimensional information such as angles, depths, distances and radius.



The ground-breaking designs of the new MarSurf series significantly increase the speed of all moving axes to reduce the cycle time of the measurement process, allowing more throughput. The drive units of the MarSurf CD series move the contour probe with positioning speeds of up to 200 mm/s, making the systems up to 25 times faster than predecessors. All Z-axis columns on the measuring stands of the MarSurf CD

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series are fully CNC-capable with fast positioning speeds of 50 mm/s, which is twice as fast as previous systems and five times faster than others on the market. The high dynamic response of the probe system also allows for significantly higher measuring speeds with newly-designed probe arms.

The new MarSurf CM's innovative confocal technology with high-precision 16-bit HDR technology delivers high-resolution 3D surface topography data, enabling new insights into surface structures and processing. MarSurf CM systems provide micron and nanometer resolution surface finish and micro-geometry information including: 2D and 3D surface roughness, bearing area, flatness, depth, volume and much more. The technology allows for the physical acquisition of a true-height signal as opposed to measuring height via pixel contrast, pattern projection, etc. Confocal technology can be used on any material from highly light scattering to highly reflective. Stable construction and a robust optical principle produce reliable results that can be used in laboratory or production environments.



Mahr will also be introducing its expanded range of Micromar 40 series digital micrometers. The Micromar 40 EWRi-L micrometer, with its high-speed measuring spindle positioning, allows for making measurements 10 times faster than a standard micrometer when numerous different dimensions need to be measured on one workpiece. The “non-rotating” sliding spindle also protects sensitive workpiece surfaces against measuring damage, and the integrated wireless system enables the measurement to be very convenient. Versions are also available with MarConnect data processing where the data output format is selected by the cable — either RS-232, USB or Digitmatic.

In addition, a series of new capacities for the Micromar 40 EWRi digital micrometer with integrated wireless data transmission are being unveiled at the show. The Micromar 40 EWRi digital micrometer is now available in eight ranges of 0 through 8" in 1" increments (0 through 200mm in 25mm increments), setting new standards. Similarly, a complete line of 40 EWR micrometers is also available in wired versions using Mahr's unique MarConnect interface. These micrometers feature 10 mm digits on a high contrast digital display, an easy to understand tolerance display with warning limits, a reference system that requires the zero position to only be set once and a “hold” function where measured values can be “frozen” on the push button and can be safely read off from a machine.

Attendees will also have the opportunity to trade up to a new wireless digital caliper at the booth. Those who trade in a digital caliper from specific competitors will receive a new MarCal 16 EWRi digital caliper at no cost. Quantities will be limited and available on a “first come, first serve” basis daily.

**For more information:**  
Mahr Inc.  
Phone: (401) 784-3100  
[www.mahr.com](http://www.mahr.com)

**Mitsubishi Heavy Industries America, Inc.**  
**North Hall, Booth 237036**

AT IMTS 2018, Mitsubishi Heavy Industries America, Inc. will be displaying gear cutting and gear grinding technology designed for high productivity. Utilizing Super Dry hobbing, the model GE15A gear hobbing machine can also be equipped with an on-board chamfering station providing multiple processes.



Additionally, MHIA will display the ZE24B generative gear grinder. Designed for mass production, the ZE24B has an automatic parts loader and can perform gear tooth polishing with a single setup using a compound grinding/polishing wheel.

Both the GE15A hobbing machine and the ZE24B gear grinder represent Mitsubishi's legendary reliability in gear manufacturing.

**For more information:**  
Mitsubishi Heavy Industries America, Inc.  
Phone: (248) 669-6136  
[www.mitsubishigearcenter.com](http://www.mitsubishigearcenter.com)

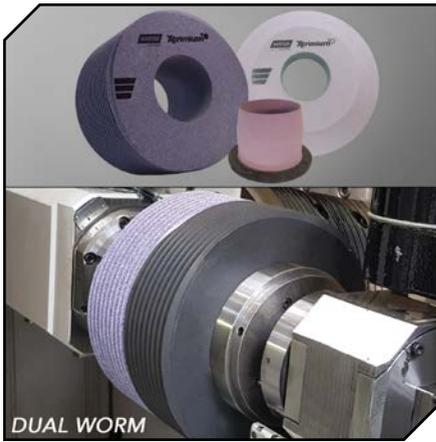
**Nachi America**  
**West Hall, Booth 432024**

Nachi offers machines for gear manufacturing, including the new GMS450 skiving machining center for gears, with integrated skiving, drilling and turning functions. Other machinery offered by Nachi includes broaching, roll-forming, skiving and shaping machines. The cutting tools division offers a wide variety of gear cutting tools, including broaches, hobs, shaper cutters and shaving cutters, as well as resharpening and coating services.

**For more information:**  
Nachi America  
Phone: (317) 530-1001  
[www.nachiamerica.com](http://www.nachiamerica.com)

**Norton | Saint-Gobain Abrasives**  
**North Hall, Booth 237042**

Taking center stage at Norton | Saint-Gobain's booth at IMTS will be the Norton Xtrimium range of gear solutions designed for high performance gear grinding in extreme, tight tolerance environment. The newly structured portfolio of gear grinding products is specifically designed by category to provide higher profile accuracy, supreme form holding and burn-free grinding in worm, profile and bevel applications. Highlighting the new range is an innovative dual-worm wheel design that enables two operations in one grinding wheel, substantially saving time and cost.



“In today’s increasingly stringent industry requirements for higher accuracy and improved surface finishes, our new high performance Xtrimium grinding wheels are engineered to deliver the highest quality gear grinding solutions,” said Jim Gaffney, senior product manager, Norton | Saint-Gobain.

Norton Xtrimium Dual-Worm grinding wheels feature a unique design with a high-performance vitrified bond section for grinding and a fine-grit resin section for polishing the gear teeth, enabling one wheel to perform what traditionally required two wheels. Substantial savings in wheel costs and productivity via the elimination of wheel swapping can be achieved with the Norton design. In addition, improved surface finishes of Rz = 1.0mm and Rpk = 0.05mm, and reduced harmonics (noise) are realized. The Norton Xtrimium Dual-Worm Grinding wheels can also be adapted to existing machines.

The Norton Xtrimium gear grinding platform also covers the whole range of gear grinding processes and leverages the whole spectrum of Norton grains and bond technologies to match each customer’s requirements, whether with:

Worm grinding wheels featuring micro-structured ceramic grain and providing free cutting action and wheel homogeneity, allowing constant performance throughout the wheel thickness for the life of the wheel. Superior grinding rates and increased form holding without burn are achieved with these worm grinding wheels.

Profile grinding wheels, which are ideal for deep profile gear grinding. The wheels feature high porosity and permeability, create exceptionally high material removal rates, and friction-free grinding.

Bevel grinding wheels featuring a highly porous bevel formation for extremely fast, burn-free cutting.

**For more information:**

Norton | Saint Gobain Abrasives  
Phone: (508) 795-5000  
[www.nortonabrasives.com](http://www.nortonabrasives.com)

**Oelheld  
North Hall, Booth 237475**

Oelheld will be introducing two new grinding oils. The first is the ToolGrind TC-X 620. The fluid is based on additive technology borrowed from Oelheld’s flagship SintoGrind series. ToolGrind TC-X 620 is formulated with highly refined base oils that have very good viscosity and temperature characteristics combined with low misting and aromatic content.

ToolGrind’s fortified additive package allows the oil to perform well under extreme pressure. Its active agents guarantee favorable cooling, wetting and lubrication. None of the additives contain chlorine, silicone or heavy metals and they are all non-toxic.



ToolGrind TC-X 620 promotes clean grinding wheels, low grinding temperature and less wheel wear. It prohibits work piece corrosion and is suitable for most filtration systems. The operative range covers all high speed grinding operations, such as profile, groove and surface grinding, with CBN, diamond or silicon carbide wheels. ToolGrind TC-X 620 is suitable for use with tungsten carbide, HSS, PCD, CBN, cermet and ceramics.

Oelheld is also adding the SintoGrind TC-X 630 as the new entry level product to its flagship and perennial best-selling SintoGrind series. SintoGrind TC-X 630, with its new base oil technology, will set new standards in productivity, surface finish and grinding wheel wear. The product is designed for flute grinding, profile grinding and outside and inside diameter grinding.

SintoGrind TC-X 630 works on a wide variety of materials including tungsten carbide, HSS, PCD, CBN, cermet and ceramics. SintoGrind TC-X 630 was especially formulated for demanding grinding tasks and delivers exceptional feed and speed rates with superior surface finish. Its lubricity lends to extended wheel life and minimal heat build-up, which in turn eliminates surface cracks and burns. It contains no hazardous elements and exhibits stable viscosity over a wide temperature spectrum.

Features which make both of Oelheld’s oils stand-out products include protection against cobalt leaching, low foaming, immaculate surface finish, superior aging, excellent flushing and cooling properties, low evaporation and misting, high flash point, physiologically safe composition and a pleasant odor.

**For more information:**

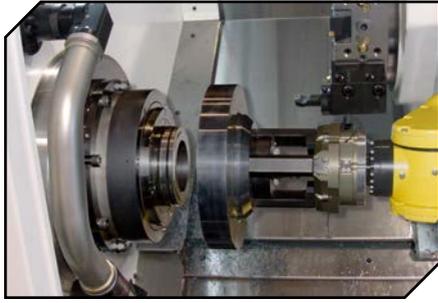
Oelheld U.S., Inc.  
Phone: (847) 531-8501  
[www.oelheld.com](http://www.oelheld.com)

**Penta Gear Metrology  
North Hall, Booth 237024  
See Kapp-Niles.**

**Positrol  
West Hall, Booth 431201**

Positrol’s Automation Chuck Change System enables an industrial robot to fully automate workholding changeovers. This is accomplished without the need for indicating in the chuck before beginning machining operations. The Automation Chuck Change System is designed to provide a quick change solution for not only chuck mounting, but also includes support for a power actuated drawbar as well without sacrificing rigidity. When paired with a robot, it operates as a fully automated cell where the robot not only loads and unloads parts but performs complete workholding changeovers without manual intervention. Through implementation of

quick connects for both the chuck and drawbar, multiple operations can be run across the same spindle.



Positrol's Automation Chuck Change System can be installed on lathes, mills, balancers and gear equipment. It accommodates any drawbar and most common machine spindle sizes. Repeatability accuracy for the X, Y, and Z axes are within .0001" TIR and an angular repeatability within  $\pm 3$  arc seconds. Sealed to account for chips and other contamination, Positrol's Automation Chuck Change offers low maintenance, faster changeovers and fully automated machining capabilities.

Positrol offers a wide array of chuck and arbor designs to allow for flexibility in tailoring a workholding solution to help maximize machining efficiencies and workpiece accuracies. Positrol specializes in providing both standard and custom solutions for turning, grinding, milling, balancing, and gear operations.

Positrol's complete product line includes Pos-A-Lock collet arbors, Chuck Change systems, hydraulic membrane chucks and arbors, cartridge chucks and arbors, drawdown chucks, split diaphragm chucks, swing arm chucks, swivel-grip chucks and Superior Cincinnati collet pads and chucks.

#### For more information:

Positrol Workholding  
Phone: (513) 272-0500  
[www.positrol.com](http://www.positrol.com)

#### Reishauer

##### North Hall, Booth 237030

Reishauer offers generating grinding machines for both automotive and job shop production, as well as grinding wheels and dressing tools to support those machines.

#### For more information:

Reishauer  
Phone: (847) 888-3828  
[www.reishauer.com](http://www.reishauer.com)

#### Siemens Industry East Hall, Booth 134502; North Hall, 215004

At IMTS 2018, Siemens Industry, Inc. will present its popular Sinumerik CNC hardware and software solutions, offering dual tracks for the machine tool builder and end-user attendees from job shops and production departments of all types. Advancements in machine tool automation will be demonstrated for various CNC machines—from basic milling and turning applications to multi-axis machining centers and the fully automated, flexible work cells used throughout the manufacturing industry. In addition, Siemens will display its new Mindsphere "software as a service" concept, which enables machine tool users to gather, prioritize and access data in real-time, using edge technology.



Reflecting the company's drive to the digital factory, a virtual experience for machine tool design and build functions will be presented to the OEMs, while end-users will experience how the machines used on their shop-floors will be operated, managed, programmed and maintained in the future. In combination with the advanced motion control technologies and PLM services offered by Siemens, the full process chain from CAD to CAM to virtual simulation to production and performance assessment will be on display.

#### For more information:

Siemens Industry  
Phone: (847) 640-1595  
[www.usa.siemens.com/cnc](http://www.usa.siemens.com/cnc)

#### Slater Tools

##### West Hall, Booth 432139

Slater Tools will unveil their comprehensive line-up of CNC broaching tools, toolholders and gages for complete machining and quality control over the full spectrum of shape making. In total, the company's rotary broach tools

and toolholders, punch broach tools and toolholders, and go/no-go gages represent the most comprehensive product offering of its kind available.



Rotary broaching is a highly productive method for making hex, square, serration, spline and many other specific shapes in a variety of materials on CNC machines. Slater's rotary broach tools are designed and manufactured to precision tolerances in a full range of internal and external shapes and diameters as both standards and specials—where the company can turn around custom orders in as little as one day. Multiple series of external and internal rotary broaching toolholders are offered, including adjustment-free versions, providing the needed connection between machine and tool that makes this operation so fast, economical and accurate.

Punch broaching offers excellent performance in applications where rotary broaching may not be suitable. Such instances include tough materials, greater depth of operation and/or tooth height, chip evacuation challenges and operations that require orientation. It is also beneficial for applications requiring no witness (pre-drill) marks, with excessive material removal, or where timing the form to a feature on the part is required. Keyways, hexagons, Torx-style sixlobes, serrations, splines and squares are all machined by using partial form broach tools and indexing either the tool or the workpiece, which in turn greatly reduces cutting pressure. Indexable punch broach holders facilitate the process and provide high-repeatability on CNC lathes, milling machines and presses.

"We have continued to add solutions for customers requiring products

and support over such a broad range of [shape making] applications,” says Kris Renner, Slater Tools director of operations. “There has been a continuous stream of new and custom products, including tools and holders, and now the full range of inspection gages to meet all of their needs.”

To ensure print tolerance compliance and eliminate process variations such as form size, twist and tool wear in popular shape making, Slater offers its line of standard and custom go/no-go gage sets for customer-specific applications. These gages are held to extremely tight tolerances, within .0002 inches (.005 mm), produced from oil hardened M2 high speed steel and can be custom made to any shape or size to fit customer needs. All plug and ring gages are offered for numerous shapes, either as full form composite, sector or progressive forms. Slater Tools also offers long form gage certification upon request for those applications and industries that require it.

**For more information:**

Slater Tools  
Phone: 586-465-5000  
[www.slatertools.com](http://www.slatertools.com)

**Solar Manufacturing  
North Hall, Booth 236341**

Solar Manufacturing manufactures vacuum furnaces for heat treating gears and other parts.

**For more information:**

Solar Manufacturing  
Phone: (267) 384-5040  
[solarmfg.com](http://solarmfg.com)

**Star SU  
North Hall, Booth 236909; West Hall,  
Booth 432258**

The Star SU team of product and technology experts will be available at two booth locations — one in the gear pavilion in the North Hall and another in the West Hall showcasing their cutting tool technology.



The North Hall booth in the Gear Pavilion will feature two machines: The FFG Modul H200 vertical gear hobbing machine and the new Star NXT tool grinder. They will also have video demonstrations of their latest grinding advancements, including the Samputensili SG 160 Sky Grind, the first gear dry grinding machine in the world. The G-160 wet grinding head will also be on display. Additionally, visitors will be able to view Star SU's enhanced interactive customer solution tool for Star SU's full line of machine tool, cutting tool and tool services from the brands they represent including Star Cutter Company, Samputensili, FFG Werke (Modul and Hessapp) and H.B. Carbide.

The centerpiece of Star SU's display, the Star NXT Tool Grinder, was designed with big machine capabilities and small machine footprint. Star SU intends for this revolutionary design to be the new standard.

Star's latest CNC 5-axis tool grinder is built with the purpose of meeting and exceeding what the market demands: a versatile tool grinder with less moving parts and a small footprint, a large grind zone, the ability to run small and large diameter wheels, with easily configurable options, a modular design, and a competitive price point.

The NXT fuses the best aspects of Star SU's current product line into a next generation machine that offers benefits of smaller size, greater diversity, increased capability, flexibility, durability and added value.

Features include a focused design to deliver a maximized grind zone with a small footprint of 2 meters wide, the smallest footprint to work envelope ratio on the market, 28kW synchronous spindle @20,000 rpm, up to 250 mm diameter tools, Fanuc robot automation with 3-38 mm gripper assembly and NUMROTOplus: the best grinding software worldwide. The NXT is engineered with the latest in linear and rotary torque motor technology to eliminate backlash, friction effects and drive vibration. Application support is available to train operators and manufacture all of your complex tools. The NXT is designed, manufactured and serviced in the USA.

Star SU will also be showing off the FFG Werke Modul H200 vertical

hobbing machine. The H 80-200 series is the latest version of the company's hobbing machine line for automotive as well as Job Shop applications. The optional automatic high-speed part changer is especially engineered for automotive applications with less than two seconds chip-to-chip time. These machines have been designed for dry cutting applications in particular, although using oil or emulsion is not a problem. Chips are conveyed immediately from the work area by means of steep and smooth stainless steel glad chutes to prevent any build up. The hob head is housed within the tool column, which is tightly fastened to the sturdy machine bed. The CNC tailstock is located on the counter column and cross bar above the hob head, leaving the work area remarkably free for workpiece loading and unloading operations. Request a budget quote and plan to see it at IMTS by visiting Star SU's H 80-200 vertical gear hobbing machine webpage.



Star SU will also show a wide variety of gear cutting tools, precision tool re-sharpening services and advanced coatings from Oerlikon Balzers, including Alcrona Pro and Balanit Altensa, the high-speed coating solution that realizes productivity gains and efficiency. Star SU will also feature their highly coveted Scudding cutters manufactured to produce gear and spline teeth for reduced cycle times and tool costs.

Star SU also welcomes visitors to join them at their West Hall tooling booth to see their complete offerings from their technology partners, including Star Cutter Company, Samputensili, Neher, 5ME and H.B. Carbide.

Star SU carries a full line of gundrills and deep hole drilling solutions, including single flute gundrills, solid carbide single flute gundrills, two-flute two-hole gundrills, double jet gundrills, double

crimp gundrills, deep hole twist drills, rifle buttons pull reamers and push reamers. Come by and let Star SU design and build a gundrill solution for you.

Star SU also offers a wide range of precision solid carbide drills and reamers, including solid and braze construction carbide drills and reamers; core drills; Super Round Tool (SRT) reamers; valve guide reamers and multi diameter cavity machining tools.

Also on display: 5ME cryogenic machining combined with Star SU BlueZone ventilated end mills, tapered ball mills, reamers and drills, designed to create a more profitable and efficient manufacturing experience by reducing the cutting temperature, using liquid nitrogen, to -321°F.

Star SU/Neher produces high performance PCD tools that are engineered to customer requirements. Their wide range of PCD products include circular milling tools, face milling tools, combination tools, counterbore tools, precision reamer/multi-step reamers and PCD drills. Their PCD products can be applied to all types of non-ferrous materials.

Finally, Star SU offers a wide variety of tungsten carbide blanks and preforms from H.B. Carbide. Using only the highest quality raw materials and employing state-of-the-art, computer controlled vacuum Sinter-Hipping furnaces, these cemented carbide preforms can be used for cutting tools, dies and wear parts in a variety of specialized applications.

#### For more information:

Star SU LLC  
Phone: (847) 649-1450  
[www.star-su.com](http://www.star-su.com)

### Suhner

#### West Hall, Booth 431474

Suhner Industrial Products now offers robot solutions for fully-automated manufacturing. The new quick change tool system offers a number of powerful machine tools that can be mounted directly on the robot arm and be ready for continuous use.



The Suhner power-pack robot machine tools are compatible with all robot manufacturers, making them versatile for demanding high-performance applications. The tools feature programmable touch forces of the active flange and interactive surface tracking. This allows operations that were previously not suitable for automation to now be automated. Other features include programmable process forces, balanced tolerances (shapes) and reduced programming time and effort for complex parts. Performance and process assurance compared to known systems, such as load cells, can be drastically increased.

Tools are available for brushing, polishing, filing, belt sanding or tool spindles, and are easily integrated.



Applications for the new robot tools range from automotive manufacturing to deburring operations, stainless steel machining to drilling and tapping operations, and all areas of manufacturing and operations.

Suhner worked in cooperation with Ferrobotics, world leader in development of flexible, intuitive robotic equipment to develop the equipment.

#### For more information:

Suhner Industrial Products Corporation  
Phone: (706) 235-8046  
[www.suhner.com](http://www.suhner.com)

### Toyoda Americas

#### South Hall, Booth 338519

Combining lean thinking with cutting edge solutions, JTEKT Toyoda Americas Corporation plans to unveil 6 new machines of their 15 featured during IMTS 2018. Toyoda's anchored position in the South Hall will exhibit live machine tools, automation, IoT solutions and innovative presentations. New machine exhibits include a 5-axis VMC for titanium machining, universal grinding machines with adjustable wheelhead, a multipurpose turning center with twin

turret and twin spindle and a production type machine for gear manufacturing.

Coming off Toyota's GS300H win at the 2017 Automotive News PACE Awards for its high-speed synchronization technology, Toyota recently released its compact sibling, the GS200H, targeting high production lines. Offering improved productivity and flexible machining by integrating gear part processes of a lathe, gear skiving and machining center capabilities in one.

Making its United States debut, the Takisawa Taiwan MX-800 multi-purpose turning center, is built for process integration and high productivity. Standard with heavy duty twin upper T15 turrets, built-in twin spindle and twin Y-axis, 2" bar capacity (up to 2.5") and 8" chucks.

Among new product releases are Toyoda's latest production advancements in pursuit of the most efficient machining methods. Revolutionizing shop floors into smart factories, Toyoda takes the fundamental approach of IoT combined with their rich automotive production history to encompass what they call IoE (Internet of Everything). IoE encompasses connectivity, data transmission and analytics of both people and machine — all fundamentals of Toyota's "Andon" system.

Toyoda's smart manufacturing product initiatives include connectivity solutions Toyopuc Plus and Nano PLCs, visualization solutions Machine Metrics, Toyopuc Touch HMI and Signal Hop, and value solution Toyopuc Touch AAA.

#### For more information:

Toyoda Americas Corporation  
Phone: (847) 253-0340  
[www.toyoda.com](http://www.toyoda.com)

### Wenzel America

#### East Hall, Booth 135622

Wenzel America are showing three new products at IMTS for the first time in North America. These three products represent each of the company's three hardware product specialties: metrology, high-speed optical scanning and computed tomography (CT).

The new SF 87 coordinate measuring machine is the ideal entry-level unit for any manufacturing environment. Its use of temperature compensation, dirt resistant guides and optional active damping make it ideal for locating alongside cutting and forming machines on the

shop floor. It has a measuring volume of 800×700×700 [mm], which is optimal in relation to its small footprint and has available the full range of Renishaw probing systems as well as Wenzel's laser and structured light sensor options. Its ridged cantilever design enables it to have high traversing speeds and acceleration to ensure high productivity and, best of all for some, it has a tremendously competitive price performance ratio.

Also on display in the Wenzel Booth is the latest version of the highly successful Wenzel Core-D high-speed optical scanning machine that is widely used for measuring polished turbine blades and medical implants. The unique feature of the Core machine is that despite being an optical system, its unique double-eye spot sensor can measure even highly polished surfaces without the need to coat the parts to dull reflection. Many optical systems are claimed to be able to scan "shiny" surfaces but the Core will measure polished or recently machined metal and the surfaces never need to be sprayed. Features of the new machine include enhanced environmental protection from temperature variation and shop floor dirt as well as a greater capability to integrate with automation. The latest version also makes available a structured light sensor for collecting point clouds in addition to the Core's unique double-eye spot sensor.

IMTS sees the North American launch of the exaCT S90 High resolution micro CT machine which will be scanning parts live at the show. This is the first exaCT S machine to utilize GPU processing power for reconstruction which in combination with state of the art detector allows unprecedented scanning and reconstruction speed. The ideal size of parts targeted by the exaCT S range from a pin-head to a hockey puck and it is particularly suited to micro-machined and molded medical device parts and implants.

**For more information:**  
Wenzel America, Ltd.  
Phone: (248) 295-4300  
[www.wenzelamerica.com](http://www.wenzelamerica.com)

## Zoller West Hall, Booth 432018

As a long-standing exhibitor at IMTS, Zoller knows that the technology and innovations on display at IMTS are shaping the future of the manufacturing industry. Zoller is committed to bringing the most efficient processes to the U.S. market as they have done since 1997.



In today's ever changing production environment, how do companies of all sizes go about meeting increasingly rigid quality standards faster while simultaneously saving money? The answer is simple: Zoller *Smart Factory Solutions*. To start, companies need to know that the tooling data they are working with is consistent across their facility.

With transparent data transfer between the Zoller *TMS Tool Management Solutions* software and CAM software, manufacturers can ensure that their 3D tooling models are produced correctly. Thanks to the central »z.One« tool database, tooling data remains consistent, regardless of who is accessing it. From the CAM software, Zoller solutions aim to focus on optimizing tool storage, organization and management next by integrating powerful *TMS* software with the extraordinary new Zoller Smart Cabinets.

With Zoller's *TMS* in conjunction with Zoller Smart Cabinets, each tool storage cabinet can be designed and graphically displayed in the software, and single components, tool assemblies and accessories can be tracked down to the individual compartment of the specific drawer and cabinet in which it's stored. Time spent looking for tools is eliminated, as Smart Cabinets provide total tooling control.

Zoller's solution doesn't stop there. Thanks to Zoller's user-friendly »pilot

3.0« operating software, measuring the most complex tool geometries is a simple task. With Zoller's tool presetting solutions, setup times are drastically reduced, while spindle up-time is increased. Companies are able to preset tools for upcoming jobs while current jobs are running, and they have the insurance of knowing that their first part is the right part, every time. This helps significantly reduce scrap and waste in manufacturing. With data output, tool offset information can be directly communicated to the machine control, eliminating potential human-error in data transfer.

At IMTS 2018, these integrated Smart Factory solutions from Zoller will be demonstrated live at their booth in one cohesive product demonstration called 'Art-to-Part.' Visitors will see how Zoller solutions tie together to make smart, connected manufacturing a reality today.

Manufacturers globally have been benefitting from Zoller's easy to use manufacturing solutions for over 70 years. Building a tool database can take time, but Zoller is there to assist in the database development process and make the transition as smooth as possible.

Zoller is committed to providing solutions to an increasingly demanding manufacturing environment. In partnering with Zoller, companies get to experience how Zoller's smart factory solutions are tailored for the challenges of Industry 4.0 they are facing currently, while concurrently feeling the security of knowing that Zoller will be there to work with them as they tackle the manufacturing challenges of the future.

**For more information:**  
Zoller Inc.  
Phone: (734) 332-4851  
[www.zoller-usa.com](http://www.zoller-usa.com)





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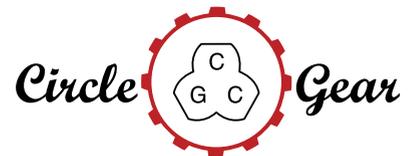
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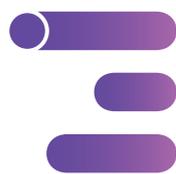
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# FNA 2018

## Furnaces North America Exhibition Highlights Future of Heat Treating

Matthew Jaster, Senior Editor

The 13<sup>th</sup> edition of Furnaces North America (FNA) is produced by the Metal Treating Institute and its media partner, *Industrial Heating Magazine*. Established in 1995, FNA brings top suppliers and heat treaters, both captive and commercial, from around the world to one location for technical education, networking, and the latest developments in furnace equipment, accessories, and services. Attendees from 17+ countries will arrive in Indianapolis, Indiana October 8–10, for 35 technical sessions, a two-day trade show and an array of business and networking opportunities.

### Technical Sessions

FNA's Educational Conference is designed by a team of heat treaters and suppliers to ensure the program has topics that hit at the needs of attendees. The following contains a list of technical sessions during FNA 2018 that might be of interest to *Gear Technology* readers:

#### October 9th

##### *Applications Advantages of the All-Metal Vacuum Furnace Hot Zone*

**Bill Jones & Re'al Fradette - Solar Atmospheres  
(8:00 am–8:35 am)**

The all-metal vacuum furnace hot zone was introduced into the commercial heat treating world in the 1960's, for processing special electronic metals like tantalum anodes for electrolytic capacitors, critical materials for the atomic energy industries and for the development of space and rocket engine materials, and "leading edge" surfaces. Today's applications center on medical uses, electric power interruptors, and processing of sensitive materials such as high alloy SS, titanium, and zirconium. We will present an overview of all-metal hot zone construction, proper design of the high vacuum pumping system, and integration of the argon gas cooling system with high vacuum isolation valves.

##### *Product Improvement and Predictive Maintenance Advancements Via the Application of the Industrial Internet of Things (IIoT)*

**AFC-Holcroft  
(8:00 am–8:35 am)**

This presentation will review the process, identify stakeholders, and outline how everyone benefits from the quickly evolving utilization of equipment data telemetry to drive continuous improvement. We will discuss more advanced data accumulation and data processing methods that can directly or indirectly identify growing equipment performance issues as we continue to take advantage of the Industrial Internet of Things.

##### *High Volume Small Part Heat Treating: An Alternative to Mesh Belts*

**Sam Stoner – Seco/Warwick Corporation  
(8:50 am–9:25 am)**

This facts and figures presentation shows the math behind why rotary retort furnaces are replacing mesh belts. Besides a cost/benefit analysis, this talk addresses the superior metallurgical results obtainable from this furnace. For high volume parts producers who have never heard of a rotary retort, or for those who remember rotary retorts of yesteryear, this presentation offers compelling reasons to consider a new rotary retort furnace.

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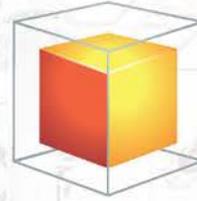
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### ***Carburizing to FNC and Back Again: Getting the Most Out of Your BIQ for CQI-9***

**Surface Combustion, Inc.**  
**(9:40 am–10:15 am)**

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### ***Fundamentals of Developing a Marketing Strategy for Commercial Heat Treaters***

**Ipsen USA**  
**(10:30 am–11:05 am)**

This presentation will examine common marketing strategies, why they are important for commercial heat treaters and tips to begin developing a marketing plan.

### **October 10th**

### ***Implementing Low Pressure Gas Carburizing on the Shop Floor: A Case Study***

**Daniel H. Herring – The Herring Group, Inc.**  
**(8:00 am–8:35 am)**

How does one go about implementing an advanced technology such as low pressure vacuum carburizing on the shop floor? What are the factors that need to be considered and what tests/trials are necessary to make a successful transition from atmosphere to vacuum carburizing? This presentation addresses many of the most important issues.

### ***Versatility of Modular Furnaces: The Heartbeat of your Multiple Requirements and Expectations for Heat Treatment***

**Vincent Esteve - ECM USA, Inc.**  
**(8:00 am–8:35 am)**

Achieving the best fit of heat treatment for your parts is the target of LPC modular furnaces by their sizes, their capacity to perform different processes at the same time, and the working range of temperature of the heating cells. This presentation will show how these furnaces suit your requirements for productivity, distortion control, metallurgical expectations, and working environment. Each process has its own solution according to the main objective of the heat treatment operation.

### **Exhibitor Previews**

The following section includes previews from exhibitors in areas of manufacturing covered in the pages of *Gear Technology*:

### **AFC Holcroft Booth 314–316**

AFC-Holcroft is a furnace supplier for equipment used for austempering and marquenching. Metal components subjected to the austempering process are shown to have improved mechanical properties such as strength and toughness along with improved distortion control during processing. Highlights include the company's universal batch quench systems, endothermic gas generators, rotary hearth furnaces, pusher furnaces and mesh belt equipment. Founded in 1916, AFC-Holcroft, is one of the US market leaders in the production of industrial furnace equipment for ferrous and non-ferrous metals. The company manufactures turn-key heat treating systems for applications including commercial heat treating, bearings, automotive, aerospace, mining, aluminum heat treatment, gear manufacturing, fastener manufacturing, and alternative energy industries. ([afc-holcroft.com](http://afc-holcroft.com))



### **ALD Vacuum Systems, Inc. Booth 104–106**

ALD Vacuum Systems designs and manufactures vacuum furnace systems used in heat treating. The company specializes in automated vacuum furnace systems with a product line that includes ModulTherm, SyncroTherm, NitroTherm and DualTherm systems. ALD focuses on markets like automotive, fuel systems, aerospace, tool and die, medical, heavy equipment, oil and gas, and commercial heat treating. ALD Vacuum Systems Inc. is a subsidiary of ALD Vacuum Technologies, GmbH of Hanau, Germany and part of the AMG Advanced Metallurgical Group N.V., Netherlands. ([www.aldvac.com](http://www.aldvac.com))

### **Ajax Tocco Magnethermic Booth 133**

Ajax Tocco Magnethermic is a subsidiary of ParkOhio Holdings Corp. The company designs and manufactures induction heating and melting equipment for various industries and applications throughout the world. In addition, they provide a range of services including laboratory process development, preventive



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#### Diablo Furnaces Booth 140

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#### ECM USA Booth 210-212

ECM's products incorporate other peripheral equipment to provide a complete turn-key heat treating solution. This allows customers to have one source for the complete heat treat installation which includes preheating, automation, heat treating (low pressure carburizing, carbonitriding, neutral hardening with oil or gas quenching) and tempering equipment all working together on one PLC based system for one source quality control. These installations are sourced and supported in North America. Product highlights include the ICBP Nano composed of one module with 3 stacked up heating cells (which can be extended to 6 heating cells, corresponding to 2 heating modules) and gas quenching cells to quench the parts. The carburizing cells are stacked up to reduce the footprint's installation as much as possible. The ICBP Nano integrates directly into the production line which allows it to reduce the cycle time while simplifying the flow between the machining and heat treatment. ([www.ecm-usa.com](http://www.ecm-usa.com))

#### Ipsen USA Booth 301-303

Founded in 1948, Ipsen has more than 10,000 systems installed worldwide. The company offers global modular platforms, as well as custom designs for specialized processes and requirements. Available in a wide range of sizes, their atmosphere and vacuum systems deliver versatility of processes, including annealing, brazing, hardening, low-pressure carburizing, solution nitriding, stress relieving and tempering. Additionally, they provide solutions that integrate with your entire operation — whether it's refining your processes or providing integrated supervisory systems. Product highlights include the Titan line, TurboTreater, SuperTurbo, batch furnace systems, continuous furnace systems, atmosphere software and more. ([www.ipsenusa.com](http://www.ipsenusa.com))

## Seco Warwick Booth 426-428

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## Solar Manufacturing Booth 211-213

Solar Manufacturing is a privately held, U.S.-based company providing technologically advanced vacuum heat treating furnaces. Together with their affiliate Solar Atmospheres, the company continually develops new solutions to vacuum processing applications and improves the science of vacuum furnace technology. Products include horizontal internal quench vacuum furnaces, horizontal external quench vacuum furnaces, vertical

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# The Three Rs of Gearbox Repair: Repair, Refurbish, Replace

Jack McGuinn, Senior Editor

**“If it ain’t broke, don’t fix it,” goes the hoary bromide.** But what if the time comes—and it most surely will—that in fact it *is* “broke”? Do you fix it—or replace it? And when does gearbox maintenance and repair arrive at a point of diminishing returns and buying new is the answer?

If it’s an industrial gearbox that happens to be an essential component of the smooth running of a production line, repair is the likely—and typically cheaper—way to go (but this can be tricky). Cheaper in that—it’s not new; cheaper because the lead (and/or down) time to repair a gearbox is typically shorter than sourcing, procuring and shipping the absolutely exact OEM gearbox—which also of course requires certification and installation.

Google “gearbox failure” and everywhere you look you’ll find the main culprits to be over-heating, excessive vibration, bearing failure, lubrication failure and/or leakage, and oil contamination. But how do you define gearbox failure? What does it look—or sound—like?

According to Chuck Schultz, chief engineer and owner of Beyta Gear, and longtime AGMA member and *Gear Technology* blogger, “Our customers have their own definition of “gear failure” and it has nothing to do with bending stress or durability rating. The average mill superintendent cares about only one thing: *Can the equipment work today?* If a little pitting or a small crack appears, the user couldn’t care less if production can continue. While some of the more sophisticated plants are rapidly moving towards a “predictive maintenance” environment, the vast majority of mills react only to catastrophic breakdowns. We’ve seen some incredible performances by gearboxes run completely without oil for months or missing sizable tooth fragments due to bearing related misalignment. We have seen very few “failures” caused by over rating or misapplication, although overloads due to process

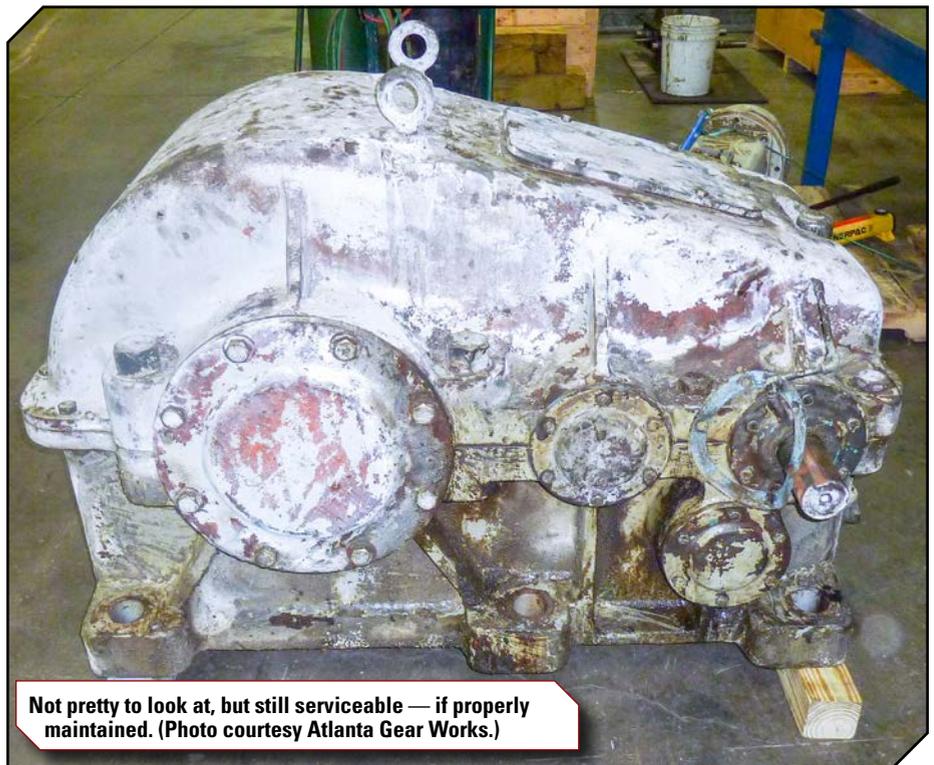
line “crashes” and field modifications remain a significant problem. AGMA’s standards writers and the application engineers can be justifiably proud of their work.” (What makes this definition especially interesting is that it was taken from an AGMA paper—“Gearbox Field Performance from a Rebuilder’s Perspective”—that Schultz wrote in 1999 and yet is still applicable applicable—and freely available in our *GT* Archive at [geartechnology.com](http://geartechnology.com).)

Meanwhile, it appears that overheating is the most common of reasons and thus

gaskets can also lead to contaminated lubrication coursing through the gearbox. Bearings are also a typical casualty of low lubrication levels, another cause of premature gearbox failure. As for noise, if a gearbox starts sounding like a calliope or some other irksome sound, it usually means you have gear issues and possibly bearing problems as well.

The takeaway here is that all of the above can be avoided—or at least anticipated—with preventive maintenance.

But in an imperfect world, sometimes even preventive maintenance cannot



the primary cause for reduced gearbox life. Oil leaks pertain much as they do with the car you drive. If you are losing oil but continue driving—only bad (and expensive) things can happen. In a gearbox, leaks typically indicate that there is a gasket or seal issue. Aside from the fact that those issues lead to a drop in oil/lubrication levels, bad seals and

predict when or if a gearbox will fail. So when that happens, repair is the viable option and usually puts things on the path of least resistance—and costly downtime.

So we asked a number of people intimately familiar with the rigors of preventive gearbox maintenance and timely repair—or replacement—a few

questions, looking for some repair-or-replace consensus regarding what is becoming an increasingly challenging endeavor as gearboxes and the sophisticated automation systems they are now being integrated into become increasingly complex.

We asked, for example, Craig S. Massa, vice president of sales for Atlanta Gear Works, Inc. — Accepting the premise, why do you think overheating is considered the most common issue regarding industrial gearbox repair and renewal?

“We don’t necessarily agree that overheating is the most common issue,” says Massa. “Overheating is easily detected without any special monitoring equipment and therefore is usually caught and addressed before gearbox failure. We would say that more commonly industrial gearboxes are pulled for repair due to catastrophic failure, oil leaks or elevated vibration readings.”

Chris Tegeder, marketing manager — wheels, gears and service for Xtek, Inc. — puts it this way: “Heat generation due to friction between moving components is the most common issue observed in gearbox repair. Proper lubrication keeps the heat within an acceptable level. However, there are many factors which can inhibit mating surfaces from seeing adequate lubrication. Some examples include poor design of the lubrication system, clogged or damaged lubrication lines, and even a human element in failing to initiate the lubrication of a gearbox after preventative maintenance.”

Another explanation, supplied by Jim Petruza, sales manager for Northern Engineering, includes the observation that size does indeed matter.

“Gearboxes are getting smaller, which can make heat dissipation more challenging,” Petruza explains. “Excess heat can degrade oil properties and destroy bearings. Overheating has become more of a problem since many newer gearboxes carry more horsepower-per-unit-of-mass, and use less oil, thus magnifying the results of an oil leak in terms of cooling capacity.”

At Machinists Inc., Jason Jonson, assembly supervisor says that “Failure to change out old oil, keeping oil cool, filtering out particles in the oil are some failure modes that cause gearbox



**Because gearboxes vary widely in shape, size and complexity, the initial costs can vary widely as well. (Photo courtesy Atlanta Gear Works.)**

damage. Sometimes the design of the gearbox is the cause of the overheating. However most of the time it’s the responsibility of the owner to make sure that the gearbox is properly maintained.” Adds Jerry Magnuson, Machinists Inc.’s vice president, sales, “It is important to note that most of the time, a failing gearbox causes overheating, not vice versa. The user should evaluate the gearbox if overheating occurs and not wait for a catastrophic failure.”

As for Schultz, the overheating is merely a symptom of a bigger problem. “(Overheating) isn’t (the cause); poor lubrication and maintenance are.”

Gasket and/or oil seal leaks are also common contributors to gearbox failure. A problem like this seems to indicate that the gearbox receives less-than-robust preventive maintenance checks, that seal and gasket leaks are something that can be reasonably detected and remedied. After all, how difficult can it be to preventively monitor something as identifiable as a potential gasket or seal leak before real problems occur?

Tegeder isn’t buying it. “Preventative monitoring of gasket and/or seal leakage is difficult. Other than periodic (daily/weekly/monthly) inspections for gasket/seal leakage, the only other thing that can be done is checking oil levels regularly and any oil pressure changes. Variances in pressure or oil level can be indicative of leakage. Often a small leak

is very difficult to detect due largely to the environment that the gearbox resides in. Usually there is residual oil, dirt and grease around the gearbox that makes it hard to determine if there is a leak and where the oil is coming from. One method (And who hasn’t done this in their own garage?) is to place an absorbent pad underneath a suspected leakage point and look for an oil spot on the pad. This is typically easier than looking for leaked oil on the ground or gearbox base.”

While Massa explains that “Gasket and seal leaks are a visual thing; there really is no way to identify or monitor before a leak occurs,” Petruza points out that “The operators might consider some smaller leaks a non-issue if the gearbox is well contained and the leak is managed with periodic additions of oil. However, this can be problematic if the rate of leakage increases or a periodic inspection is missed.”

Simply put, Jonson states that “Proper maintenance is needed for oil leaks to be a non-issue. Depending on the accessibility of the gearbox, it should not be difficult to check for leaks with a good maintenance schedule.” And Magnuson refers to another step in the process in that “All gearboxes should be spin tested after they’re repaired to check for leaks. This should be required.”

Also high on the list of contributors to gearbox failure are excessive noise

and/or vibration. But are those conditions—usual suspects—as impactful as is commonly believed?

“It is more complicated than just the ‘usual suspects,’” says Tegeder. “Any change in noise or vibration is a cause for concern, but does not necessarily mean there is an imminent failure. It simply reflects a change of environment and/or operation. That is why a vibration and noise analysis is more of a study of the complete system over time to determine reliable indication of faults or failures.”

For Schultz, it is in part a matter of being alert and paying attention. “Changes in noise, vibration, temperature, and amperage draw are what to look for.”

Northern Engineering’s Petruca points out “Almost every problem in a gearbox can be identified via vibration analysis. (Noise is just more audible vibration). As such, there are no real ‘usual suspects’ that are picked up solely because vibrations are being analyzed. Typical problems found would be things like bearing wear, gear tooth defects, misalignment, soft foot—or problems being introduced to the gearbox from the driving or driven machines.”

“Noise or vibration can be caused by either something in the gear mesh or a bearing having an issue,” says Machinists Inc.’s Jonson, while other reasons, according to Magnuson, are “improper alignment, lubrication, and harmonics.”

Oftentimes, bearings are cited as the cause of gearbox failure. But isn’t it really a question of what caused the bearings to fail?

Tegeder seems to agree in that “While there are bearings that fail due to under rating, or poorly manufactured bearings, the real root cause is often from sources other than the bearing itself. Since there are experts in the field of bearing failure modes, we often defer to them when analyzing bearing failures, but we often look at the complete assembly for indications, (rust/corrosion, contamination, loads, misalignments, etc.), that might provide insight into the cause of any bearing failure.”

So let’s say that a vitally important gearbox in a vitally time-sensitive production line is showing indications of imminent failure—or has stopped working altogether. The manager wonders

—can it be repaired? Should it be repaired? Is refurbishment (reconditioning) an option? Or should it be replaced? How long will any of the above take? The answer, as one might suspect, can get complicated.

Extek’s Tegeder:

**Repair:** “To us, a ‘repair’ is a specific issue or problem that is being addressed/ fixed and not much else. For example, a gearbox comes to us with a broken shaft; our customer wants the shaft repaired. We would fix the shaft and send it back to the customer. We consider that a ‘repair.’ We basically fixed the known problem and not much else at the request of our customer.”

**Recondition:** “We use the terms ‘recondition’ and ‘refurbish’ interchangeably at Xtek. In this instance we perform a full disassembly of all components (usually leaving gearing mounted on shafting). All of the components are cleaned thoroughly, full mechanical, metallurgical and hardness inspections are performed as well. We offer a detailed inspection report with our engineered recommendations, along with pricing. In this report we offer improvement suggestions regarding design, material type and hardness, as well as bearing upgrades or changes. After the ‘reconditioning’ or ‘refurbishment’ is complete, we perform a full

no-load run test on every gearbox and record all the important run-off parameters electronically and keep them on file permanently.”

**Replace:** “Replace is just what it says; we replace either components in the drivetrain or the entire drivetrain/gearbox assembly.”

Taking issue with how the question is posed, Ramberg states that “This should (presented) as reuse/repair/replace. Reuse (means) OK to use as is. Repair involves refurbishing or repairing parts.” Replace is full replacement of the part. Adds Magnuson, “Economics is the big factor in making the reuse, replace, repair calculus. (We) typically go beyond repairing the gearbox; we analyze the cause of failure and enhance the gearbox—either by design or production quality—to increase its service life.”

At Northern Engineering, according to Petruca:

**Repair:** “A process carried out on a part or machine to fix a specific problem.”

**Recondition (refurbish):** Recondition and refurbish are basically the same thing. Taking an original part and fixing some defect with it to bring it to a level that meets or exceeds the OEM specifications.

**Replace:** A new part provided by the OEM or made to their specification.



A work of manufacturing art—a shiny-red industrial gearbox. (Photo courtesy Northern Engineering.)



**Big or small, gearboxes overheat. The repair goal is to find out why. (Photo courtesy Atlanta Gear Works.)**

Atlanta Gear Works:

Repair: "Simple oil seal change only. Typically done on a rush basis to keep equipment running."

Recondition (refurbish): "Change bearings, seals and potential replacement or kiss grind of gears and replacement of shafts."

Replace: "With OEM or drop in replacement; typically done if repair is equal to or more than 50-60% of new."

And Schultz qualifies it this way, adding a slight distinction regarding recondition vs. refurbish:

Repair: "Take out a worn or broken part; replace it with an OEM spare."

Recondition: "Strip down, clean, inspect, and replace worn bearings and seals, possibly re-cut or re-grind some gears."

Refurbish: "Same as recondition except more new parts and possible housing rework."

Replace: "Could be an OEM spare gearbox or similar."

Now that we have the repair-refurbish-replace nomenclature more or less defined, let's see how these various steps are priced. When does the meter start running? One assumes there's an evaluation of the problem process; and then a fix the problem process; and then some sort of post-fixing monitoring process. When does buying new become the best option? What determines the point of diminishing returns for repair vs. replace?

"The best results are often seen when Northern Engineering provides on

on-site assessment, rebuilds the gearbox in-shop, then installs and aligns the rebuilt gearbox at the customer's location (to the proper OEM specifications)," says Petruca. "Ensuring that the gearbox is properly installed is key as misalignment and soft foot can be real gearbox killers. 'Post fix,' Northern Engineering will run a rebuilt gearbox on a no-load test table for several hours. Smaller gearboxes, shaft-mounted gearboxes, for example, are often not cost-effective to rebuild. The less expensive gearboxes are easily replaced with a new gearbox that is available off-the-shelf."

Atlanta Gearworks' Massa puts it this way:

- "Our typical process is as follows:
- Receive gearbox for evaluation
  - Disassemble and inspect at no charge
  - Evaluation of gearing by MPI etc.
  - Provide detailed inspection report/quotation to customer
  - After customer approval proceed as quoted
  - No-load, spin test of gearbox
  - Prepare for return shipment

Massa adds, "buying new is at the customer's discretion, which is typically 50-60% cost of new."

At Machinists Inc., Magnuson explains, "The repair or buy option has many factors. What is the availability of a new unit? Sometimes they're not available or the lead times are too long. Each repair has its own recipe. If too many parts need replacement, replacing the unit becomes more common. This is where a vertically integrated company

like Machinists Inc. has an advantage. We have the ability to refurbish gears, oftentimes by re-grinding the teeth. Typically, the larger gears, which see fewer revolutions, can be saved by reconditioning — saving the customer money without sacrificing quality. The pinions that are driving them see more revolutions. These are replaced more often. Smaller units tend to be replaced more often. If a person can pick up a unit on their own, it would be a likely candidate for replacement."

Xtek's Tegeer: "Typically, the gearbox comes to us; we perform all of the disassembly/inspection/evaluation, and then provide our engineering report/proposal. We look at how many hours it took to perform all the aforementioned tasks, consider inbound freight and what the repair scope is, and determine the pricing from there. Gearboxes vary widely in shape, size and complexity, so the initial costs can vary widely as well. Buying new usually occurs when the recondition price reaches around 60-70% the cost of a new unit. Keep in mind that when comparing the price of reconditioning of a unit versus buying new, the new unit does not have the freight/disassembly/inspection/evaluation costs that a reconditioned option carries." ⚙️

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# Influences of the Residual Stress Condition on the Load-Carrying Capacity of Case-Hardened Gears

C. Güntner, T. Tobie and K. Stahl

## Introduction

Highly loaded gears are usually case-hardened to fulfill the high demands on the load-carrying capacity. Several factors, such as material, heat treatment, or macro and micro geometry, can influence the load-carrying capacity. Furthermore, the residual stress condition also significantly influences load-carrying capacity. The residual stress state results from heat treatment and can be further modified by manufacturing processes post heat treatment, e.g. — grinding or shot peening.

A variety of investigations was performed in several research projects concerning the influence of residual stresses on the load-carrying capacity limits of gears. The investigations were focused on the tooth root bending strength as well as the flank load-carrying capacity. The gears were analyzed in un-peened, mechanical-cleaned, and shot peened condition. The investigations included different materials, e.g. — 16MnCr5 or 18CrNiMo7-6 — and different gear sizes.

Compressive residual stresses generated by shot peening, for example, result in an increased tooth root bending strength. The tooth root bending strength of shot peened gears can be increased by more than 50% compared to gears in the un-peened condition. Per mechanical laws, the increase of the load-carrying capacity is limited. In the case of highly loaded shot peened gears, other failure mechanisms may arise, such as subsurface-initiated cracks. Shot peening can also significantly increase the flank load-carrying capacity. Due to a shot peening process, the surface of the gears is influenced. As a consequence, other failure mechanisms can occur, such as micropitting. Furthermore, shot peening and the resulting compressive residual

stresses can also be used to repair grinding burn or to avoid facing edge tooth flank fractures.

All in all, the investigations show that shot peening can significantly increase the load-carrying capacity of case-hardened gears. Furthermore, correlations between the residual stress state and the load-carrying capacity limits were determined. This paper will provide an overview of the main results of different investigations and discuss influences of the residual stress condition on different failure modes of case-hardened gears.

Case-hardening is a typical heat treatment process used to achieve an adequate load-carrying capacity of highly loaded components, such as gears. The challenge is always either to minimize the size of the component to transfer the same torque or force, or to be able to transfer a higher torque or force using the same size of the component. Several factors influence the load-carrying capacity of gears, such as material, heat treatment, or macro and micro geometry. Furthermore, the residual stress condition has a significant influence on load-carrying capacity; the residual stress state is changed during the manufacturing process by the heat treatment and a possible downstream shot peening.

Within the scope of this paper will be shown the influence of the residual stress state — especially influenced by a peening process — on the load-carrying capacity of gears. The main focus is set on the tooth root bending strength. Besides this, influences on the tooth flank characteristics will also be discussed. This paper will summarize the main results of different, previously published investigations. Therefore, the different projects are compared by showing the main results.

## Characterization of Residual Stresses

Residual stresses are stresses which occur in a component that is not loaded by any force or torque. There are tensile and compressive residual stresses. Both kinds of residual stresses are balanced within a component. Compressive residual stresses in the surface layer typically have a positive influence on the load-carrying capacity, whereas tensile residual stresses in the surface layer can significantly *reduce* load-carrying capacity. The residual stress state is influenced by the manufacturing process, which includes soft-machining, heat treatment, and finishing. The “case-hardening” heat treatment process usually leads to compressive residual stresses in the surface layer and tensile residual stresses in the core. The residual stresses take only small compressive stress values in a range of about  $-200$  up to  $-400$  N/mm<sup>2</sup>. During quenching the component does not cool down uniformly, so a volume difference occurs whereby residual stresses arise; furthermore, austenite transforms into martensite. Both microstructures have different yet specific volumes that result in additional residual stresses. All in all, the residual stress state results from a combination of quenching and volume change.

Usually the gears are subjected to a shot blasting or peening process after case-hardening. There is therefore a distinction between mechanical cleaning and shot peening. In both cases the generation of the residual stresses is based on the model representation of Wohlfahrt (Ref. 26). For case-hardened steels (e.g., 16MnCr5 or 18CrNiMo7-6), the residual stresses are generated by the elastic-plastic deformation of the surface. Due to the

local stresses that exceed the yield point of the material, compressive residual stresses arise. Furthermore, as mentioned above, the retained austenite transforms into martensite during the shot peening process. Due to different specific volumes of the microstructures, compressive residual stresses arise (Ref. 22).

During the “grinding” finishing process, the residual stress state also changes in that the surface layer is mechanically and thermally influenced (Ref. 21). Due to the mechanical influence of the grinding wheel, compressive or tensile residual stresses may be generated. Excessive heat exposure during the grinding process results in tensile residual stresses. The residual stress condition post grinding is a result of a superimposition of both influences. The process parameters have a significant influence on the residual stress state. In the surface layer, tensile as well as compressive residual stresses may arise.

### Mechanical Cleaning

The aim of the mechanical cleaning process is to remove the scale layer and clean the component after heat treatment. The process is mostly done by an impeller; a schematic presentation is shown (Fig. 1). The blasting material is mostly cut wire or glass beads. The process is not defined; only the process time and the speed of the impeller are controlled and monitored (e.g., 5 minutes-per-side). By this process, compressive residual stresses are induced that have a positive effect on the load-carrying capacity. Furthermore, according to ISO 6336-5 (Ref. 4), the bending stress numbers for

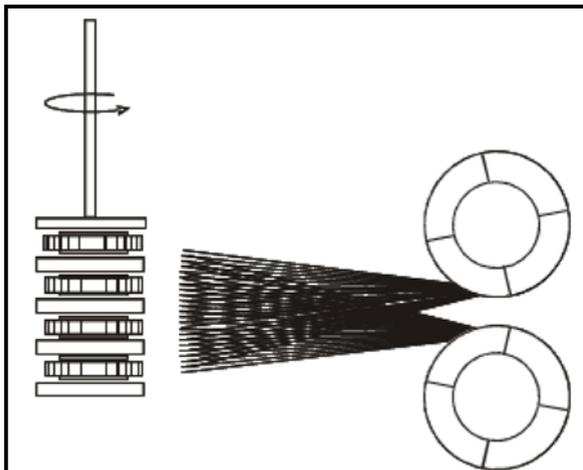


Figure 1 Schematic presentation of the mechanical cleaning by an impeller (Ref. 10).

case-hardened gears of material quality MQ are purposefully achievable with mechanical cleaning.

### Shot Peening

Shot peening differs from mechanical cleaning. As opposed to blast cleaning, several parameters — such as blasting material, hardness of the blasting material, size of the material, degree of coverage, and intensity — are defined and monitored. According to ISO 6336 (Ref. 4), “The recommended minimum control should be based on SAE AMS 2430 (Ref. 16), SAE AMS 2432 (Ref. 17) or SAE J 2241 (Ref. 18).” The blast material in this case is steel balls, with the aim of a specific increase of the compressive residual stresses. The steel balls have to be round and the hardness of them has to be at least identical to the hardness of the

component. Therefore, the steel balls are accelerated by jet nozzles. The size and hardness of the steel balls can be varied as well as the ejection speed (Fig. 2) and the duration of the process. Before the component is shot peened, a measurement of the intensity is done; on the basis of this measurement the peening time is determined. With these parameters the depth of the maximum and the maximum value of the residual stresses can be varied within some limits. Furthermore, the steel balls underlie a continuous processing in order to maintain a constant result of the shot peening process. Due to the comprehensive monitoring, the process can achieve reproducible results. To achieve the expected results of the shot peening process, the component has to be cleaned in advance.

In Figure 3 typical residual stress values

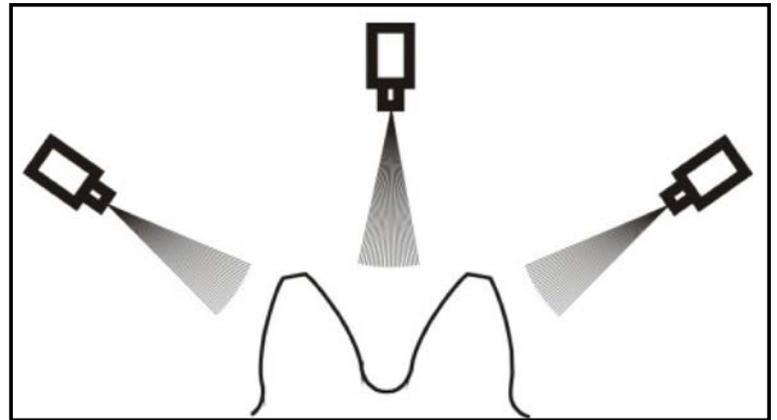


Figure 2 Schematic presentation of the shot peening by jet nozzle (Ref. 10).

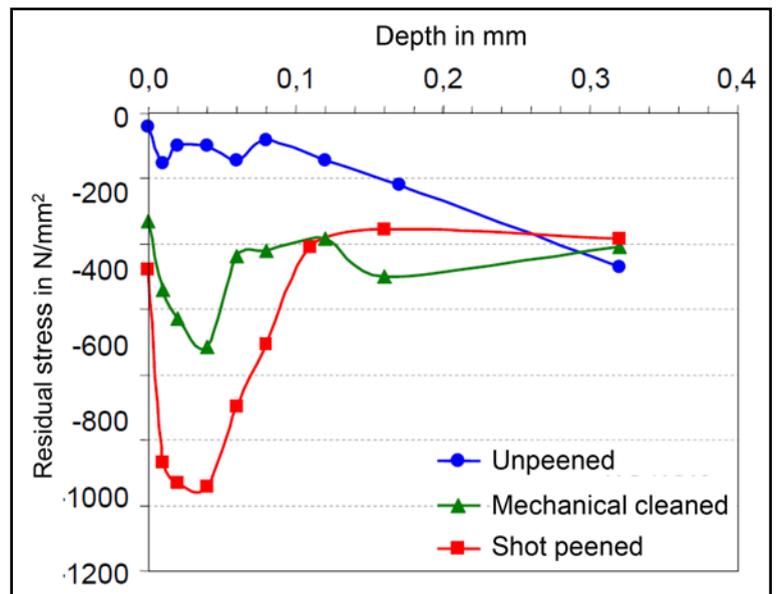


Figure 3 Comparison of the residual stresses in the un-peened, mechanical-cleaned, and shot peened condition (measurement results, exemplary presentation) (Ref. 22).

in the surface layer are plotted for gears in the un-peened, mechanical-cleaned, and shot peened condition. The influence of increased residual stresses due to mechanical cleaning or shot peening is limited to only a depth of about 0.1-0.15 mm. The highest compressive residual stresses are achievable with shot peening.

Furthermore, it is also possible to combine two shot peening processes with different parameters (Ref. 12). So, high compressive residual stress values on the surface, as well as high compressive residual stress values in a greater material depth, can be realized. In Figure 4

the residual stress states of different shot peening processes are compared to the un-peened condition. Here, a shot peening process with big steel balls (diameter of 0.8 mm) is combined with a shot peening process with small steel balls (diameter 0.1 mm), which is called WHSP. By this combination, high compressive residual stresses on the surface and high compressive residual stresses in greater material depths are achievable.

Another aspect of the shot peening process is that the roughness of the component/gear is influenced. Especially in the case of a grinded surface, the shot

peening process often leads to a higher surface roughness compared to the grinded condition (Refs. 10 and 6). In Table 1 the surface roughness of a grinded tooth surface is compared to a grinded surface with an additional shot peening (after grinding). Due to the shot peening process, the measured surface roughness of the tooth flank increases from  $Ra \approx 0.30 \mu\text{m}/Rz \approx 1.97 \mu\text{m}$  after grinding to  $Ra \approx 0.87 \mu\text{m}/Rz \approx 4.76 \mu\text{m}$  after shot peening.

### Investigations of the Gear Strength—Test Rigs and Test Conditions

#### Tooth root bending fatigue strength.

The bending fatigue tests were carried out by means of an electro-magnetic, pulsating test rig (Fig. 5). The test rig consists of a machine frame that incorporates test device, load cell, and test gear. The pulsating load is generated by a dynamic actuator that is connected to a dynamic spring by the exciting magnet, which is directly connected with the pulsating cross-beam by two rod springs. The test gears were symmetrically clamped and tested over a certain number of teeth (generally four teeth) between two jaws. The exact position of the test gear in relation to the clamp jaws (i.e., the exact angle and point of load incidence) was adjusted by means of a special jig. Flank angle deviations were offset by means of a precision adjustment, thus a uniform load distribution across the whole face width can be assumed. The test gear was friction-locked between both jaws; therefore an underload was needed—which was always lower than 10% of the test load. The test runs were normally

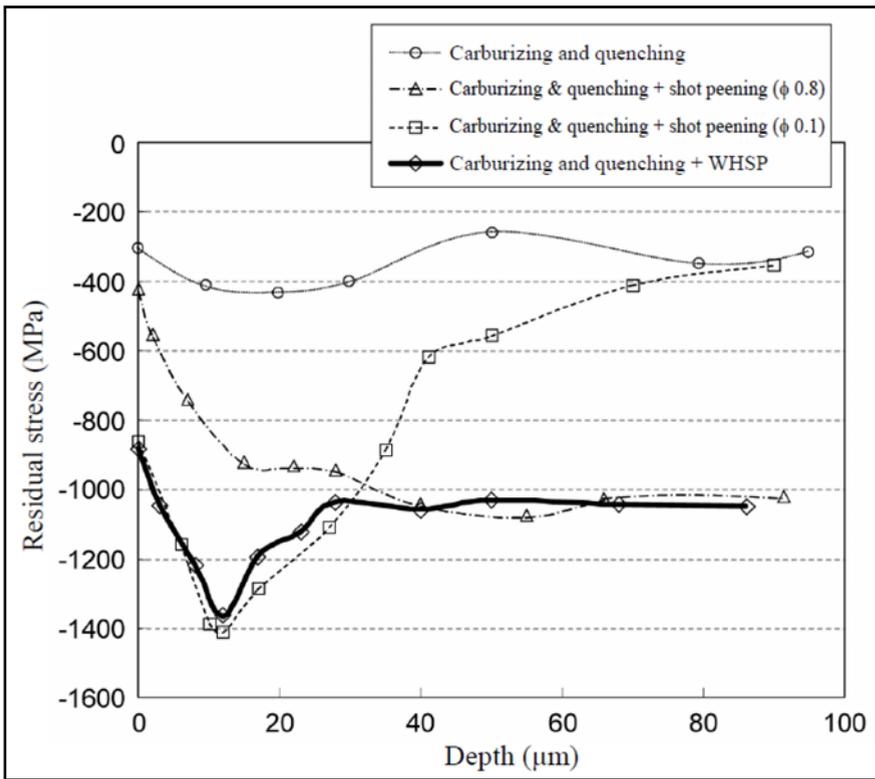
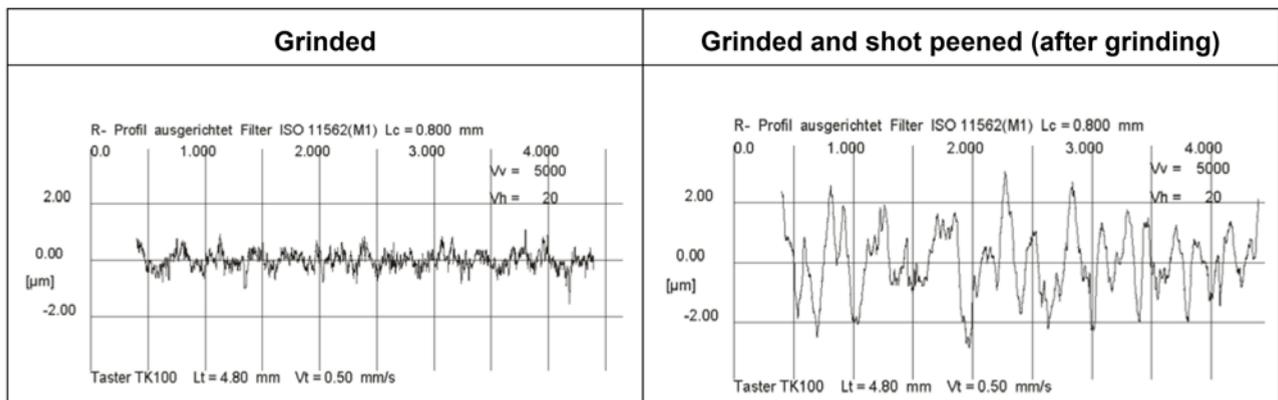


Figure 4 Comparison of the residual stress states generated with different processes (Ref. 12).

Table 1 Comparison of the surface roughness of a grinded gear surface and a grinded gear surface with an additional shot peening (after grinding) according to [10]



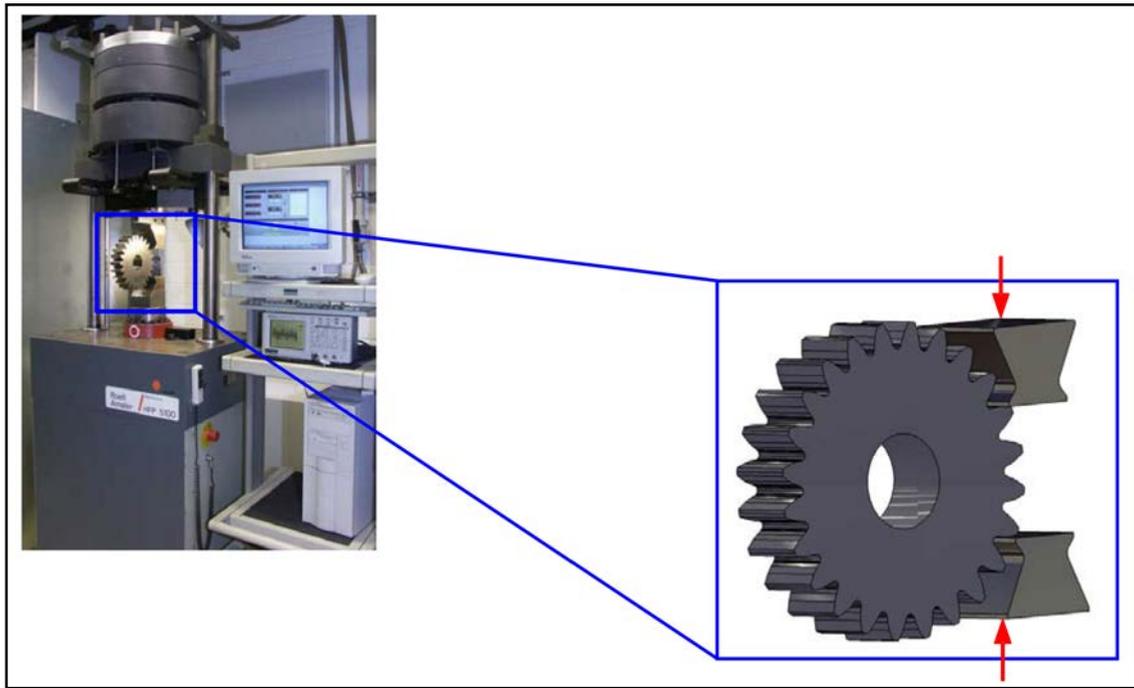


Figure 5 Pulsator test rig.

stopped after  $6 \cdot 10^6$  load cycles. In case of the investigation of the high cycle fatigue, the load cycles were increased.

**Tooth flank (contact) fatigue strength.** The test runs for the determination of surface durability (pitting) were performed on FZG back-to-back gear test rigs, with a center distance of  $a = 91.5$  mm. Figure 6 shows a picture of the test rig with a center distance of 91.5 mm. The test rig is driven by a three-phase, asynchronous engine with a constant speed of 3,000 rpm. Test pinion and test gear are mounted on two parallel shafts that are connected to a drive gear stage with the same gear ratio. The shaft of the test pinion consists of two separate parts which are connected by a load clutch. A defined static torque is applied by twisting the load clutch and using defined weights on the load lever or by twisting the load clutch with a bracing device. The torque can be controlled indirectly at the torque measuring clutch as a twist of the torsion shaft. The engine only has to provide the power loss of the two gearboxes in this closed power loop. For the tests described herein, the pinion was mounted on the torsion shaft and had the same speed as the engine. The load was applied in a way that the pinion was the driving gear and the gear was driven. All test runs were performed with FVA-reference oil FVA3A under oil spray lubrication (approx. 2 l/min into

the tooth mesh) with  $\vartheta_{oil} = 60^\circ\text{C}$  ( $\pm 2^\circ\text{C}$ ). The test runs were stopped after 50, 100 and  $10^6$  load cycles.

### Influence on Tooth Root Bending

The investigations concerning the tooth root bending strength (Refs. 1, 19, 20, 22 and 25 were performed on the described pulsator test rig.

**Increase of the load-carrying capacity.** Due to the increase of compressive residual stresses on and near the surface of the gears by mechanical cleaning or shot peening, the tooth root bending strength of case-hardened gears can be increased. Investigations done by Weigand (Ref. 25) or Stenico (Ref. 22) dealt with the influence of blast cleaning and shot peening using case-hardened gears made out of 16MnCr5 and 18CrNiMo7-6. Different gear sizes were used, including module 1.75-8 mm. Weigand (Ref. 25) identified an increase of the tooth root bending strength of 30% (concerning material 16MnCr5, module 5 mm) and 15% (concerning material 18CrNiMo7-6, module 5 mm) between case-hardened gears in the un-peened condition, and in the blast-cleaned condition. By

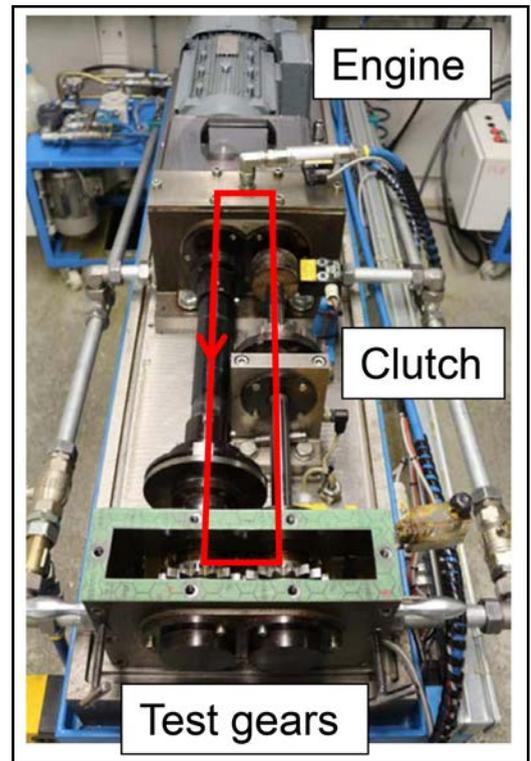


Figure 6 FZG back-to-back test rig.

using two different shot peening processes the increase in the tooth root bending strength was of 35–45% (material 16MnCr5) and 30–50% (material 18CrNiMo7-6), compared to the un-peened condition.

Inoue et al. (Ref. 2) dealt with the effect of shot peening on the bending strength of carburized gears. In this research work,

gears (module 5 mm) made of JIS SCM 415 and JIS SCM 420H were shot peened with different process parameters and different resulting residual stress states. The results show that an increase of tooth root bending strength of up to 30%, compared to the unpeened condition, is possible.

Stenico (Ref. 22) investigated the influence of different shot peening parameters on the tooth root bending strength of case-hardened gears with different materials and gear sizes. The investigations revealed an increase of the tooth root bending strength of about 27%–43% for material 16MnCr5 (gear sizes 1.75; 3 and 5 mm) between the un-peened condition and after blast cleaning; the increase can be further enhanced by shot peening. With shot peening, the tooth root bending strength was about 42%–66% higher than in the un-peened condition. The

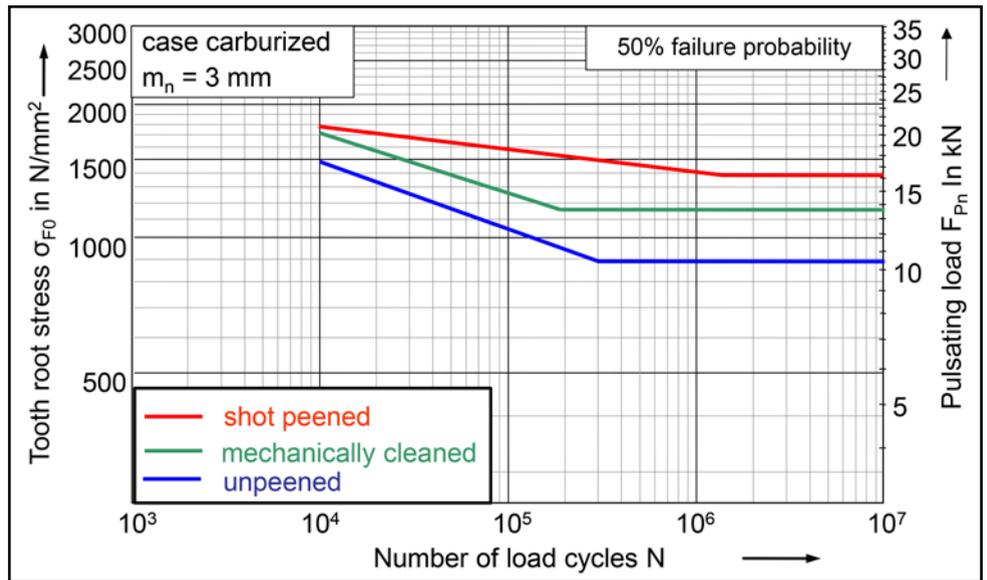


Figure 7 Exemplary presentation of the influence of mechanically cleaning and shot peening on the tooth root strength of a carburized gear (material 16MnCr5, module 3 mm) (Ref. 22).

material 18CrNiMo7-6 showed increases of about 38%–50% between the un-peened and shot peened condition for the gear size module 5 mm. In Figure 7 the determined S-N curves for the tooth root bending strength material 16MnCr5

(module 3 mm) are plotted in the un-peened, blast-cleaned and shot peened condition (failure probability 50%). The results prove that by blast cleaning or shot peening, the tooth root bending strength can be increased significantly. A consideration of the low cycle fatigue indicates that the slope of the low cycle fatigue curve gradient is different for the three variants. The un-peened variant has the highest value and the shot peened variant the lowest one. This means that blast cleaning, as well as shot peening, influences especially the endurance limit—but not the static tooth root bending strength. The consequence is that blast-cleaned—but especially shot peened—gears show higher overload sensitivities than gears in the un-peened condition. Furthermore, for gears, especially in the shot peened condition, failures due to subsurface cracks were detected.

Figure 8 (Ref. 1) presents the results of the tooth bending strength of the material 16MnCr5 (gear size module 5 mm) in the shot peened condition. The test runs were terminated after  $100 \cdot 10^6$  load cycles. The test runs that fail in the range lower than  $10^6$  load cycles are characterized by surface-initiated tooth root fracture damages. In the range of higher load cycles, all breakages originate from the subsurface. Furthermore, the results show that the nominal tooth root stresses  $\sigma_{F0}$  of the failures in the range of more than  $10^6$  load cycles are lower than for breakages from the surface.

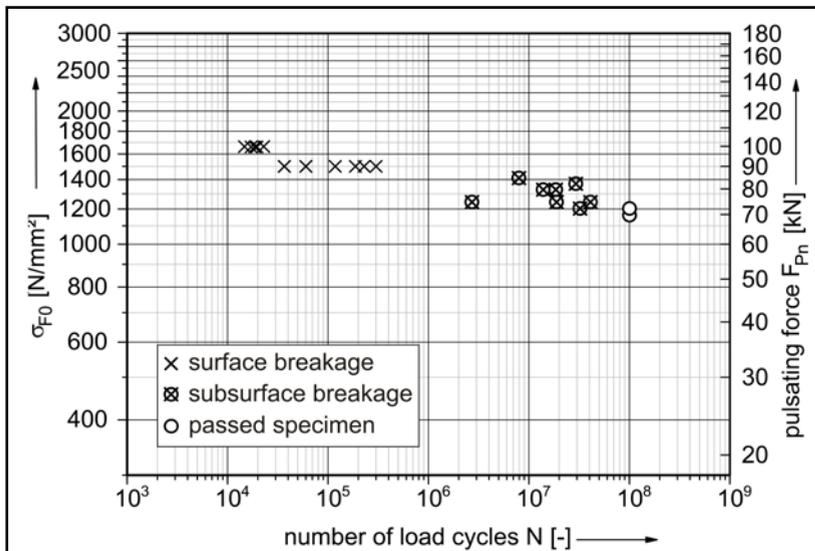


Figure 8 Tooth root bending test results of a shot peened variant at a cycle limit of  $100 \cdot 10^6$  (Ref. 1).

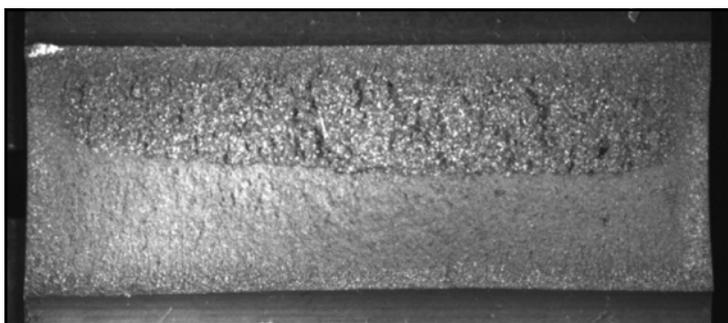
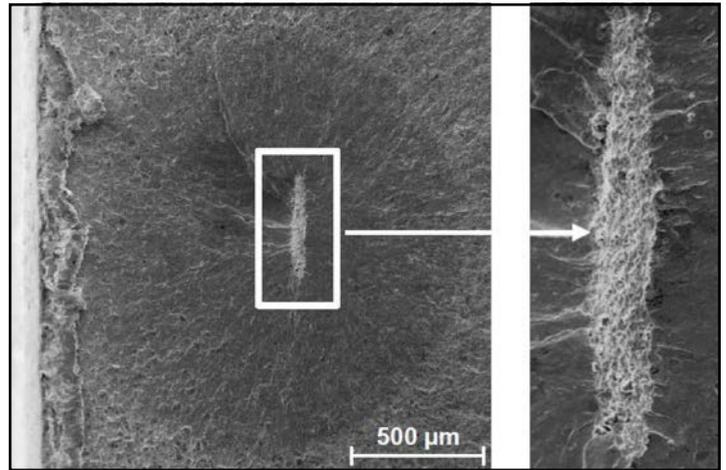


Figure 9 Typical tooth root fracture surface, crack initiation on the surface (Ref. 20).

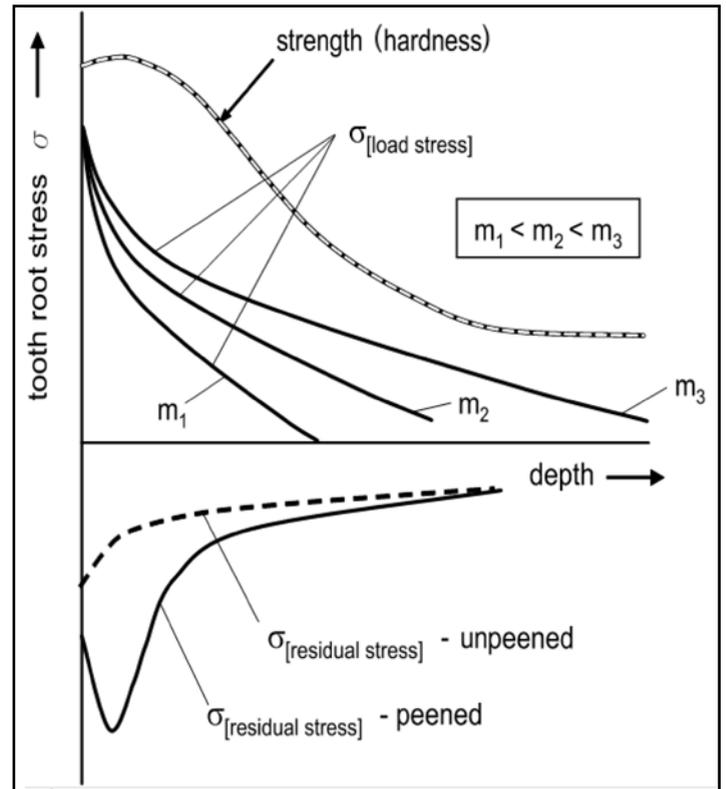
**Change in the fracture mode — un-peened vs. shot peened condition.** Case-hardened gears in the un-peened, and most of the gears in the blast-cleaned condition, fail due to tooth root breakages with a crack initiation on the surface. Figure 9 displays a typical tooth root fracture surface; typical load cycles for such damage are in the range of  $10^5$  to  $10^6$  load cycles.

Tooth root breakages of gears in the shot peened condition that fail in the region of endurance limit show mostly a different fracture surface compared to gears in the un-peened condition. The fracture surface contains a small, round and bright spot. In the literature, this is often called “fish-eye” due to the characteristic appearance; Figure 10 represents such a typical fracture surface. The crack is initiated on an inclusion (oxide) sub-surface. Shot peened gears in the range of endurance life usually fail in the range of more than  $10^6$  load cycles.

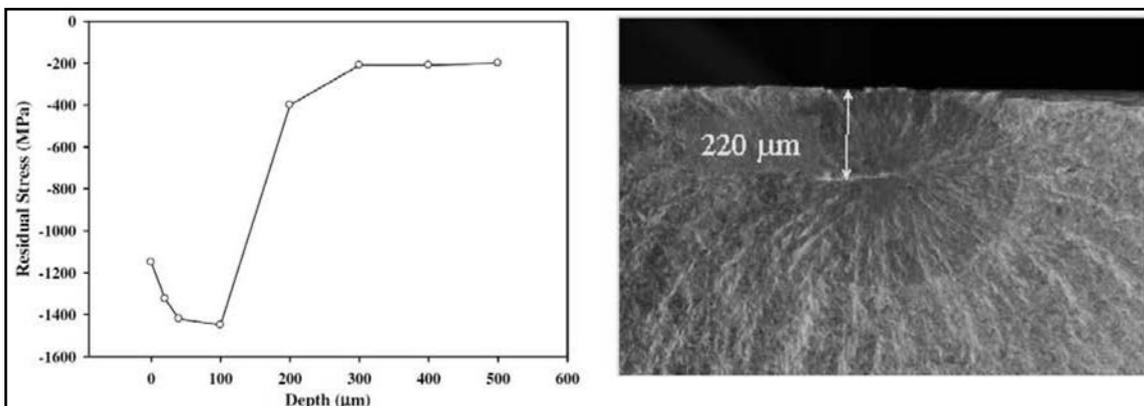
In Figure 11 the load stresses for different gear sizes are plotted, as well as a typical hardness profile of case-hardened gears. Furthermore, typical residual stresses of un-peened and shot peened gears are shown. The schematic distribution of the load stresses presents that the highest load stresses occur on the surface of the tooth root. Furthermore, it is shown that the decrease of the load stresses depends on the gear size, whereas the compressive residual stresses do not. Considering case-hardened gears in the un-peened condition, crack initiation occurs on the surface where the highest load stresses occur. By shot peening, the surface is strengthened and a crack initiation on the surface is virtually prevented. The crack initiation takes place sub-surface — usually at an inclusion or other defect of the material. Bretl (Ref. 1) developed a model that considers the local strength of the material. Thus the material strength is compared with the local stress situation. The material strength depends mainly on the hardness; the local stress situation is characterized by load stresses and residual stresses. Compressive residual stresses have a positive effect on the tooth root bending fatigue strength, and are taken into account in an appropriate way. According to this model, a crack can be initiated when the local stress situation exceeds the local load capacity of the material. An inclusion or defect in the material causes a local increase of the stresses that can lead to an excess of



**Figure 10** Typical tooth root fracture surface, crack initiation sub-surface on an inclusion (oxide) (Ref. 20).



**Figure 11** Schematic distributions of load stress, residual stress, and hardness in tooth root area of case-hardened gears depending on material depth (Refs. 1 and 19).



**Figure 12** Residual stress distribution (left) and subsurface crack initiation (right) (Ref. 15).

the local strength, leading in turn to a subsurface crack. With the calculation model of Bretl it is possible to determine whether an inclusion can cause a crack that is growable.

Prasannavenkatesan (Ref. 15) determined that sub-surface crack initiation occurs in material depths in which the positive influence of the shot peening is lessened. Figure 12 shows that the residual stress state is plotted and the depth of the crack initiation is determined. The subsurface crack initiation took place in a material depth of about 220 μm. The maximum of the compressive residual stresses is located in a depth of about 100 μm. In a material depth of more than 200 μm, the compressive residual stresses of the shot peening are already subsided. This is also confirmed by the extensive investigations of Bretl (Ref. 1) and Schurer (Ref. 20). The results show that the crack initiation takes place in a material depth in which the high compressive residual stresses due to shot peening are subsided, but still remain within the case-hardened layer.

**Stepwise S-N curve.** All the results and theoretical considerations draw a conclusion that there is a kind of “double” S-N curve for the tooth root bending fatigue of shot peened, case-hardened gears; Figure 13 offers a schematic illustration of the stepwise S-N curve. In the literature it is also often called “two-fold” S-N curve. The “classical” S-N curve for tooth root bending strength is limited by crack initiation on the surface and

is extensively validated for un-peened and blast-cleaned gears. Besides this, for shot peened gears, there is a second S-N curve that is determined by sub-surface crack initiation. This S-N curve determines the load-carrying capacity in the high cycle fatigue. Due to the sub-surface crack initiation, a further decrease of the tooth root bending strength has to be considered.

As shown in the research (Refs. 1 and 19), such two-step S-N curves also exist for un-peened and blast-cleaned gears. But because the surface is not strengthened by increased compressive residual stresses, the load-induced stresses exceed the fatigue strength at the surface before a critical stress condition below the surface can initiate sub-surface cracks. And so the crack initiation on the surface decisively determines the lifetime of un-peened and blast-cleaned gears.

**Influence on Tooth Flank Load Carrying Capacity**

Investigations of the tooth flank load capacity were performed using the FZG back-to-back test rig. When the tooth root is mechanically cleaned or shot peened, the tooth flank is also influenced. For the tooth flank, there are several possibilities/manufacturing routes:

- Shot peening followed by grinding
- Grinding followed by shot peening
- Grinding, shot peening, and finally barrel-finishing

In the first case the grinding process removes the layer that is influenced by

shot peening of the tooth flank. Grinding removes about 0.1–0.2 mm of the tooth flank; this is the material depth that is influenced by shot peening. In this case the residual stress state is decisively determined by the grinding process.

In the two other cases, the shot peening process can increase the tooth flank load capacity (pitting).

**Increase of the Tooth Load-Carrying Capacity (Pitting)**

In (Ref. 6) the influence of shot peening on the tooth flank capacity (pitting) was investigated. Therefore the gears were grinded (tooth flank) and then shot peened. The gears used in the investigation have a gear size of module 5 mm and were made out of 16MnCr5 and 18CrNiMo7-6 (old name: 17NiCrMo6). The results indicate that an increase of the tooth flank load-carrying capacity up to 10% is possible. Furthermore, especially concerning 16MnCr5, a correlation of the load-carrying numbers to the amount of retained austenite was detected. Regardless of the material, all shot peened gears have a higher surface roughness after shot peening, compared to the grinded state. Consequently, in the experimental investigations the shot peened gears showed a higher tendency toward micropitting. This type of damage can be reduced by using an adjusted oil with a higher micropitting load-carrying capacity.

Townsend (Ref. 24) investigated the influence of shot peening on the tooth flank load-carrying capacity of gears. Therefore some gears were additionally shot peened after grinding. The test runs were performed at a constant Hertzian stress. The gears that were shot peened showed a pitting lifetime that is about 46% higher than without shot peening. The increase of the load-carrying capacity is assumed to revert to the residual stress state. In a further investigation, the influence of the intensity (a middle one and a high one) of the shot peening process on the lifetime of case-hardened and shot peened gears was determined. After the shot peening the tooth flanks were honed to improve the roughness condition of the tooth flanks. The results show that the lifetime of the gears that were shot peened with the high intensity was 1.7 times higher than the lifetime of the

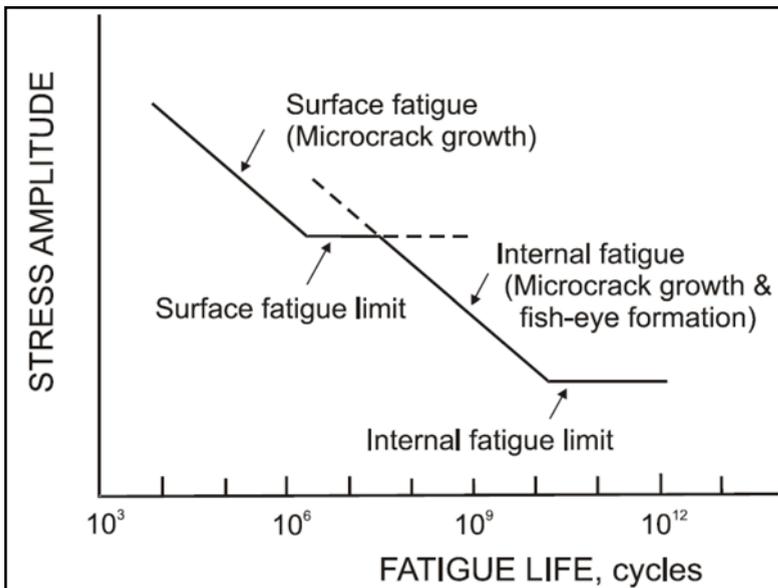


Figure 13 Schematic illustration of the two-step S-N curve (Ref. 14).

variant with the middle intensity (failure probability 50%).

Due to the fact that a shot peening process often leads to increased surface roughness values, a further processing of the shot peened surface typically is necessary to use the potential of the flank load-carrying capacity. Therefore the influence of shot peening treatment and a finishing process was the focus in a research project (Refs.10-11) to further increase the flank load-carrying capacity of gears. In experimental test runs the flank load-carrying capacity (pitting) of gears made of the material 16MnCr5 and a gear size of module 5 mm was determined. The finishing of the gears was varied, which included grinding, barrel-finishing and shot peening with an additional barrel-finishing. The results plotted in Figure 14 show that the highest pitting load-carrying numbers can be achieved by shot peening after grinding and an additional barrel-finishing. In this case the increase of the nominal contact stress for endurance was about 20% compared to the variant that was grinded. With the gain in the pitting load-carrying capacity, the risk of tooth flank fracture damage rises. Tooth flank fractures are characterized by a crack initiation subsurface in the area of the active tooth flank.

### Further Applications of Shot Peening

#### Repair measures for grinding burn.

Grinding burn affects the material characteristics of the surface layer. As a consequence of grinding burn, the surface hardness decreases and even tensile residual stresses can arise. The tooth flank load capacity (pitting) is influenced in a negative way, which leads to a significant decrease of the load-carrying numbers. A downstream shot peening process of the gears with light-to-medium grinding burn can increase the load-carrying capacity of gears. According to (Ref.6), load-carrying numbers comparable to gears without grinding burn are achievable; but the scatter of results is greater compared to gears without grinding burn. This results from the fact that the shot peening process cannot influence the whole damaged layer (Ref.6). According to (Refs.7-9; 21) a reliable repair is only possible concerning light-to-middle grinding burn (maximum FB

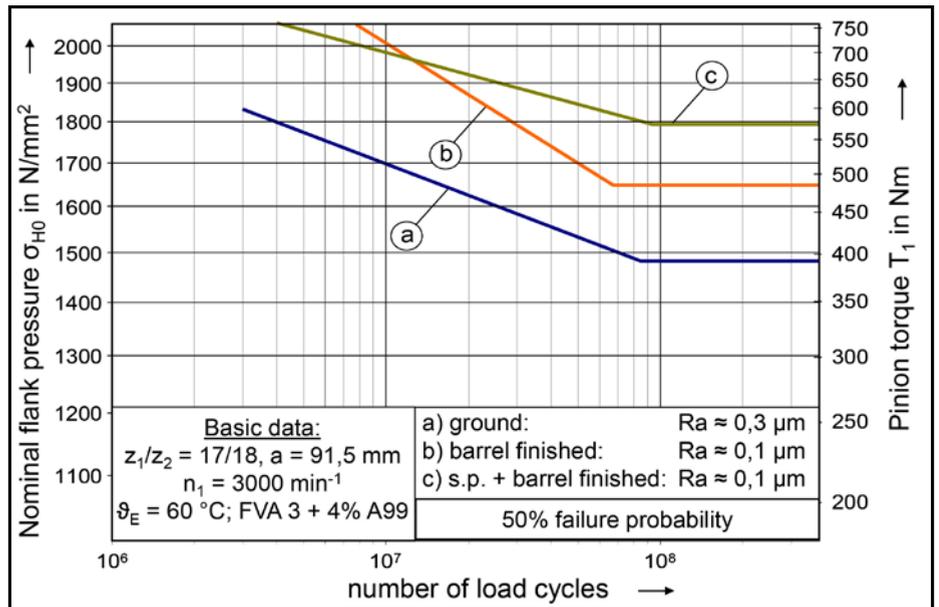


Figure 14 S-N curve of the pitting load-carrying capacity (s.p. means shot peening) (Refs.10-11).

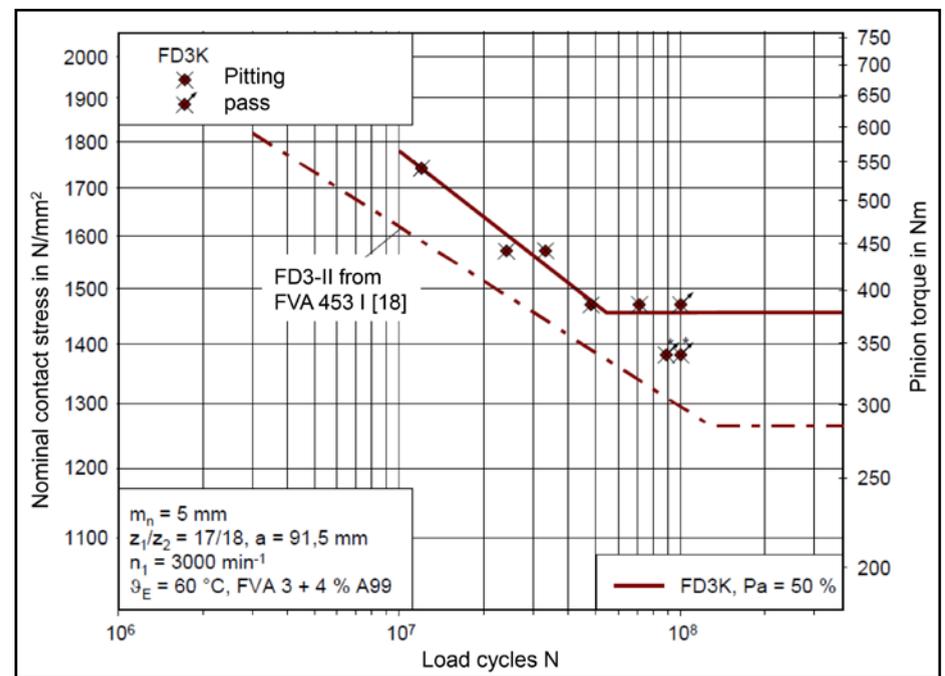


Figure 15 Exemplary presentation of the repair measure by shot peening and barrel-grinding of gears with grinding burn; FD3-II: variant with grinding burn; FD3K: variant with grinding burn that was shot peened and barrel-finished (Ref.9).

according to ISO 14104 (Ref.3)). Shot peening and barrel-finishing are necessary repair measures because shot peening not only increases the compressive residual stresses but also increases the surface roughness. Thus enhancement of the lifetime is possible, generally speaking, but the lifetime is limited due to local wear as well as a local modification of the tooth profile. In Figure 15 the influence of the repair measure shot peening and barrel-finishing for gears with grinding burn is shown. Variant FD3-II is

damaged by grinding burn, variant FD3K is additionally shot peened and barrel-finished. The results prove that by shot peening and barrel-finishing, the tooth flank load capacity (pitting) of gears with grinding burn can be increased up to a level compared to gears without grinding burn. The underlying mechanism includes the following two aspects: due to the shot peening, the tensile compressive residual stresses are changed into compressive residual stresses. Furthermore, the barrel-finishing achieves a fine

surface structure. In the case of a strong grinding burn, the tensile residual stresses reach deeper into the material, which cannot be completely changed into compressive residual stresses by shot peening.

To sum up, shot peening can be used to repair grinding burn if the tensile residual stresses in the surface layer can be changed into compressive residual stresses, and if a sufficient surface quality can be achieved. The grinding burn up to class FB according to ISO 14104 can be repaired.

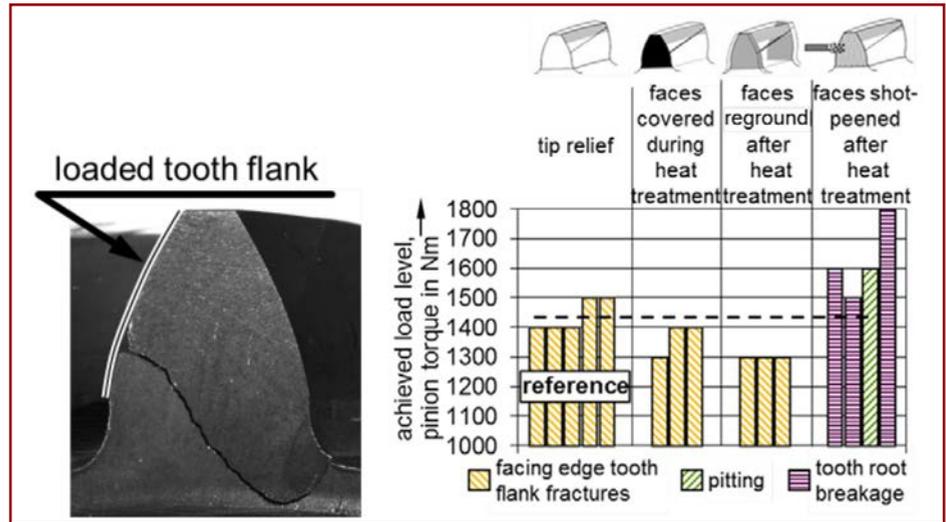
**Avoiding facing edge tooth fracture.** Facing edge tooth fracture is an unexpected tooth flank fracture that is sometimes observed on helical gears (Fig. 16, left). The crack initiation takes place in the area of the acute facing edge. This kind of damage reduces the tooth flank load capacity. In a research project the influence of face end modifications to avoid face edge tooth fractures on helical gears was investigated (Fig. 16, right).

A shot peening of the face side increased the face edge load-carrying capacity. Instead of face edge tooth fractures, the helical gears failed due to tooth breakage or pitting (Refs. 5 and 13). The results also prove the positive effect of compressive residual stresses that strengthen the face side in this case. This strengthening of the face side leads to an increased tooth flank load-carrying capacity.

**Conclusion**

There are tensile and compressive residual stresses that are balanced in a component that is not loaded by any torque or force. The residual stress state is influenced by many factors, such as manufacturing or heat treatment. Furthermore, the residual stress state can be further modified by blast-cleaning or shot peening. In dependence of the process parameters, high compressive residual stresses up to  $-1,200 \text{ N/mm}^2$  can be achieved.

There are numerous investigations concerning the influence of the residual stress condition on the load-carrying capacity of case-hardened gears. These investigations highlighted that compressive residual stresses have a positive influence on the load-carrying capacity, whereas tensile residual stresses decrease the load-carrying numbers. The tooth



**Figure 16** Left: typical face edge tooth fracture, view on the face side (Refs. 5 and 13); Right: influence of face end modifications on load-carrying capacity (Refs. 5 and 13).

root bending strength can be increased by more than 50% by shot peening, compared to the un-peened condition. But in the case of shot peened gears, the failure mode may change from surface crack initiation to subsurface-initiated cracks, which can limit the tooth root bending strength and benefits from shot peening. A shot peening of the grinded tooth flank can also increase the flank load-carrying capacity (pitting). But as a consequence of the shot peening, surface roughness increases, too. Due to a higher surface roughness on the tooth flank, the risk of micropitting rises. For a further increase of the pitting load-carrying numbers, a barrel-finishing after shot peening is possible. Then, increases of up to 20% are achievable. Nevertheless, also for the tooth flank, the risk for subsurface-initiated damages (tooth flank fracture) may increase with increased, allowable transmitted torque based on the benefits from shot peening on the pitting load-carrying capacity. Another benefit of shot peening and the resulting compressive residual stresses is that it can be used to repair grinding burn to a certain degree, or to avoid facing edge tooth flank fractures.

All in all, by shot peening and the resulting high compressive residual stresses in the surface layer, the load-carrying capacity of case-hardened gears can be increased significantly. But other failure modes have to be considered, which may come to the foreground in highly loaded gears.

In order to benefit from the advantages of increased, compressive residual

stresses in the surface layer, increased requirements on further gear characteristics may need to be considered. This includes, for example, gear materials with high purity to reduce the risk of subsurface-initiated failures, fine tooth flank surfaces and high-performance lubricants to reduce the risk of micropitting and wear, as well as an adequate macro and micro-geometry with adapted modifications of the gears. ⚙️

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# UNIMILL for Prototype and Small-Batch Bevel Gear Manufacturing

Hermann J. Stadtfeld

## Introduction

The manufacturing of spiral bevel and hypoid gears can be conducted in several ways. The following methods are commonly known:

- A. Face hobbing with a circular face cutter that rotates while the work rotates in the opposite direction (continuous indexing).
- B. Face hobbing with tapered hob (peripheral cutter) that rotates while the work rotates as well (continuous indexing).
- C. Planing method with one or two tools that move linearly, while the work either is performing a roll rotation or a combination of roll rotations and an additional rotation for a spiral-shaped flank line (single indexing).
- D. Face milling with circular face cutter that rotates while the generating gear is not rotating, the work only performs a roll, but no indexing motion (single indexing).
- E. Universal 5-axis milling with pencil-shaped end mill or disk-shaped cutter (single slot manufacturing).

Methods A through D are well known and have been performed for more than 70 years. Method E became available with the possibility to enter complex free-form surfaces into the control of 5-axis universal milling machines. While the manufacturing time is between 10 and 100 times that of the processes A through D, the accuracy might generally be lower than that of the dedicated machines used to perform methods A through D. The advantage of 5-axis bevel gear machining is the flexibility; no special cutting tool is required and the bevel gear size is only limited by the size of the 5-axis machines available (Refs. 1–2).

Five-axes machining uses a spherical- or cylindrical-shaped mill to shape the flank surfaces. The data post-processing uses flank surface points and, in some cases, normal vectors to calculate the machining paths. The machining paths must be close enough to achieve enveloping paths that approximate the target surface with sufficient precision. The orientation of the enveloping paths (flats) is linked only to the machining strategy in order to minimize the machining time and the deviation from the target flank surface. It has to be considered in manufacturing of bevel gears with machining centers that a generated bevel gear tooth consists of up to 7 different areas:

1. Flank surface — first flank
2. Flank surface — second flank
3. Root fillet radius — below first flank
4. Root fillet radius — below second flank
5. Slot bottom — between both root fillet radii
6. Undercut section — below first flank and above root fillet
7. Undercut section — below second flank and above root fillet

The true profile and lead generation, according to the gearing law, only works within the flank surface and in the root fillet area, i.e. — from the flank transition down towards the root bottom, ending in the area of the 30° tangent point. Depending on the severity and character of the undercut, it is impossible to generate this area precisely with correct normal vectors. Also

the slot bottom — connecting the fillet region from the 30° tangent through the deepest bottom land to the opposite side root radius at the 30° tangent — cannot be generated using the common surface-generating algorithm for bevel and hypoid gears.

In regards to face-hobbed gears with extended toe or heel ends, it is also equally difficult or impossible to generate the extension of the flank surface, which in many cases does not consist of a true flank surface according to the gearing law. One typical example is slotted nose pieces that represent flank surface extension far behind the heel of the pinion to be clamped in front of the nose piece. However, those problem areas are formed with a face cutter head that represents one tooth of the generating gear. The generating gear (Fig. 1) will form them as: an undercut section, as root bottom area, or as enveloping form cuts beyond the theoretical face width. If the undercut, root bottom area, etc. are formed by the generating gear, then it is assured that rolling without disturbances between pinion and gear can occur. Undercut, for example, is not an “evil” caused by the manufacturing process; rather, it is a geometrical necessity in order to assure correct rolling without interferences (Ref. 3).

But the solution for the problem areas is not a substitution of those sections with plane, cylindrical or parabolic surface elements, because of the risk of either weakening the teeth or causing rolling disturbances.

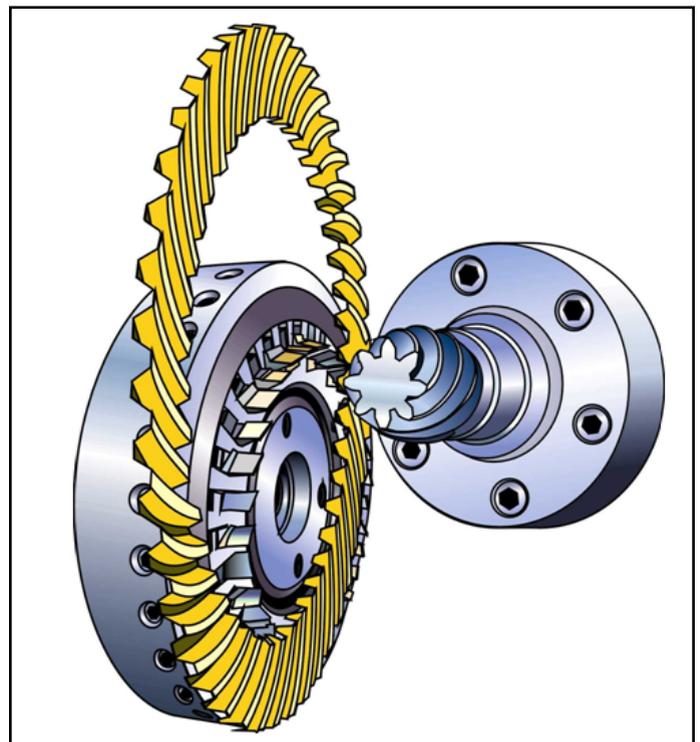


Figure 1 Face cutter representing one tooth of a generating gear.

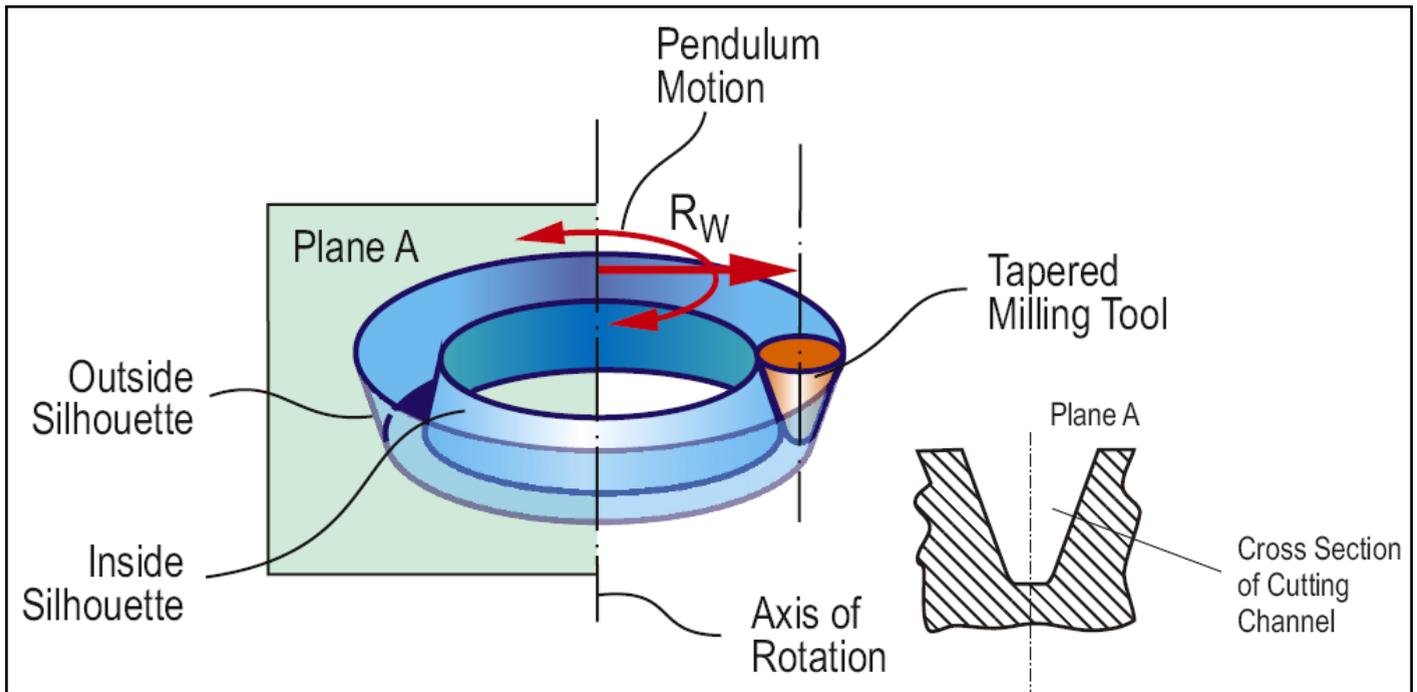


Figure 2 A typical cutting or grinding channel.

### Universal Method Derived from Face Cutting Process

The face milling method defines flank surfaces dependent on basic settings that define the relative location between a face cutter head, a generating gear axis and a work axis — as well as a kinematic relationship between those three components. A spread blade face milling cutter envelopes both an outside cone and an inside cone which in turn form a circular channel. Cup-shaped grinding wheels are dimensioned to duplicate the cutting channel for one particular gear design (with stock allowance taken into account).

A typical cutting or grinding channel is shown (Fig. 2). Particularly for large spiral bevel gear sets, it is common to use pressure angles of  $20^\circ$  for concave and convex flanks. In such cases, outside and inside silhouettes of the cutting channel are cones with angles of  $+20^\circ$  and  $-20^\circ$  relative to the axis of rotation. A tapered milling tool with a cone angle of  $20^\circ$  and a tip diameter with the value of the point width compared to the face

mill cutter head (Fig. 3) would fit into the cutting channel.

If the milling tool has an edge radius and a straight or curved profile with additional features, then the cross-sectional view of the milling tool can exactly duplicate the cross-section of the cutting channel. Such a milling tool can be positioned in the cutting spindle of a free-form bevel gear cutting machine. If the cutting machine axis would perform the regular cycle of movements as it is applied to generate a bevel gear in the conventional face cutter head process, then the pencil-shaped milling tool would not form the correct tooth geometry.

However, the milling tool would in this case be located in the center of the face milling cutter. In order to duplicate the flank surface forming action (cutting and generating), two additions to the standard setup and cutting cycle are necessary to accommodate the pencil milling tool. First, the milling tool is required to be moved from the face mill cutter center to an offset location (“a” in Fig. 4). The offset vector is identical to the average

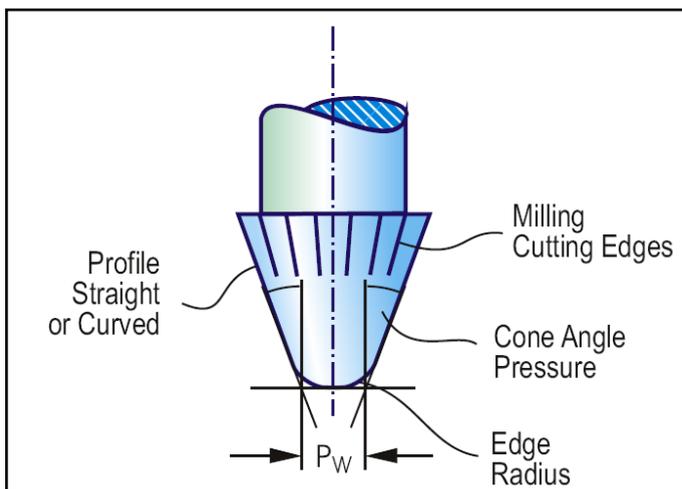


Figure 3 Conical milling tool.

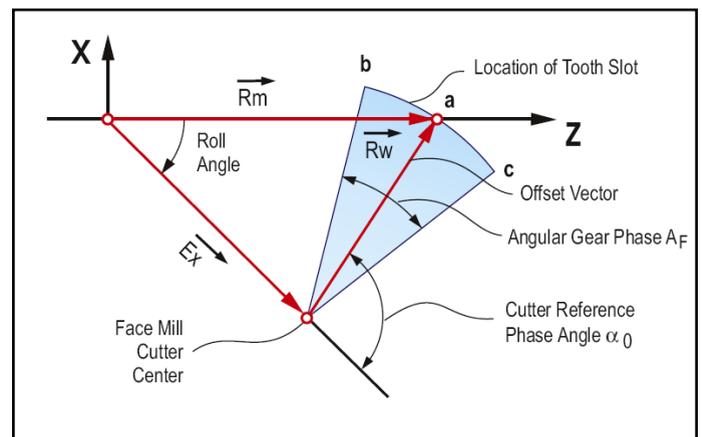


Figure 4 Pencil milling tool moved to offset location.

cutter point radius vector and can be located in the center of the tooth face width (point “a” in Fig. 4). Second, the milling tool has to follow a circular arc in the plane of the face milling cutter. Figure 4 shows the case where the face milling cutter rotational plane is identical to the plane X-Z.

The conventional cutting machine setup positions the cutter center at the tip of the vector  $E_x$  (Fig. 4). To enable use of a tapered milling cutter, the center of the cutter spindle must be positioned along the path of the arc b-a-c (Fig. 4) and also move between the positions b-a-c (and reverse), while the cutting machine is in one roll position. In the next roll position the movement along b-a-c must repeat. It is also possible to use a continuous slow roll motion, while the machine axes perform a fast pendulum motion of the tool center between b-a-c.

The cycle described can utilize a standard free-form bevel cutting machine with a modified cutting cycle. The only change vs. the conventional part program is the additional term shown in the formulas below:

Milling Cutter Location	Conventional Face Cutter Center	Additional Term
b:	$\vec{E}_x$	$+ R_w \times \begin{Bmatrix} \sin(-q_0 + \alpha_0 + \frac{A_F}{2}) \\ 0 \\ \cos(-q_0 + \alpha_0 + \frac{A_F}{2}) \end{Bmatrix}$
a:	$\vec{E}_x$	$+ R_w \times \begin{Bmatrix} \sin(-q_0 + \alpha_0) \\ 0 \\ \cos(-q_0 + \alpha_0) \end{Bmatrix}$
c:	$\vec{E}_x$	$+ R_w \times \begin{Bmatrix} \sin(-q_0 + \alpha_0 - \frac{A_F}{2}) \\ 0 \\ \cos(-q_0 + \alpha_0 - \frac{A_F}{2}) \end{Bmatrix}$

In order to generate the profile of a tooth, the generating gear must rotate. This rotation is equal to a rotation of the vector  $E_x$  (Fig. 4) about the axis Y (perpendicular to the drawing plane).

The introduced, proprietary new process is called *UNIMILL*. The infrastructure and accuracy level of the free-form bevel gear machine are a desirable platform for bevel gear cutting with the *UNIMILL* process.

One advantage of the *UNIMILL* method is the fact that it produces identical bevel gear geometries as produced with face

milling cutters. Even the generating flats have the same characteristics and angular orientation between the presented method and the face milling cutter method. Figure 5 (left) shows a three-dimensional representation of the conical milling tool as it simulates the face cutter in one instantaneous roll position. Since the face cutter would produce in this roll position one generating flat-per-flank (indicated on the outside silhouette, Fig. 5), the tapered milling tool will produce the identical flat. As the rolling motion progresses, further flats will be produced. Figure 5 (right) shows how the generating flat sections of the tool silhouette relate to the real generating flats on a flank surface.

The generating flat orientation of the 5-axis methods E differ from the face milling or face hobbing cutting methods, which will introduce in many cases different roll conditions. A surface structure identical to the original face cutter process is a significant advantage of the *UNIMILL* process. A second advantage of this method is the fact that standard cycles can be applied (super-imposed by said pendulum motion); e.g.—for soft cutting that leads to manufacturing times of 10-to-50 times that of the processes A and D—and is, in most cases, only 50% of the manufacturing time of a 5-axis machine using an end mill according to process E. At the same time, the gear accuracy of the *UNIMILL* method is comparable to the A and D process, due to the use of a gear machine tool concept.

A third advantage of *UNIMILL* is the unlimited compatibility to the cutting and grinding with face cutters; all existing design and optimization computer programs can be used. Also the nominal data calculations and correction matrixes that are well established and proven in correction software tools such as *G-AGE* can be applied without limitation. Yet another advantage of *UNIMILL* is the fact that undercut conditions and root fillet geometry are identical to the original geometry, generated by the face cutter process. As already noted, the elimination of undercut in an existing design is not an option because of the roll disturbances this will cause.

Even with unequal inside and outside blade angles of the analogue face cutter process, a tapered milling cutter with half the included blade angles  $(\alpha_{IB} + \alpha_{OB})/2$  as cone angle can be used if the milling tool will be inclined by  $\kappa_{\text{mill-tool}} = -(\alpha_{IB} - \alpha_{OB})/2$ .

The calculation of the position of a tapered milling tool in the general case can be achieved based on the geometric

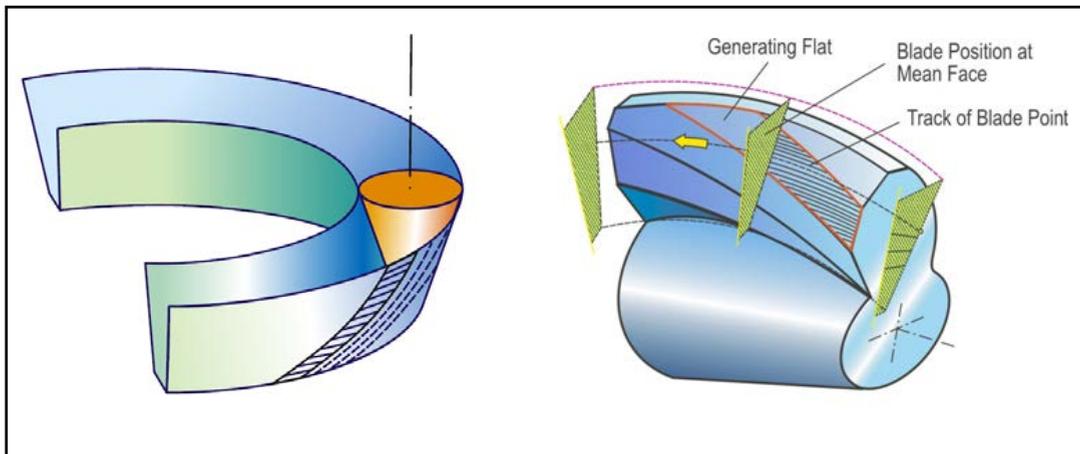


Figure 5 Cutter blade silhouette and generating flats.

relationships of Figures 6 and 7, as follows:

Input:

- Cutter tilt =  $W_x$
- Cutter swivel =  $W_y$
- Mean cutter radius =  $R_w$
- Cutter phase angle reference value =  $\alpha_0$
- Cutter phase angle =  $\alpha_x = \text{Swing Angle}$
- Roll position =  $q$
- Blade reference height =  $H_R$
- Sliding base position =  $X_B$
- Additional milling tool inclination =  $\kappa_{\text{Mill Tool}}$
- Radial Setting =  $S$
- Cutter Radius vector at reference position =  $R_w$  ( $\alpha_0$ )

After performing the transformations from conventional basic settings to the settings of a tapered mill cutting tool, the following steps can be applied in order to prepare all data for the *UMIMILL* process:

- Choose a number of roll positions that split  $q_{\text{start}}$  and  $q_{\text{end}}$  in 50 increments:

$$\rightarrow q_1, q_2, q_3 \dots q_{51}$$

where:

$$q_1 = q_{\text{start}}; q_2 = q_{\text{start}} + \Delta q; q_3 = q_{\text{start}} + 2\Delta q; \dots q_{51} = q_{\text{start}} + 50\Delta q$$

$$\Delta q \Rightarrow \Delta q = (q_{\text{end}} - q_{\text{start}}) / 50$$

- Apply for each roll position the formulas for the tool position, e.g. — for 200 increments:

$$\rightarrow \alpha_1, \alpha_2, \alpha_3 \dots \alpha_{201}$$

where:

$$\alpha_1 = \alpha_0 - A_F / 2; \alpha_2 = \alpha_1 + \Delta \alpha; \alpha_3 = \alpha_1 + 2\Delta \alpha;$$

$$\alpha_{201} = \alpha_1 + 200\Delta \alpha$$

$$\Delta \alpha = A_F / 200$$

## Data Processing for Generation and Swing Motion

While the described method was shown and explained for the single indexing process, it can also be applied to the continuous indexing process. The cutter rotation  $\omega$  is in a timed relationship with the work rotation, superimposed to the roll motion on the work (in a continuous mode) or applied in discrete roll positions. This is similar to the previous explanations, where either roll and/or cutter rotation angle (equal tapered mill position) have been observed in discrete increments:

$$\omega_{\text{work}} = \Omega_{\text{Cradle}} / R_A + \omega Z_{\text{Tool}} / Z_{\text{Work}}$$

or

$$\delta_{\text{work},i,j} = \delta_{\text{work},\text{start}} + q_i / R_A + \alpha_j Z_{\text{tool}} / Z_{\text{work}}$$

However, the discrete observation and the processing of the roll positions lead to a looped data and position processing:

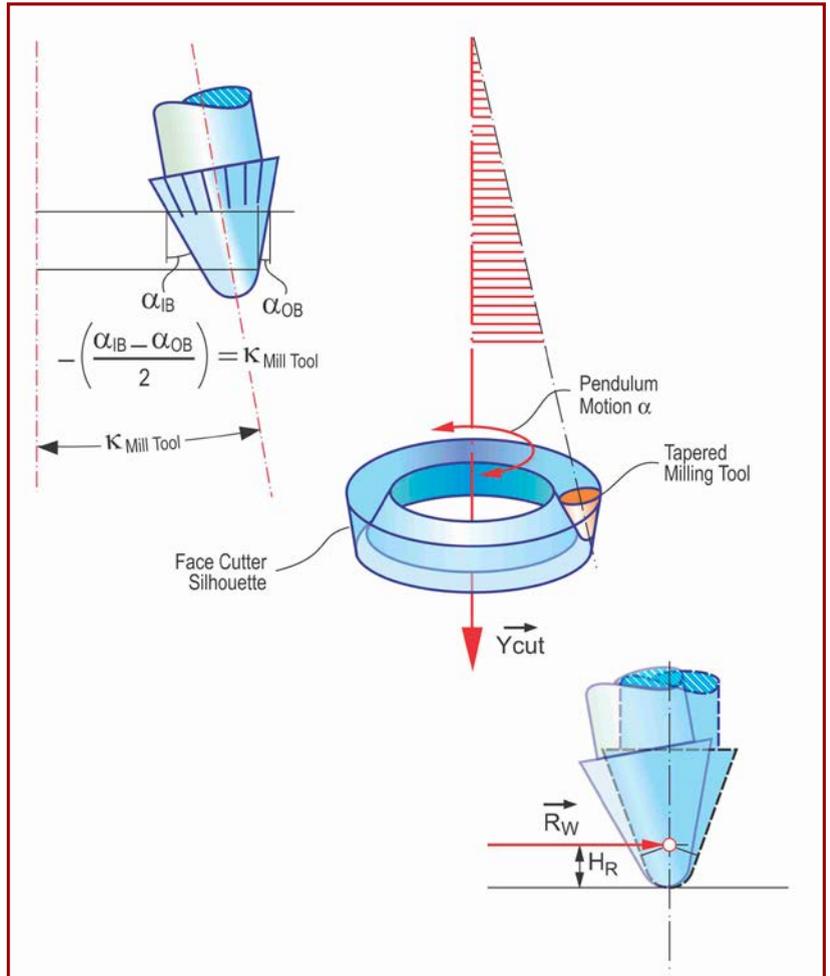


Figure 6 Inclination of tapered milling tool.

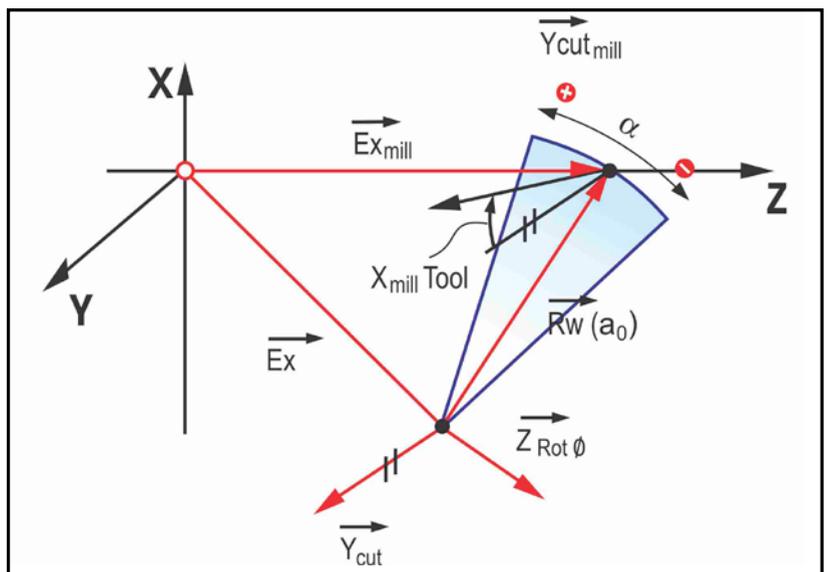


Figure 7 Triangular vector for generating bevel gears with tilted end-mill.

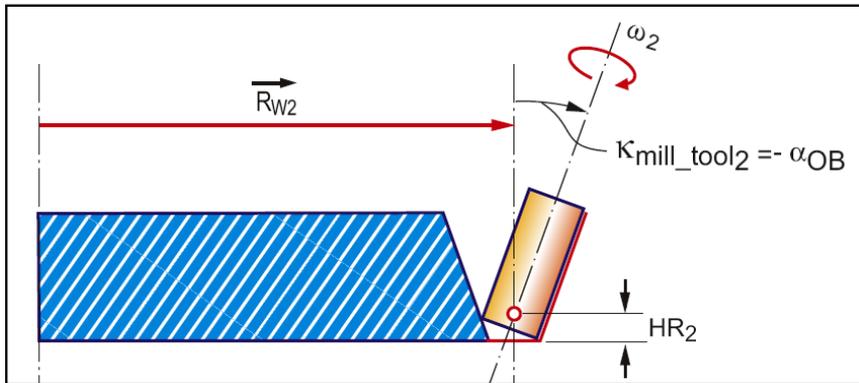


Figure 8 Cylindrical tool, machining outside profile only.

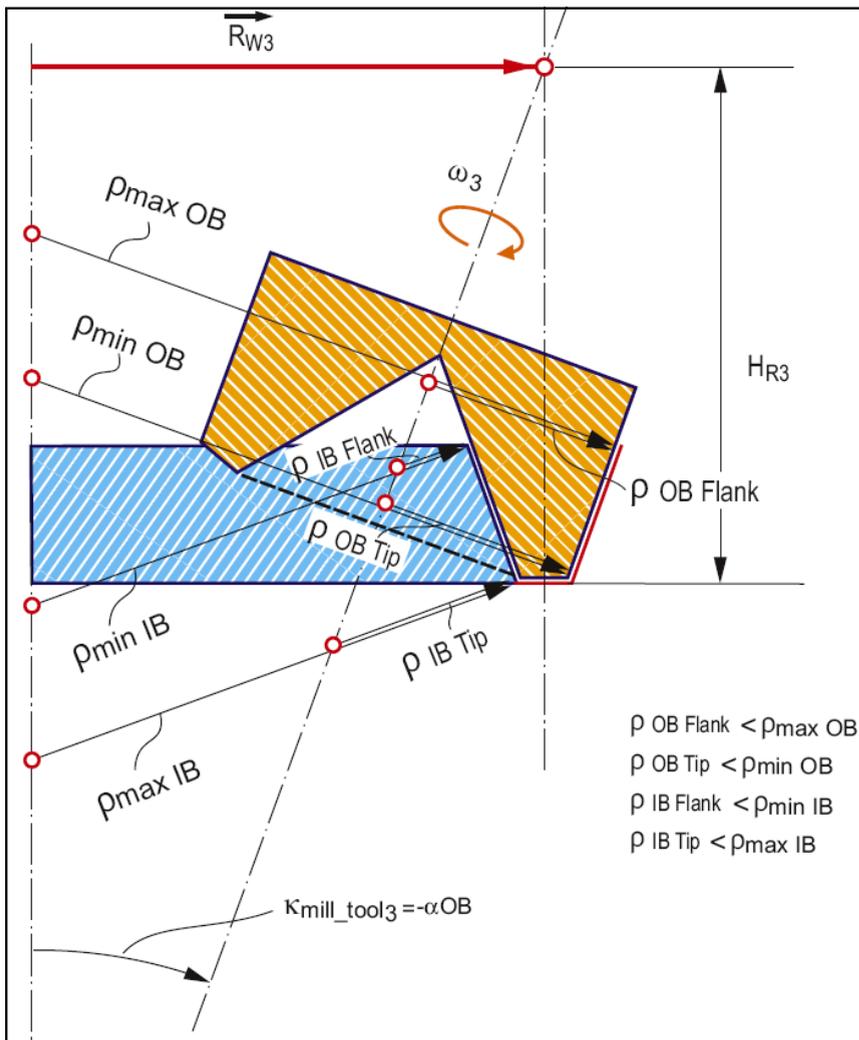
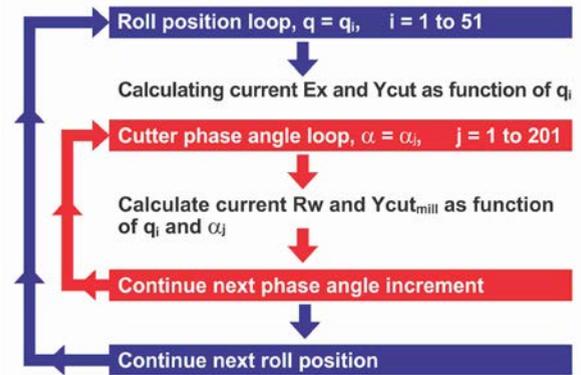


Figure 9 Cylindrical tool with conical inside profile.



In both cases — continuous or single index — machining, the last presented formulas are valid and can be applied. Those formulas can be applied for an asymmetrical cutting channel (Fig. 6), as well as for a symmetrical cutting channel (Fig. 2). The symmetrical cutting channel only presents a special case of the more general asymmetrical cutting channel ( $\kappa_{mill\_tool} = 0$ ).

There are a multitude of possibilities to derive the formulas in order to position and move the tapered milling tool. However, trigonometric calculations would in their solution show intrinsic function depending on roll, tool rotation, and work rotation angles, as well as linear constants. The derivations shown here use the basic machine settings that relate to the generating gear. The resulting vectors  $Ex_{mill}$  and  $Ycut_{mill}$  can be converted to basic settings:

- $S_i = \sqrt{Ex_{mill,x}^2 + Ex_{mill,y}^2}$  → Radial Distance
- $q_i = \arctan(Ex_{mill,x}/Ex_{mill,y})$  → Roll Position
- $X_{B,i} = Ex_{mill,y}$  → Sliding Base
- $Wx_i = \arccos(Ycut_{mill,y})$  → Tilt
- $Wy_i = \arctan(Ycut_{mill,x}/Ycut_{mill,z}) - q_i$  → Swivel

Additional basic settings, such as:

- $X_p...$  Head Setting
- $E_M...$  Machine Offset
- $\gamma_M...$  Machine Root Angle
- $R_A...$  Ratio of Roll

do not change during the conversion from conventional tool to tapered mill. The basic settings, as shown above, can be converted into a 6-axes Phoenix coordinate system.

### Expanding to a Variety of Highly Efficient Tools

The UNIMILL machining method can be expanded to use a milling tool which is, for example, cylindrical and only machines one flank surface at a time (like outside flank shown in Fig. 8). The tool inclination angle in this case is  $-\alpha_{OB}$ . The maximal diameter of such a tool is limited (Fig. 8). A diameter larger than shown in Figure 8 causes mutilation of the opposite flank (inside flank). It is



**Tools and Examples**

If *UNIMILL* is utilized as a prototyping method, the use of disk cutters is most productive; but the use of tapered end mills requires the lowest tool investment (Fig. 12, right and middle). Due to the use of standard inserts (Fig. 12, left), multi-start fly cutters similar to bevel gear chamfer cutters present certain restrictions regarding blade point width and edge radius. Flared disc cutters that use stick blades (PentacSlimLine) are also available (Ref. 4). The advantage of tapered end mills is that most gear manufacturers can find nearby local tool shops that can manufacture a new milling tool from carbide material — including coating — in less than two weeks. The basic dimensions of a tapered end mill are point width, edge radius, and the included angle of the taper.

The cutting scenario of a face-hobbed hypoid pinion is shown (Fig. 13, left). The end mill moves from heel to toe while it is milling one generating flat at the convex pinion flank. After the end mill exits the slot at the toe, the machine axes set over to the concave side in order to machine the corresponding drive side generating flat.

The movement along the face width is called “swing motion.” Changing the swing motion between start and end roll position is possible in three sections, depending on the different chip load in the different areas. After a part is finished, a coordinate

measurement is conducted and, in case of significant deviations between nominal and actual flank, *G-AGE* corrections are calculated and sent via network to the Phoenix machine control. Similar to the procedure in conventional bevel gear manufacturing, the corrections are applied in a menu to the basic settings and the *UNIMILL* software converts the basic settings to a part program with axes motion commands.

In Figure 14 the scenario of a nose piece milling with a disk-shaped HSS cutter is shown. In the case of nose pieces, disk cutters are very beneficial; the slots are normally very wide and the root fillet radius can be standardized, because root bending strength is not a criterion for those parts.

Today, all the *UNIMILL* software is implemented in the machine control. The control computer receives a download file that includes basic settings with gear blank data — very similar to regular bevel gear machining. The operator screen allows the entering of speeds and feeds, as well as the number of generating flats and over travel amounts, etc. In order to utilize existing experiences in bevel gear manufacturing, the basic settings are calculated by the machine control and displayed to the operator. The basic settings can be changed not only with *G-AGE* corrections, but also by adding or subtracting delta values. The “*Master Summary*” feature allows return from the developed summary to the original summary at any time.



Figure 12 Variety of *UNIMILL* tools.

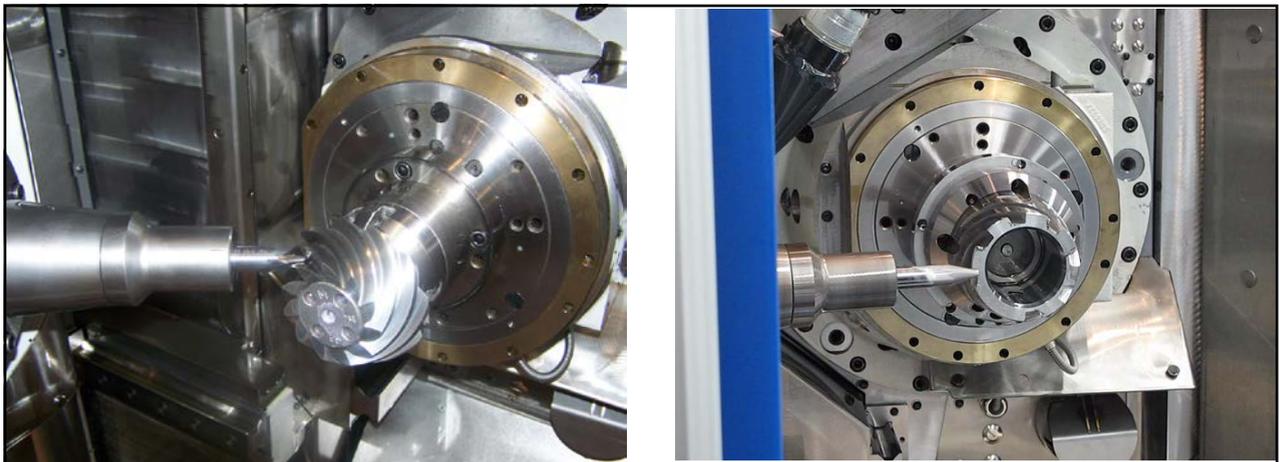


Figure 13 Milling of a face hobbed hypoid pinion (left) and a slotted nose piece (right).

A variety of different parts manufactured with *UNIMILL* is shown (Fig. 15). In addition to spiral bevel and hypoid gears, the milling of straight bevel gears has also been developed. Figure 15 (right) shows a large spiral bevel gearset that was soft cut with *UNIMILL* and then hard skived after heat treatment. The *UNIMILL* process has shown to be suitable for a hard skiving process, which replaces either grinding or skiving with a dedicated face cutter. Just like in soft cutting, the *UNIMILL* hard skiving process also applies to small quantities as, for example, prototypes, in order to minimize the cost of required equipment and tooling.

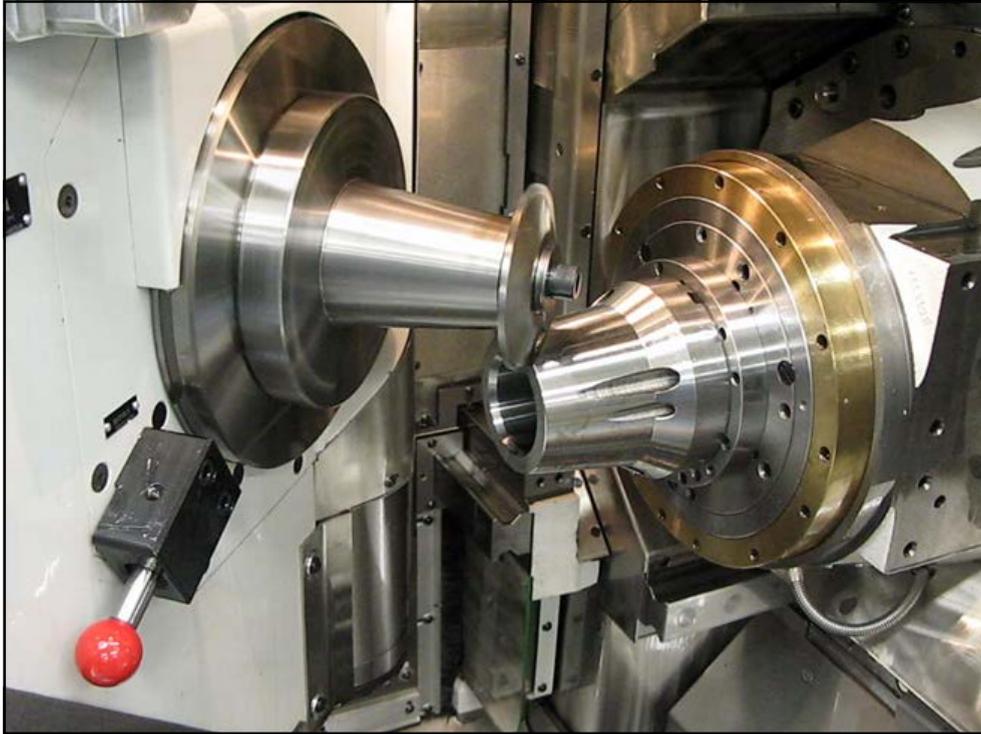


Figure 14 Milling of slotted nose piece with HSS disk cutter.



Figure 15 Different gear types machined with the *UNIMILL* process.

**Practical Experience with Straight Bevel Gears**

With straight bevel gears — in addition to prototype manufacturing — the possibility of machining parts with a front bearing hub is an attractive application for UNIMILL. These parts have been manufactured in the past with two-tool generators, which only deliver medium quality in a rather slow process. Often, the material of solid parts with an integrated front hub was difficult to machine because of a high strength requirement. The possibility to use coated carbide tools in UNIMILL gives manufacturers an incentive to replace their aged two-tool generators with modern CNC equipment, allowing for state-of-the-art closed-loop manufacturing. The straight bevel gear (Fig. 16) requires a manufacturing time of 2 hours, with a tool life of 4 parts. The tools can be re-sharpened up to 10 times before requiring replacement.

Experience in the cutting of straight bevel gears with UNIMILL has been gained over the past few years. A variety of tool holder and coated-carbide cutting tools was applied. In some cases the manufacturers of these gears prefer using pre-slotted parts in order to reduce the amount of chip removal and, subsequently, reduce the UNIMILL cutting time. The software was also expanded for stock division capability, vector feed and a Coniflex quick cycle.



**Figure 16** Straight bevel gear with front hub.

GLEASON CORPORATION R&D - BEVEL GEAR TECHNOLOGY HYPOID & SPIRAL BEVEL GEAR DIMENSIONS			
	PINION	GEAR	
NUMBER OF TEETH.....	25	25	
PART NUMBER.....			
FACE MODULE.....		4.233	
NORMAL MODULE AT CENTER.....		3.606	
FACE WIDTH.....	22.17	22.17	
PINION OFFSET.....	0.00		
PRESSURE ANGLE - PIN CONCAVE.....	20.00		
PRESSURE ANGLE - PIN CONVEX.....	20.00		
LIMIT PRESSURE ANGLE.....	0.00		
SHAFT ANGLE.....	90.00		
TRANSVERSE CONTACT RATIO.....	1.640		
FACE CONTACT RATIO.....	0.034		
MODIFIED CONTACT RATIO.....	1.640		
OUTER CONE DISTANCE.....	74.84	74.84	
MEAN CONE DISTANCE.....	63.75	63.75	
PITCH DIAMETER.....	105.83	105.83	
ADDENDUM.....	4.23	4.23	
DEDENDUM - THEORETICAL.....	5.03	5.03	
WORKING DEPTH.....	8.47	8.47	
WHOLE DEPTH.....	9.26	9.26	
OUTSIDE DIAMETER.....	111.82	111.82	
CORE DIAMETER PINION HEEL.....	98.72		

**Figure 17** Section of dimension sheet.

**Basic Milling Tool Data**

The basic information is retrieved from the dimension sheet and from the blade profile grinding summary of the particular job. Figure 17 shows a section of the dimension sheet with the convex and concave pressure angles (highlighted yellow). Both added together (in the present case 20° + 20°) results in the included pressure angle (here equals to 40°). The end-mill cone angle must be less than half of the included pressure angle. In the present case, a cone angle of 15° is optimal.

The axial height of the end-mill can be retrieved from the Blade Profile Grinding Summary in Figure 18, item 16 “Axial Grind Depth.”

For the correct dimensioning of the edge radius  $R_E$ , it is advisable to calculate first the maximum possible edge radius for the given dimensions. In addition to the cone angle  $\alpha_T$ , the end-mill point width  $P_W$  is required. The end-mill point width should match the blade top width (item 09 in Fig. 18). A larger  $P_W$  can be used within limits, but  $P_W$  cannot be larger than the smallest point width of the gear slot (item 8 in Fig. 18, top). The formula (Fig. 19) is used to calculate the largest possible edge radius for the end-mill  $R_E$ . In the present case, using  $P_W = 1.84$  mm, the largest possible edge radius is  $R_E = 0.65 \times P_W = 1.2$  mm. After  $R_E$  is calculated, it has to be compared to the Edge Radius Pressure Angle Side (item 06 in Figure 18). If the result of  $R_E$  is smaller than item 06 in Figure 18, then the calculated number of  $R_E$  must be used for the end-mill.

In the present case, the summary item 06 in Figure 18 is 0.51 mm, which is smaller than the calculated maximum

BPG/300 CG BLADE PROFILE GRINDING SUMMARY V. 2.4 COPYRIGHT (c) 2015 THE GLEASON WORKS	
1. SUMMARY: GLEASON CONIFLEX 9" RUNOFF JOB	
PINION BLADE SPECIFICATIONS - CONIFLEX (R) Plus	
3. CUTTER DIAMETER.....	8.999 " = 228.573mm
4. NO. OF BLADES PER SIDE.....	24
5. CUTTER NUMBER.....	132
6. HAND OF CUTTER - BLADE GRINDING.....	RIGHT
7. TYPE OF BLADES.....	PENTAC 2-FACE
8. SMALLEST POINT WIDTH AT TOE.....	2.14 mm
9. TOP WIDTH IN PCT OF PT WIDTH.....	85.671
10. CALC. SOFTWARE.....	UNICAL-CONIBLD
BLADE DATA ALL BLADES ==> OUTSIDE	
01. BLADE PRESSURE ANGLE.....	17.17deg
02. BLADE CLEARANCE ANGLE.....	11.17deg
03. BLADE DEDENDUM.....	4.28 mm
04. RADIUS OF CURVATURE - P.A.....	0.00 mm
05. RADIUS OF CURVATURE - CLEAR.....	0.00 mm
06. EDGE RADIUS PRESS. ANG. SIDE.....	0.51 mm
07. EDGE RADIUS CLEARANCE SIDE.....	0.51 mm
08. BLADE DISTANCE.....	6.60 mm
09. BLADE TOP WIDTH.....	1.84 mm
10. TOPREM DEPTH.....	0.00 mm
11. TOPREM ANGLE.....	0.00deg
14. RELIEF ANGLE P.A. SIDE.....	8.00deg
15. RELIEF ANGLE CLEAR SIDE.....	6.00deg
16. AXIAL GRIND DEPTH.....	12.04 mm
17. TOP RELIEF ANGLE.....	16.00deg
18. TOP SLOPE ANGLE.....	-5.00deg
19. BLADE SLOT TILT ANGLE.....	7.42deg
20. BLADE SIDE RAKE ANGLE.....	12.00deg
21. BLADE WIDTH.....	12.70 mm
22. BLADE THICKNESS.....	10.16 mm
26. BLADE FLAT WIDTH.....	0.76 mm

**Figure 18** Blade profile grinding summary.

possible radius for  $R_E$ . In this case,  $R_E=0.51$  is the correct edge radius for the end-mill. In the present case, the end-mill design, according to the graphic (Fig. 20), will have a flat spot at the tip, connecting the two edge radii in the cross-sectional drawing (which of course is) only one edge radius of the rotationally symmetric end-mill.)

Measurement of the stock division probe reference height is shown (Fig. 21, left). The probe is placed in the milling tool holder and an electronic height measurement caliper on a granite plate, or any other precisely flat surface, is used to determine the overall height (stock division probe reference height) of the assembly. The same procedure (Fig. 21, right) is applied to determine the cutter reference height. Both reference heights are entered into the machine summary. For the initial stock division teaching, the probe is inserted into the tool holder on the machine instead of the tool. The next step is performed manually by joggling the probe along a predetermined feed vector while the unclamped work is rotated back and forth until the probe sphere begins to contact both flanks (Fig. 22). Now the part is clamped and the automatic stock divider teaching is done by simply running the teaching routine via menu. To begin the milling, the probe is now exchanged with the milling tool.

Coniflex cutting with *UNIMILL* uses basic settings from a AAA data file. Because the original Coniflex process is not a completing, but a single side cutting method, it is recommended to use the standard *UNIMILL* cycle if the parts are not pre-slotted. The standard cycle mills a surface flat in one roll position on the lower flank (from heel to toe), and then a surface flat in the same roll position on the upper flank in the return swing, as schematically explained (Fig. 23, left). This cycle, which constantly alternates between lower and upper flank, avoids double flank contact of the fast rotating tool — thus assuring a

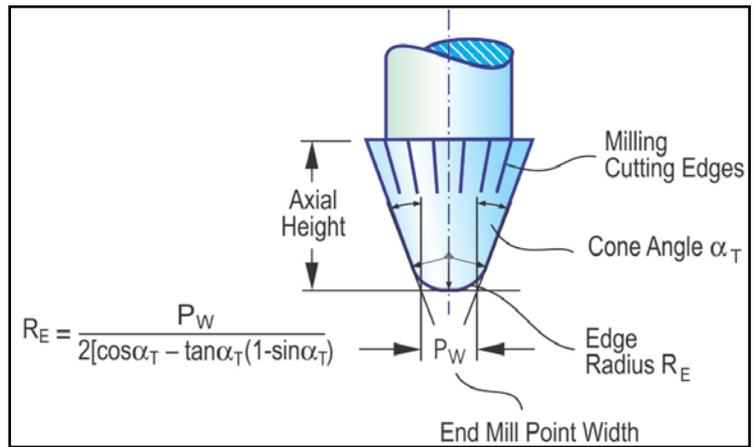


Figure 19 Fully rounded end-mill tip.

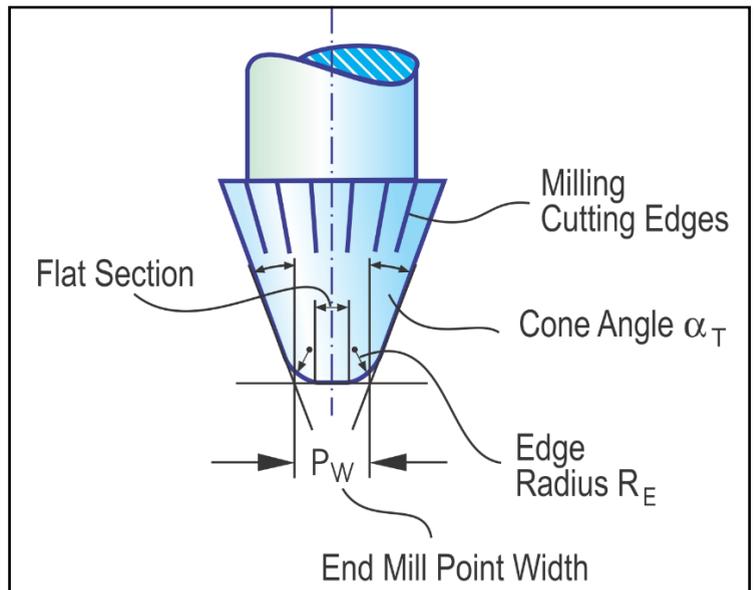


Figure 20 Conical end-mill with edge radius smaller than the fully rounded radius.



Figure 21 Reference height measurement of stock division probe and milling cutter.

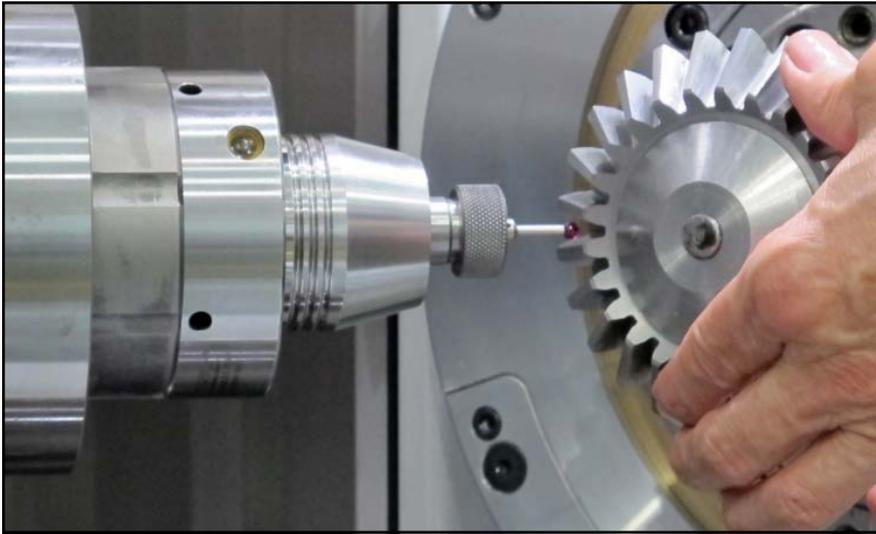


Figure 22 Manual stock division of pre-slotted part.

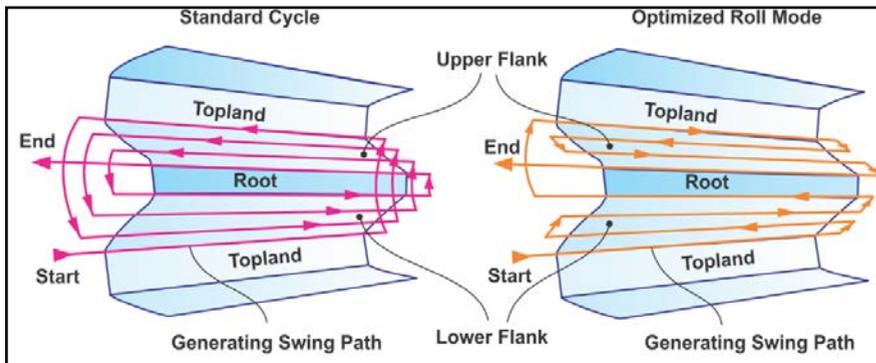


Figure 23 Standard and optimized roll mode for straight bevel gears.

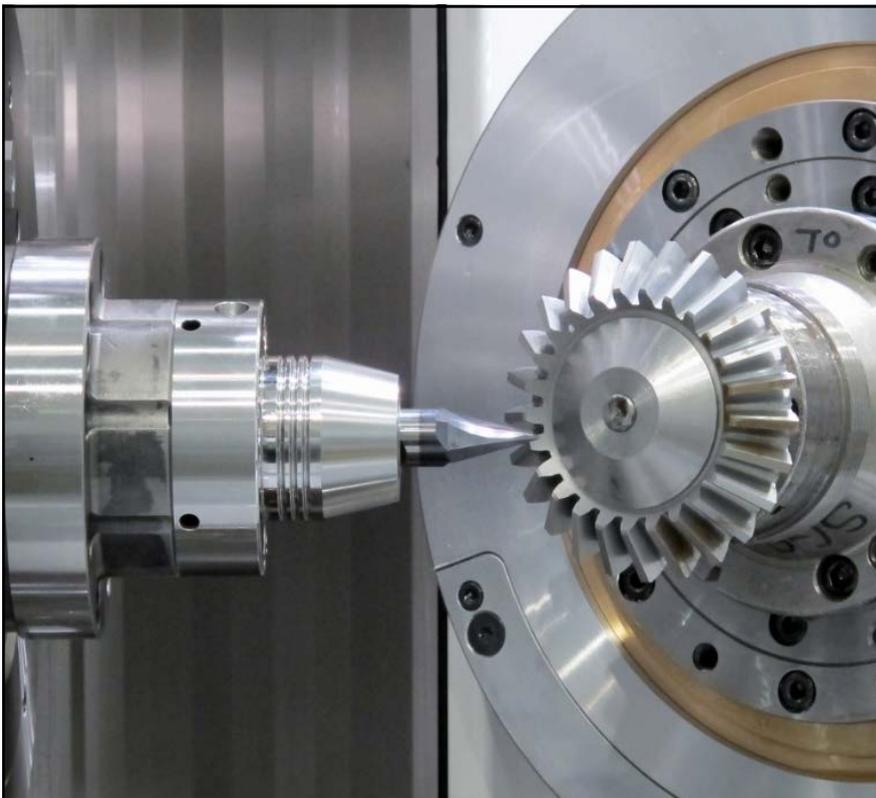


Figure 24 UNIMILL straight bevel gear milling.

smooth milling action.

If straight bevel gears are pre-slotted, the slotting can be done on a two-tool generator or on planers with an indexing head. For the case of pre-slotted parts, the “Optimized Roll Mode” is recommended. In the optimized roll mode the tool swings from heel to toe in one roll position (cutting the lower flank), and then returns from toe to heel in the next roll position, still milling the lower flank, as indicated in the right-side graphic in Figure 23. The heel to toe swing is, for example, conventional cutting, while the return swing is climb cutting. After finishing the complete lower flank, the milling tool changes to the upper flank and repeats the same cycle. With the described optimized cycle the constant change between lower and upper flank is avoided, which saves about 15% cycle time. The pre-slotted allows faster milling with a lower number of roll positions, which saves 25% of the original cutting time. Both cycle time reduction elements together will reduce the cycle time for cutting pre-slotted parts down to about 40% of the original cycle time of cutting un-slotted parts.

An interesting observation is the fact that the optimized roll mode mills consecutive surface flats alternating between conventional and climb cutting; this results in a very good average surface finish and two completely equal flank surface structures. In the standard cycle that alternates after each swing between upper and lower flank, the lower flank is milled in conventional cutting, while the upper flank is milled in climb cutting. This leads to slightly different surface textures between the two flanks.

In order to allow for easy contact pattern development via roll tester, the UNIMILL MMC software was expanded to accept and process standard proportional changes. In addition, independent depth and slot width changes can be entered into the UNIMILL summary.

After setup and summary entry, the outer swing position on toe and heel can be tested for sufficient clearance in the start and end roll positions. If the clearance values appear too small or too large, corrections of the input items for swing over-travel as well as roll positions can be independently entered into the UNIMILL summary.

Before starting the cutting cycle, a hold-back value can be entered for cutting of a first slot with some stock allowance. If cutting surface finish, over-travel on toe and heel

and correct flank form have been verified, the hold-back can be cleared via soft key.

The cutting engagement of a tapered *UNIMILL* end-mill in the end-roll position of the lower flank is shown (Fig. 24). The surface speed of 250m/min is calculated in the middle of the whole depth of the tooth, which is at the blade dedendum point of the end-mill. The end-mill material is Alcona Pro coated tungsten carbide with a 10% cobalt content.

## Summary

*UNIMILL* is a milling method for the manufacture of prototype bevel gears using end mills or disk cutters. The *UNIMILL* software requires basic settings in form of SPA of AAA files as an input. Additional input items — like speeds and feeds, number of generating flats, over travel amounts, etc. — are entered into the process parameter input screen directly on the Phoenix cutting machine. If high RPMs are required, as in the case of tapered end mills, it is possible to use Phoenix grinding machines or cutting machines with high-speed spindles.

In contrast to general multi-axes machining that utilizes surface coordinates and normal vectors, *UNIMILL* does not depend on certain grid specifications and definitions regarding undercut and root fillet (which are difficult to obtain). *UNIMILL* tools follow the path of a face cutter head silhouette, while the face cutter is performing a generating (or form cutting) motion. The result is a faster process with surface finish characteristics very similar to the traditional cutting process. *UNIMILL* is available on all Phoenix II cutting and grinding machines, as well as on all later models. 

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### Dr. Hermann J.

**Stadtfeld** received in 1978 his B.S. and in 1982 his M.S. 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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# Children's Technology Club

## VISITS GLEASON-PFAUTER TO LEARN ABOUT GEARS

The Technical Club "TeClub" visited Gleason-Pfauter Maschinenfabrik in Ludwigsburg, Germany and learned about the building of gear manufacturing machines.

Once again, Gleason-Pfauter worked with TeClub and offered 20 elementary school students between the ages of 8 and 10 the opportunity to visit the plant in Ludwigsburg and to experience live gear manufacturing processes. The Management of Gleason-Pfauter, Dr. Ing. Ulrich Brahms and Karl-Heinz Kübler, emphasizes the need to get children interested in technology at an early age.

Gleason-Pfauter commercial trainees welcomed the students and gave an overview of the company and showcased the high tech products in a simple and easily understandable presentation. Then, the students had the opportunity to tour the Gleason-Pfauter plant in small groups, where budding industrial mechanics shared gear technology knowhow and answered



many curious questions. Afterwards, the students were asked to assemble small electric motors in the training center and make their own product. It proved to be a challenging activity that made our young visitors think and get creative. The students were visibly proud of their work and it seemed to be their favorite part of trip. Finally, the chairman of the works council concluded the visit with freshly grilled sausages and drinks.

Dr. Ulrich Brahms, managing director of Gleason-Pfauter, was delighted with the successful event.

"We want to create tomorrow's employees' sense of achievement and give them the feeling that they are working independently and actively on technical products, true to the motto: 'We Are Doers!'" Brahms said.

The manager of the TeClub, Anette Gagsch, had lots of praise for the organization and execution of the event by the committed Gleason-Pfauter trainees. The TeClub is sponsored by Südwestmetall - Verband der Metall- und Elektroindustrie Baden-Württemberg. ([www.gleason.com](http://www.gleason.com))

# Seco/Vacuum

## ANNOUNCES DIRECTOR OF NITRIDING AND SPECIAL VACUUM FURNACES

Seco/Vacuum Technologies, LLC (Seco/Vacuum) is pleased to welcome **Mark Hemsath** as director of nitriding and special vacuum furnaces. Hemsath had previously held a position with Seco/Vacuum's sister company, Seco/Warwick Corp., as manager of the thermal group from 2014–2017



before taking time away to serve as director of sales and marketing with Advanced Heat Treat Corporation in Waterloo IA. Hemsath will be the primary contact for gas nitriding furnace applications in North America; he

will cover the Southeast USA from North Carolina to Texas for all Seco/Vacuum products; and he will handle special vacuum furnace products throughout North America.

Hemsath boasts a long and rewarding history in thermal processing, having operated his own heat treat furnace manufacturing and alloy fabricating company from 1993–2009. He has also designed, built, and sold vacuum, nitriding, hydrogen annealing and various other furnaces since the 1980s. And he is a descendant of a well-respected leader in thermal processing; his father acquired nearly 65 patents as vice president of technology for Midland Ross, parent of Surface Combustion. ([www.secovacusa.com](http://www.secovacusa.com))

# Röhmm Products of America

APPOINTS NEWS ILLINOIS AND WISCONSIN SALES MANAGER

To further support its Midwestern customers, clamping and gripping provider Röhmm Products of America has announced that **George Burleson** will manage the sales of the company's world-class products in the Illinois and Wisconsin territories. In this role, he will hold responsibility for supporting the company's efforts to provide chucks, centers, vises, tool clamping and automation systems as well as customized solutions for turning, milling, drilling and grinding to customers across the region.



"We are thrilled to welcome George to the team and are confident he will help our customers implement the high-productivity, high-quality workholding solutions for which Röhmm is well-known," said Steven Onik, national sales manager for Röhmm.

Burleson brings a significant understanding of the cutting tool industry to Röhmm after spending more than three years as the technical sales manager for the Rowley, Massachusetts-based Harvey Tool Company LLC, where he has worked in various positions since 2012. In his sales management position, he achieved constant year-over-year growth while managing relationships with distributors and customers in the medical, aerospace, defense, plastic injection molding and technology manufacturing industries. Prior to joining Harvey Tool, he earned his bachelor of science in mechanical engineering at Union College in Schenectady, New York, and studied Chinese during a term abroad at Fudan University in Shanghai. ([www.rohmm-products.com](http://www.rohmm-products.com))

# Walter Surface Technologies

ACQUIRES BLACKSTONE SUPPLY AGREEMENT FROM SUNDISC ABRASIVES

Walter Surface Technologies recently announced the acquisition of the Fastenal Blackstone supply agreement and all related inventory from Sundisc Abrasives USA LLC. With this agreement, Walter becomes one of Fastenal's trusted private label suppliers across the Americas.

"This transaction allows us to accelerate our expansion in the United States by servicing one of the fastest growing industrial distributors in the country," said Marc-André Aubé, president and COO of Walter Surface Technologies. "We are excited to help contribute to the success of the Blackstone brand, and we believe this agreement will also contribute to the success of Walter's own high-performance line of products regarded as 'Only the Best' throughout the industry."

Blackstone is one of Fastenal's leading brands of abrasives

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03/2018

## KISSsoft Highlights

- Strength calculation of asymmetrical gears
- Displacement for bevel and hypoid gears
- Interface to GEMS® with data exchange
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## Sandvik Coromant Center

SET TO OPEN IN RENNINGEN, GERMANY, FOCUS ON AUTO INDUSTRY

A decision has been taken to open a new Sandvik Coromant Center in Renningen, Germany that will include a showroom, training facilities, and a design and project office. These centers are world class facilities for productivity, applications, machining and research in manufacturing. In Renningen, the team will focus on the automotive industry. The aim of this investment is to further improve customer experience. Sandvik Coromant Centers are meeting places where visitors can interact and cooperate in a modern and inspiring environment, enabling physical and digital collaboration. The centers are truly digital, offering improved connectivity for live machining demonstrations from Asia, Europe and the United States, ultimately utilizing the company's global knowledge in the best possible way. The new facility will be approximately 3,000 m<sup>2</sup> in size and is expected to be operating from the end of Q1 2020. ([www.sandvik.coromant.com](http://www.sandvik.coromant.com))



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**September 10–15—IMTS 2018** Chicago, Illinois. More than 115,000 industrial decision-makers attend the International Manufacturing Technology Show to get ideas and find answers to their manufacturing problems. They will see new technology demonstrated in areas like aerospace, automotive, machine shop, medical and power generation. The IMTS Conference Program will focus on six topics in 2018 including Process Innovations, Alternative Manufacturing, Plant Operations, Automation, Quality and Industry 4.0/IIoT. Co-located shows include Hannover Messe USA: Integrated Automation, Motion & Drives, Surface Technology, ComVac and Industrial Supply. The Smartforce Student Summit will once again promote student and educator attendance and other familiar attractions such as AMT's Emerging Technology Center will highlight the latest manufacturing technologies. For more information, visit [www.imts.com](http://www.imts.com).

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

**September 17–20—Gear Dynamics and Gear Noise Short Course 2018** Columbus, Ohio. The Gear Dynamics and Gear Noise Short Course will be offered this year on the Ohio State campus from September 17 to 20, 2018. It has been offered for over 38 years and is considered extremely valuable for gear designers and noise specialists who encounter gear noise and transmission design problems. Attendees will learn how to design gears to minimize the major excitations of gear noise: transmission error, dynamic friction forces and shuttling forces. Fundamentals of gear noise generation and gear noise measurement will be covered along with topics on gear rattle, transmission dynamics and housing acoustics. This course includes extensive demonstrations of specialized gear analysis software in addition to the demonstrations of many Ohio State gear test rigs. A unique feature of the course is the interactive workshop session that invites attendees to discuss their specific gear and transmission noise concerns. For more information, visit [www.nvhgear.org](http://www.nvhgear.org).

**September 18–20—CTI Symposium China** CTI Symposium is a three day event providing the latest automotive transmission and drive engineering for passenger cars and commercial vehicles. The international industry event delivers the appropriate platform to find new partners for purchase and sales of whole systems and components. Automobile manufacturers, transmission and component companies give an overview and outlook on technical and market trends. Speakers include representatives from Audi AG, Jatco Ltd., CH-Auto Technology and more. For more information, visit [drivetrain-symposium.world/cn/](http://drivetrain-symposium.world/cn/).

**September 18–22—AMB 2018** Stuttgart, Germany. AMB, International Exhibition for Metal Working, has become established as a top event in even years. It occupies a leading position among the exhibitions in the industry and ranks among the world's top five events. All the world market and technology leaders come together on a total exhibition area of more than 120,000

square meters to present technologies for future production. For more information, visit [www.messe-stuttgart.de/amb/en/](http://www.messe-stuttgart.de/amb/en/).

**September 20–21—AGMA Fundamentals of Worm & Crossed Axis Helical Gearing** Alexandria, Virginia. Provides an introduction and emphasize the differences between parallel (the experience base) axis and worm and crossed axis helical gears. Describe the basics of worm and crossed axis helical gears, their fundamental design principals, application guidelines and recommendations, lubrication requirement, a discussion of accuracy and quality and summarize with a brief review of common failure modes. The instructor is William "Mark" McVea. For more information, visit [www.agma.org](http://www.agma.org).

**September 25–26—PM Sintering Seminar** Penn Stater Conference Center Hotel, State College, Pennsylvania. Held only every two years, this two-day seminar is meant for industry professionals either new to sintering or with intermediate experience in the industry. Topics covered will include information from basic theory and practices to troubleshooting and how to drive down the costs of sintering. Learn from industry experts about: Sintering parts at normal or elevated sintering temperatures; increasing productivity by reducing rework and scrap; improving properties of PM parts with sintering; the latest equipment capabilities; troubleshooting sintering problems; efficiency in daily sintering operations. For more information, visit [www.mpif.org](http://www.mpif.org).

**September 27–29—AGMA Epicyclic Gears Systems: Application, Design and Analysis** Rosemont, Illinois. Learn and define the concept of epicyclic gearing including some basic history and the differences among simple planetary gear systems, compound planetary gear systems and star drive gear systems. Cover concepts on the arrangement of the individual components including the carrier, sun, planet, ring and star gears and the rigid requirements for the system to perform properly. Critical factors such as load sharing among the planet or star gears, sequential loading, equal planet/star spacing, relations among the numbers of teeth on each element, calculation of the maximum and optimum number of planet/star gears for a specific system will be covered. This session provides an in-depth discussion of the methodology by which noise and vibration may be optimized for such systems and load sharing guidelines for planet load sharing. The instructor is Raymond Drago. For more information, visit [www.agma.org](http://www.agma.org).

**September 29–October 3—WEFTEC 2018** New Orleans, Louisiana. WEFTEC, the Water Environment Federation's Technical Exhibition and Conference, is the largest annual water quality event in the world. WEFTEC is the largest conference of its kind in North America and offers water quality professionals from around the world with the best water quality education and training available today. An increasing number of abstract submittals from experts in the water quality field results in a world-class technical program of technical sessions and workshops that addresses a diverse and comprehensive list of contemporary water and wastewater issues and solutions including: Energy management, plant operations, regulations, research, utility management, recycling and more. For more information, visit [www.weftec.org](http://www.weftec.org).

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# Lively New Book on what Distinguishes Manufacturing Precision from Perfection

Jack McGuinn, Senior Editor

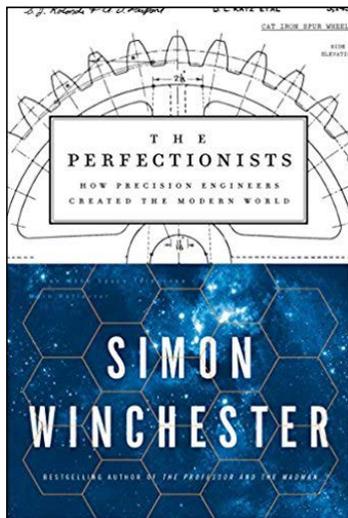
**Most of us would agree that the idea of a perfect world is absurd. Just for starters, who gets to decide what “perfect” means?**

Indeed, *perfection* — according to the Oxford English Dictionary — is defined as “The action or process of improving something until it is faultless.”

And that is the premise of a fascinating new book — *The Perfectionists: How Precision Engineers Created the Modern World* (Harper Collins, 411 pages) — by Simon Winchester. In this book the best-selling author (*The Professor and the Madman, A Crack in the Edge of the World*) delineates the “birth,” if you will, and evolution of technology — from the dawn of Industrial Age to the Digital Age — in search of the single component crucial to advancement — precision. The findings of his research serve both as homage to the search for precision and cautionary tale for our cyber-intensive future.

Winchester explains in detail how manufacturing could not have happened without attention to precision. He demonstrates how, even in the earliest days of the Industrial Revolution in eighteenth-century England, standards of measurement were established. He describes how this paved the way to the revolutionary concept and realization of machine tools, i.e. — machines that make machines. Winchester describes in entertaining detail how the embryonic creation and application of precision tools and methods resulted in the mass production of precision-based products such as guns, mirrors, lenses, watches and cameras. He also describes in entertaining detail how the former technology led to further breakthroughs, including gene splicing, microchips, and the Hadron Collider. His account of the development of the Hubble telescope and why it is so important is fascinating.

Winchester takes us back to the origins of the Industrial Age, to England where he introduces the scientific minds that helped usher in modern production: John Harrison, John Wilkinson, Henry Maudslay, Joseph Bramah, Jesse Ramsden, and Joseph Whitworth. Thomas Jefferson later brought these mechanical wonders to the fledgling United States, setting the nation on its course to becoming the leader of the manufacturing world. Winchester moves forward through time, to today’s cutting-edge developments occurring around the world, from America to Western Europe to Asia.



As he introduces the minds and methods that have changed the modern world, Winchester explores fundamental questions. Why is precision important? What are the different tools we use to measure it? Who has invented and perfected it? Has the pursuit of the ultra-precise in so many facets of human life blinded us to other things of equal value, such as an appreciation for the age-old traditions of craftsmanship, art, and high culture? Are we missing something that reflects the world as it is, rather than the world as we think we would wish it to be? And can the precise and the natural co-exist in society?

The word “perfectionist” can conjure up the image of a fussy, slightly anxious person who needs to relax more. Indeed, the constant pursuit of the flawless can be exhausting. Nothing in our world, after all, is exactly perfect. But what if perfection is not only a goal in its own right but also something on which the lives of others depend? What if, for example, the slightest misalignment of a tiny tube in a jet engine could cause a fatal catastrophe?

In “*The Perfectionists*,” Simon Winchester celebrates the unsung breed of engineers who through the ages have designed ever more creative and intricate machines. He takes us on a journey through the evolution of “precision,” which he believes is the major driver of what we experience in modern life.

Our cars, planes, cellphones, washing machines, computers — every manufactured mechanism — are all the result of our pursuit of this fundamental concept. Winchester tells us that precision had a birth date. Our ancestors made some truly beautiful and impressive objects — like the ancient Greek “antikythera” mechanism used to predict astronomical positions and eclipses. But it wasn’t until the 19th century — and with it the ability to harness and utilize steam power — that true precision engineering was born. It might be difficult to accept the notion that there was such a “precise” turning point in our history, but Winchester makes a convincing case.

But perhaps the most entertaining portion of the book is the pages devoted to Henry Ford and Henry Royce. Amidst the description of how each of these manufacturing titans brought their dreams to fruition, Winchester tells us why ultimately Ford and Royce were not competitors. For Royce, it was all about seeking perfection. For Ford, it was all about *production*.

Winchester ends with a take on Sir Isaac Newton that — shall we say precisely? — describes that falling apple incident that we first learned about in grade school:

“*Woolsthorpe Manor was the home of Sir Isaac Newton. It was to Lincolnshire that Newton had fled from Cambridge in 1666. And it was here, during the summer of that annus mirabilis (remarkable or auspicious year), that he famously observed the apple falling from the tree. It was here, and from wondering of the force that might have impelled the apple’s fall, that he came up with the notion of gravity as a force that affected both this humble fruit and, by logical extension, affected the constant motion and altitude of the moon in orbit around the planet Earth.*” 



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