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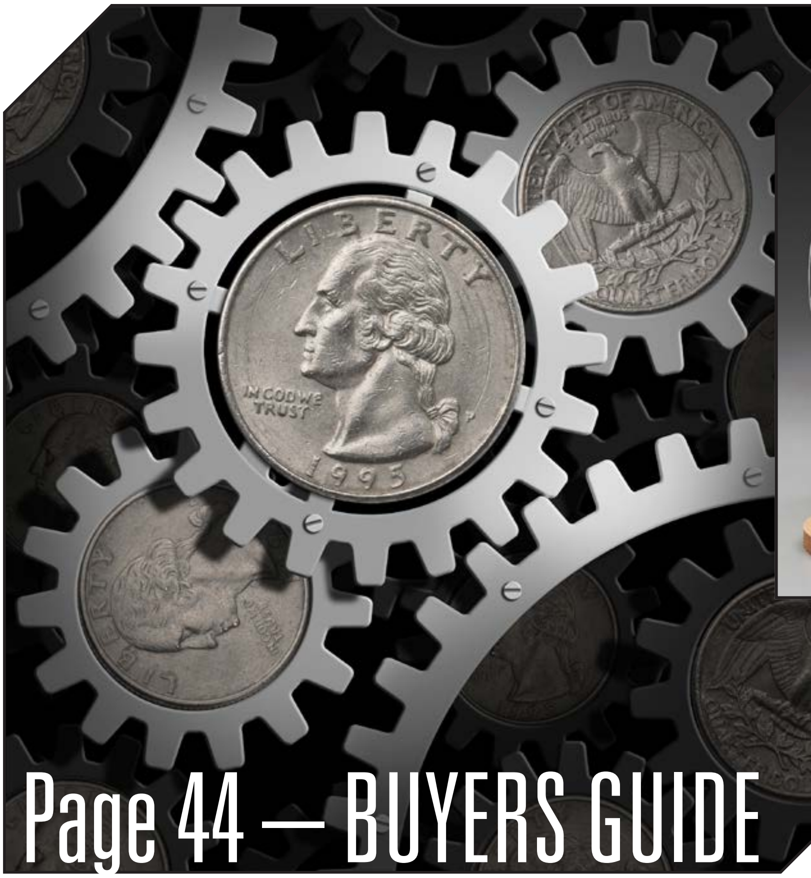

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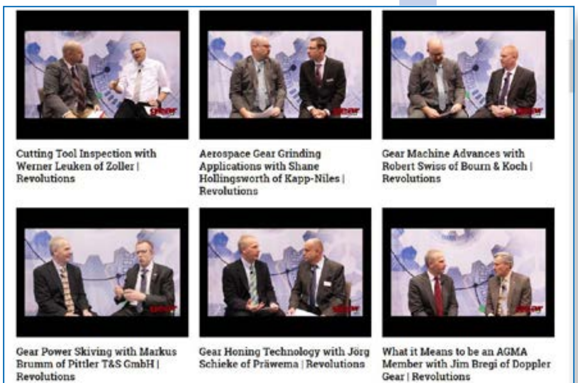

GT Revolutions

Find original video content prepared by our editors, along with the help of gear industry experts from around the world including the latest from IMTS 2018:

www.geartechnology.com/tv/#REV2018

Gear Talk with Chuck

Catch up on gear topics with resident blogger Charles D. Schultz. Recent topics include upgrading gearboxes, repairing and rebuilds and 3D printing. Visit the website below for the latest entries:

www.geartechnology.com/blog/

Event Spotlight: Power-Gen International 2018

Displaying a wide variety of products and services, Power-Gen International represents a horizontal look at the industry with key emphasis on new solutions and innovations for the future.

www.geartechnology.com/news/9025/Power-Gen_International_2018/

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Free Knowledge Served Daily

Publisher & Editor-in-Chief
Michael Goldstein

Technical articles have been the hallmark of *Gear Technology* since we first started publishing, more than 34 years ago, in 1984. One of the achievements I'm most proud of is the development of the ***GT LIBRARY*** at *geartechnology.com*, where you can find every single one of those articles, going all the way back to the beginning.

In those early days, magazines were produced mechanically. Pages were printed from film, not digital files. The PDF didn't even exist. So, in order to make all or our content available to you, we had to go back into our archives and scan the old issues. We had to create separate files for each article, tag the articles with keywords and enter them in a database. Then we built a search engine to help you find those articles.

Sure, at most of your companies there's probably some grizzled veteran who has every issue of *Gear Technology* on a shelf somewhere. Maybe he's even nice enough to let you browse through his collection (as long as you put everything back where it was). But if you're looking for something on a specific topic, it's a lot easier to go to the website and just type in "carburizing" or "bevel gear grinding."

Building the ***GT LIBRARY*** took a lot of work over several years, but it was worth it.

One of the reasons I'm most proud of that work is that we did it without any regard for financial gain. It was our gift to the industry—a repository of knowledge that is accessible to everyone, for free, anytime they want it. You can download any of our articles any time you want. And the only thing we get from those downloads is the satisfaction of having served the industry.

For me, that's always been enough.

In fact, that's the main reason I started *Gear Technology* in the first place. I saw a lot of really good technical content being produced, all over the world, on the subject of gears. Unfortunately, that content was only made available to a tiny, select few: those who attended the technical conferences where they were presented. None of that information was ever widely disseminated, at least not until we came along. We've always tried to choose the best of what was presented around the world and bring it to you.

That tradition continues with this issue as well. We have articles from several authors whose contributions to the knowledge base of the gear industry spans decades. They're some of the most prolific researchers and developers of the technology all of you rely upon. So don't miss out on any of these:

- **The Influence of a Grinding Notch on the Gear Bending Strength Rating**, by Dr. Ulrich Kissling and Ioannis Zotos (p. 64)
- **PentacMono-RT: High-Performance Face Milling Cutter Heads**, by Dr. Hermann J. Stadtfeld (p. 74)
- **Full Contact Analysis vs. Standard Load Capacity Calculation for Cylindrical Gears**, by Dr. Michael Otto, Uwe Weinberger and Dr. Karsten Stahl (p. 84)

In addition to all of our technical content, we also do our best to bring you the type of practical information you can use. This issue is also our annual Buyers Guide issue, so if you're looking for a supplier in the gear industry, your search starts on page 44.

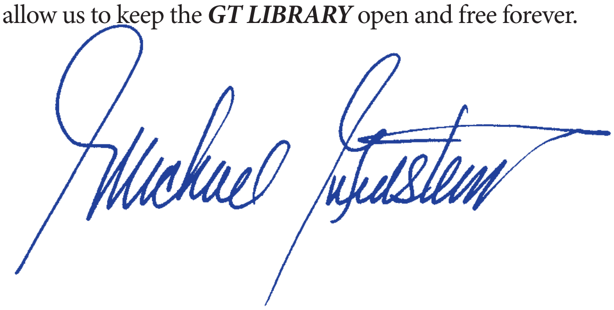
On top of all that, our editors are always talking to the providers of technology in our industry, and you can read their articles to find out about the latest trends in grinding wheels (p.22) and gear steel (p.34) in this issue.

We're proud to be "The Gear Industry's Information Source" as well as its public library, and we're going to continue building on the industry's library of knowledge as long as we're able.

But we need your help. Although you don't need a library card to access the ***GT LIBRARY***, we do need you to check in once in a while—and by that I mean we need you to subscribe. The only way we're able to do all of this is with the support of our advertisers, and the only reason they're willing to provide that support is because they know we're reaching the gear industry.

So even if you think you've already done so recently, please go to *www.geartechnology.com/subscribe.htm* and fill out the form. For most of you, all you have to do is enter your e-mail address and confirm the information that's already in our system. Give us 15 seconds, and we'll give you two years.

It's really important that you do so right away, because your help will allow us to keep the ***GT LIBRARY*** open and free forever.



Gleason

ANNOUNCES HOBBING MACHINE WITH INTEGRATED CHAMFER HOBBING

The new Genesis 160HCD Hobbing Machine for cylindrical gears integrates a newly developed process for chamfer cutting. Chamfer Hobbing ensures precise chamfers according to customer specification — with minimal tool cost.

The new Gear Hobbing Machine with Integrated Chamfer Hobbing is based on the extremely successful Genesis Machine Series with hundreds of installed machines globally. With the new Genesis 160HCD, Gleason integrates a newly developed chamfer cutting process which is executed in parallel to gear hobbing. Chamfer Hobbing provides very short cycle times and minimal tool cost per workpiece. This new chamfering process ensures burr-free gear faces without the requirement of additional, subsequent deburring steps. Likewise, no measurable burrs are created on tooth flanks. The workpiece is ideally prepared for the subsequent hard finishing process.

Chamfer Hobbing is a very efficient process due to the ability to shift the chamfer hobs for maximum tool life. Compared to special deburring tools, chamfer hobs can be easily reconditioned, keeping tool cost under control and cost-per-piece at a minimum.

Ideally suited for the highly economical manufacture of cylindrical gears up to a module of 4 mm and an outside diameter of 160 mm, the 160HCD can be optionally extended to a workpiece diameter of 210 mm. Its updated part loading concept with a fast gantry system minimizes part handling and setup times, thanks to its complete integration into the machine's control software.

The new 160HCD is the latest addition to the Genesis Series of Hobbing Machines offering another method to chamfered gears precisely and economically: Whether as a dedicated hobbing machine or integrated with different chamfering solutions available through Gleason — a Genesis Gear Hobbing Machine can satisfy a wide range of customer requirements.

For more information:
Gleason Corporation
Phone: (585) 473-1000
www.gleason.com

Liebherr

INTRODUCES NEW GEAR GRINDING MACHINE

Based on its LGG 280 generating grinding machine, Liebherr recently presented the larger LGG 400 M model at IMTS in Chicago.

The new Liebherr LGG 400 M was developed with an eye towards aerospace and job shop customers. It fits into the same footprint as the smaller LGG 280, but is well-suited to machining long shafts because the travel of the main and counter column has been extended.

"Our users can utilize a variety of grinding heads for internal and external gears," says Oliver Kraft, manager development and design of gear cutting machines at Liebherr-Verzahntechnik GmbH. "They can perform generating grinding with high productivity on workpieces up to 280 millimeter in diameter or profile grinding on even larger components up to 400 millimeters. This means even greater flexibility than its sister machine."

Ideal for long shafts

The machine concept came about from the requirements of the market. Long shafts with small diameters have come into demand, required by customers in the aerospace and job shop industries—often for short runs. Liebherr offers an optional crane for optimal handling of large parts."We have ergonomically adapted the machines overall," Kraft explains. "Due to the height, we have incorporated fold-out stair steps so

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Forest City Gear

ADDS METAL ALLOY ANALYSIS TO GEAR INSPECTION CAPABILITIES

Forest City Gear can now perform fast, comprehensive analysis and verification of metal alloys for quality assurance and control using its new Thermo Scientific Niton XRF Analyzer.

The Niton XRF Analyzer enables Forest City Gear to quickly and easily verify that the metal alloys used in barstock and/or near net shape blanks received from outside suppliers meet specifications before gears are produced. It can also be used to confirm that the chemical composition of metal alloys after heat treat meets requirements. The Analyzer can even be used to verify the plating thickness over metal to ensure that plating performed by outside vendors conforms to specification.

The lightweight, handheld and purpose-built construction of the Niton Analyzer makes it ideal for application in a wide range of environments, from shop floor to even outdoors.

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GMTA

EXAMINES MICRO-FINISHING TECHNOLOGY ON PROFILATOR MACHINES

Recently at IMTS in Chicago, GMTA introduced a new technology (patent-pending since May, 2018) by Profilator called micro-finishing via scudding. Micro-finishing takes place *after* the hard-scudding process has been completed. The process will take an already high quality, hard-scudded part and make it better in terms of surface finish.

While the overall AGMA, JIS or DIN quality may not change, the surface roughness of the gear teeth will be dramatically improved. It should also be noted that superfinishing gear processes such as this have been shown to reduce friction, increase pitting resistance and increase the life of gears. Additionally, this technology from Profilator GmbH & Co. KG. is a completely dry machining process and requires no cutting fluids or MQL technology.

The hard-scudding time for a standard automotive ring gear (approx. 125–140 mm ID) is 37–52 seconds (25–40 seconds cutting/12 seconds load-unload-stock division time). In the company's testing, they are seeing that the micro-finishing process takes approximately 20 seconds on a standard automotive size ring gear. That being said, they estimate that the total cycle time for finishing a ring gear via hard- scudding and micro-finishing would be approximately 64 seconds, if completed sequentially. As they continue to test and develop the micro-finishing process, GMTA feels that the time estimate noted above could be optimized to decrease the hard-scudding and micro-finishing cycle by 10%, thus keeping the total cycle time under one minute for all automotive ring gears.

The market is turning toward hybrid and e-Drive technology at a rapid pace. In these applications, noise (or lack of noise) is a very important consideration. The gears in these transmissions rotate at extremely high velocities and that increases the possibility of gear noises being perceptible to the human ear. As previously stated, the micro-finishing technology addresses noise sensitive applications and is aimed at making a quieter gear. The gear *may* also be a slightly higher overall quality, but the goal is to increase the quality of the surface roughness of the gear tooth flanks.

The Rz measurements do not exceed 0.8 µm in either lead or profile direction. This is in line with much more expensive abrasive gear finishing processes which require expensive machining fluids and filtration systems. So, in short, gear makers can achieve this high quality using a dry process from Profilator GmbH & Co. KG.

The micro-finishing process utilizes a high quality diamond plated tool. This tool concept was designed and developed by Profilator GmbH & Co., located in Wuppertal, Germany. This unique process is designed to remove only a small amount of part material where the


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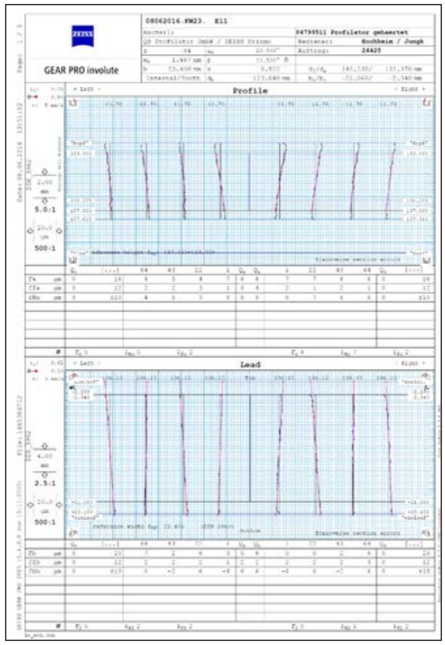

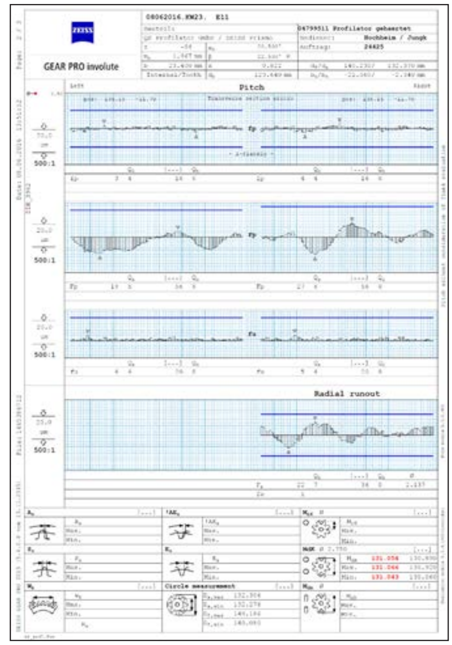

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R-PROFIL	(Profile Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.14 µm
Rz	**0.8 µm**
Rms	0.18 µm

L-PROFIL	(Profile Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.15 µm
Rz	**0.8 µm**
Rms	0.19 µm

R-PROFIL	(Lead Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.12 µm
Rz	**0.7 µm**
Rms	0.13 µm

L-PROFIL	(Lead Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.11 µm
Rz	**.6 µm**
Rms	0.12 µm

Surface Roughness "Hard Scudding®" Only

R-PROFIL	(Profile Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.38 µm
Rz	**2.0 µm**
Rms	0.42 µm

L-PROFIL	(Profile Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.33 µm
Rz	**1.7 µm**
Rms	0.36 µm

R-PROFIL	(Lead Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.28 µm
Rz	**1.6 µm**
Rms	0.29 µm

L-PROFIL	(Lead Measurement)
Ausw. – L	4.0
λc	0.8mmX5
Ra	0.25 µm
Rz	**1.3 µm**
Rms	0.28 µm

resulting part provides the user a great benefit, in terms of surface quality on the gear teeth as well as noise reduction. This fine finishing process is completed using the high quality industrial diamond tool (noted above) with an average particle size of 45 µm. During the process, the tool will remove approximately 20 µm of stock per flank which will not largely alter the gear geometry but drastically improve the surface finish on the gear teeth. Due to the relatively small amount of stock removal, it is believed that the tool life will be very good (testing continues to confirm this fact).

The micro-finishing technology can be applied in several ways on Profilator equipment. It can be a stand-alone process on a scudding machine, it can be a sequential process where hard-scudding and micro-finishing are completed utilizing a tandem tool set-up or it can be applied on a double spindle Profilator scudding machine, where the processes of the hard-scudding and micro-finishing can be completed simultaneously. In many cases, the part geometry will define the optimal process for the user.

Micro-Finishing tool.

For more information:
GMTA
Phone: (734) 973-7800
www.gmtamerica.com

Starrett Digital Gages

OFFER DIVERSE FORCE MEASUREMENTS

The L.S. Starrett Co. has introduced its DFC and DFG Series of Digital Handheld Force Gages. Depending on the series, advanced automatic testing can be attained with the DFC Force Gage controlling a Starrett FMM Digital Force Tester, or basic testing can be performed using the DFG gage.

The Starrett DFC and DFG Digital Force Gages are part of the new Starrett L1 line of entry level digital force measurement solutions. Optimized for production and quality control testing, the versatile, innovative architecture of the Starrett L1 system is designed for fast, easy-to-use, reliable and repeatable operation.

Starrett DFC and DFG Digital Force Gages feature an easy-to-view high-resolution OLED color backlit display and auto-off function. A primary and secondary window shows test results, and out-of-tolerance results display in red. A simple multi-function keypad has softkeys that are programmable to the users' most repetitive functions.

Adjustable sampling rates help capture peak loads, and filters can be applied to peak and display values. The Starrett L1 Digital Force Gages' battery life provides over 30 hours of continuous operation and have a USB port for transmitting data to a computer. The gages have a cast aluminum housing with a comfortable grip design for handheld testing, and a metric threaded top post enables screw-on attachments and clevis adapters that fit hundreds of Starrett test fixtures.

"Whether for simple, basic economical testing via handheld gaging, or more advanced testing when mounted on our L1 stands, our innovative Digital Gages provide the ultimate solution in force measurement versatility," said Emerson Leme, head of metrology division at Starrett.

DFC Digital Force Gages

The DFC Series is a revolutionary concept for force measurement via a handheld force gage. The DFC may be used as an advanced digital force gage and controller with Starrett FMM Force Testers, or as an advanced digital force gage with Starrett MTL and MTH Manual Force Testers. The DFC Gage can serve as a universal interface where the user tests and can configure load limits, distance limits, break limits, crosshead travel direction, crosshead speed and more. The DFC features a precise measurement accuracy of 0.1% full scale with internal data sampling at 25KHz. Display resolution is 10,000:1 and the DFC features Bluetooth, USB and RS-232 communications plus digital I/O.

DFG Digital Force Gages

The DFG Series is a basic force gage that measures force at an accuracy of better than 0.2% full scale. It is ideal for basic handheld tensile and compression testing. Test setup and operation is fast, efficient and easy. The DFG display shows the test direction and dynamic load during testing. Results are displayed at the completion of testing, including "Pass-Fail" when tolerance is applied. The gage will display statistics when results are saved to the gage's internal memory and it can store up to 50 test results in local memory.

Both the DFC and DFG Digital Force Gages are supplied with a complete accessory kit and carrying case that includes hook, notch, chisel and flat attachments, a chisel and point adapter, a 6" extension rod and a NIST-traceable certificate of calibration.

When more sophisticated and complex testing is required, Starrett also offers a range of force solutions via its L2, S2, L2 Plus and L3 Systems. Starrett force measuring equipment is manufactured in the U.S.A. and is available to order now in several configurations including Handheld Force Gages and Digital and Manual Force Testing stands.

For more information:
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Phone: (978) 249-3551
www.starrett.com/force

Kennametal

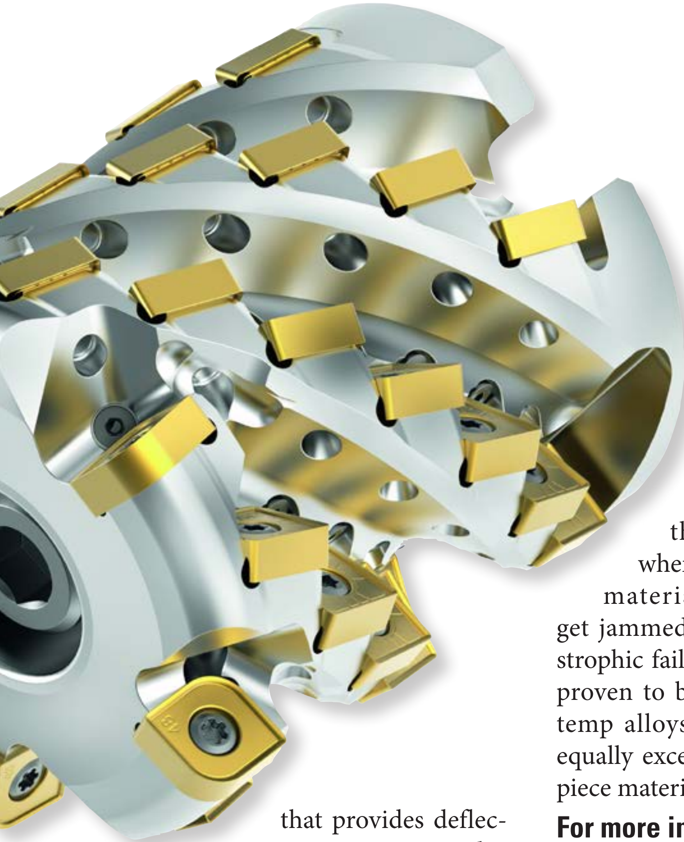
RELEASES LATEST HELICAL MILLING CUTTER

Kennametal recently released its newest helical milling cutter, the Harvi Ultra 8×.

Using a 95 mm (3.74 in.) axial depth of cut, 20 mm (0.78 in.) radially, and a feedrate of 423 mm/min (16.65 ipm), the 80 mm (3.15 in.) diameter Harvi Ultra 8× helical milling cutter from Kennametal recently worked through a difficult aerospace superalloy. Tim Marshall, senior global product manager for indexable milling, has tested the Harvi Ultra 8× with a variety of customers, pushing the limits of the new cutter on everything from 15-5 PH to cast iron to Aermet 100 (high strength steel) and seeing outstanding results with each.

"Kennametal developed the Harvi Ultra 8× to meet two distinct needs," Marshall says. "The first came from the aerospace industry, which thanks to the large numbers of aircraft being built today requires the highest metal removal rates possible but still achieving excellent tool life. At the same time, machine tool builders and users alike are asking for tools able to withstand higher cutting speeds but generate lower machining forces, so as to reduce wear and tear on machine components during extreme cutting conditions. The new HARVI Ultra 8× does all that, and a lot more besides."

Marshall said the Harvi Ultra 8× was designed to predictably remove 20 cubic inches (328 cm^3) of Ti-6Al-4V each minute while attaining 60 minutes of tool life per cutting edge. To do this, Kennametal combined a number of innovative technologies into this cutting tool solution including a double-sided yet positive rake insert, a unique AlTiN+TiN PVD coating that provides robust resistance to thermal fatigue, a higher quality steel for improved stiffness and rigidity under high cutting forces, a unique BTF46 (bolt taper flange) connection



that provides deflection resistance and a variable helix design that breaks up the harmonics that lead to chatter, further improving tool life, part quality, and throughput.

"We've optimized everything about the Harvi Ultra 8×," said Marshall. "The flutes and the coolant nozzles assure maximum chip flow, something that's very important when you're removing this much material—without it, the chips get jammed up and you're facing catastrophic failure. Our KCSM40 grade has proven to be a top performer in high-temp alloys, but we also offer several equally excellent grades for other workpiece materials."

For more information:
Kennametal
Phone: (724) 539-8033
www.kennametal.com

Spin City

Grinding Wheel Technology Focuses on Speed, Efficiency and Time Savings

Matthew Jaster, Senior Editor

Gear grinding is all in the details—surface quality, cycle times, lower costs, quicker results, less energy consumption, etc. Gear producers want to make product faster, quicker and more efficiently than ever before. This means the grinding wheel needs to meet and exceed customer expectations with each and every turn. Thanks to a heavy dose of grinding conversation during and after IMTS 2018, we're able to provide the latest trends, technologies, challenges and future considerations for grinding wheels in the gear market.

The Need for High-Speed

It's no surprise that speed tops the list when it comes to grinding wheel technology. Faster grinding times produce more parts which results in a much more efficient machining operation.

"The gear industry is looking for higher-quality, more precise wheels that can grind very fast and provide the best surface finishing capabilities on the market," said Amandine Martin, worldwide gear platform leader, Norton | Saint-Gobain.

TJ Boudreau, category manager for high volume production at Weiler Abrasives, said grinding wheel technology starts and ends with addressing the specific needs of each customer.

"If you can develop a grinding wheel that cuts faster and can be easily utilized on existing equipment, this is much more valuable to your customer. You can produce more parts per hour, reduce dress and save production time," said Boudreau.

On the machine tool side, Andreas Mehr, grinding and shaping technology developer, at Liebherr, said gear customers are seeking out the following key capabilities: They want High Q-Prime (metal removal rate) for fast grinding times with a low risk of grinding burn. In combination with a fine surface roughness ($Rz < 3\mu m$) and good profile form deviation ($ff\alpha > 2\mu m$). They also want good tool life with a high number of parts per dressing.

"They want constant cutting and wear behavior over the shift-length and usable diameter range. The experience from us and our customers shows that when the worm diameter gets small the performance of the wheel sometimes gets bad," Mehr added.

Regarding cylindrical gear technology, Martin Boelter, COO, Klingelnberg, cites high-speed and high-feed rates as well as an extremely open structure of grinding wheels in combination with innovative grit material that allows for high stock removal without the risk of grinding burn.

Meeting Efficiency and Productivity Demands

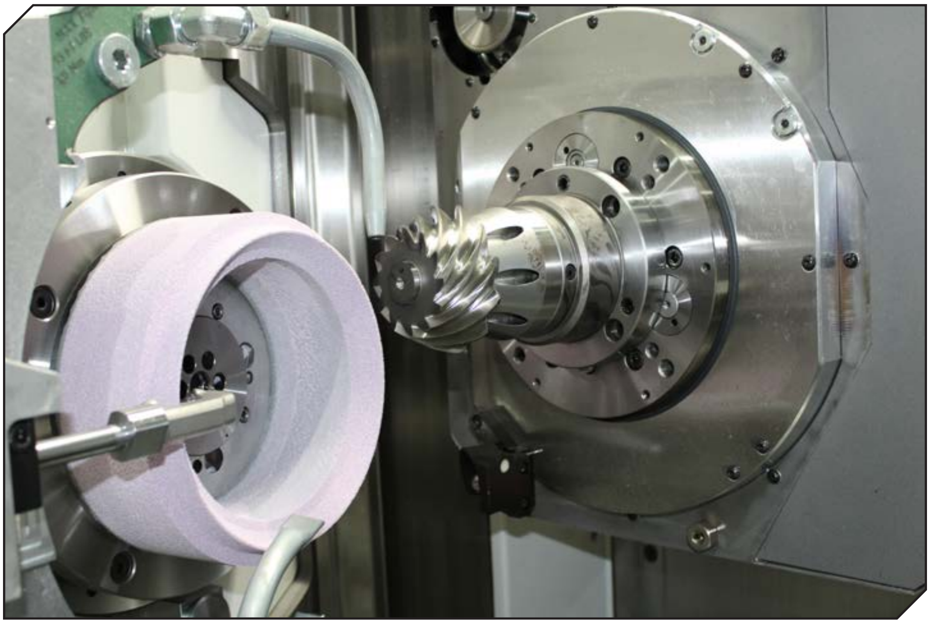
In order to make better gears, machining efficiency and productivity improvements are necessary to remain competitive in the gear market.

Understanding the metallurgy of the latest gear materials will play a huge role in meeting these demands now and in the future, according to Boudreau.

"The marketplace is advancing so quickly that many customers are working with materials that are harder to grind. Some customers have no idea where to start. Our job is to make sure our grinding wheels are doing what they were asked to do in the first place," said Boudreau. "Tooling can be a tremendous expense for gear manufacturers and we want our wheel technology to provide the greatest efficiency gains."

High metal removal rates are achieved due to fast cycle times as well as the increased stability of the grinding wheels today, according to Dr. Rolf Schalaster, head of competence center grinding technology at Klingelnberg.

"Klingelnberg machines enable a good performance for deep grinding (from solid). Deep grinding enables high flexibility in the gear design (tool profile). This strategy can be seen as an alternative to blade grinding, coating and setting up the cutter head for a cutting process," Schalaster said.



Xtrimium bevel gear grinding wheel from Norton | Saint-Gobain.

Grinding Challenges

Mehr at Liebherr cites several challenges that need to be met in grinding today saying that the increased quality requirements and NVH behavior, especially for E-Drive are some of the greatest challenges. There is also a clear tendency for more topological modifications on gears and asymmetric tooth profiles.

"Here Liebherr is already well positioned due to the latest software developments like, GER (Generated End Relief) and generating grinding of asymmetrics," he said.

For collision critical gears, Mehr said you need worms with a small outside diameter (< 120 mm) in combination with a length of 200 mm and a bore of 40 mm. These wheel dimensions are a technical challenge to manufacturing.

"Especially on these small worms the requirement on a homogenous wheel structure and constant hardness is very high. Both characteristics are a 'must-have' for a successful generating grinding process," Mehr said.

Boelter agreed that the electrification of the drivetrain will require higher precision and lower tolerances. This will also increase the requirements for tooth waviness and noise characteristics.

Many of today's challenges are simply a result of opposing requirements, according to Boelter.

"Customers want high precision as well as high productivity, special tool modifications, superfine surface finishes and increased load carrying capacity and noise requirements," he said. "Many of these requirements contradict each other."

Dual Design

With so much emphasis on multifunctional machining, several machine tools can take advantage of wheels today that handle multiple operations.

Norton | Saint-Gobain featured a new dual-worm wheel design during IMTS 2018 that enables two operations in one grinding wheel, substantially saving time and cost. 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 = 1.0 mm and Rpk = 0.05 mm, and reduced harmonics (noise) are realized. The Norton Xtrimium Dual-Worm Grinding wheels can also be adapted to existing machines.

"Our customers are seeking solutions where grinding parameters can be met for higher accuracy and improved surface finishes," Martin said. "This is where Norton Xtrimium can offer an advantage in quality."

Boudreau also believes the gear market is following general metalworking by combining as many operations as possible into a single machine.

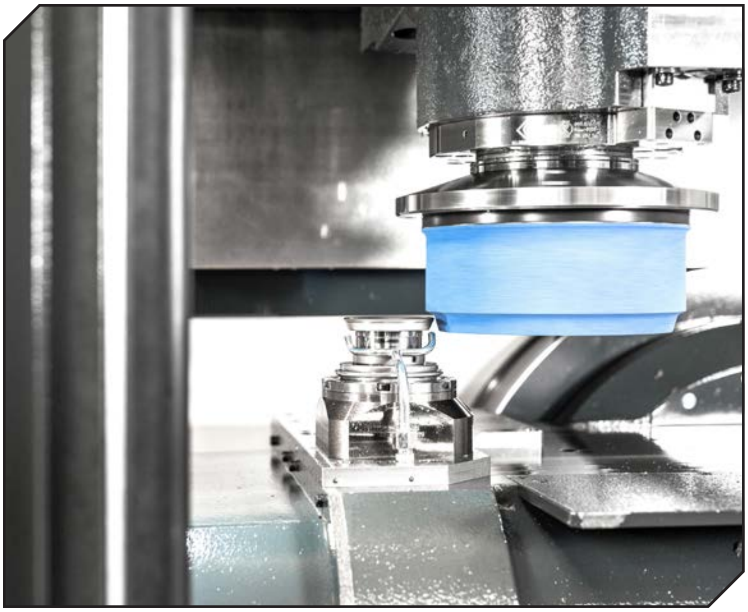
"Grinding and polishing in one operation. This is what's happening in the gear industry. Weiler is currently developing this for a customer's honing operation," he said.

An Eye on Service & Support

With dual wheel designs and new gear materials, companies offering grinding wheels have to go above and beyond just selling consumables to a job shop or OEM.

"Our goal is obviously to meet the long-term needs of our customers with a full line of technology and a full line of application engineers who can come in and streamline the process," said Joshua Fairley, product engineer, bonded abrasives at Norton | Saint-Gobain. "This starts with the service and support team. It's about getting the full value out of the entire grinding operation."

Adds Jim Gaffney, senior product manager at Norton | Saint-Gobain. "I'm proud to say our organization is always expanding capabilities through capital investments and hiring a tremendous amount of grinding talent around the world to serve our diverse global customer base."



Many of today's grinding challenges are a result of opposing requirements, according to Martin Boeltner, Klingelnberg COO.

This is one of the number one critical needs that Boudreau hears from the gear industry in general.

"Service and support is always a challenge in this industry. It's pivotal that you get the product out in a timely fashion and your response time is efficient when the customer needs a problem solved. When Weiler acquired SwatyComet it was an easy transition because both organizations shared a common focus on service and support," Boudreau said.

Global Competency

Gaffney discussed the company's global impact in grinding during IMTS 2018. "Strong wheels that sustain higher speeds need dimensional integrity for optimal success," Gaffney said. "Norton | Saint-Gobain has made significant enhancements to our global technology centers including locations in Germany, Spain, India and North America. We share research and knowledge across these centers, working hand-in-hand with OEMs to build better relationships along the way."

"Following this successful in-house collaborative approach, we start with the grains and then add the speed and grinding dynamics needed to maximize efficiency," Gaffney said. "We're actually the first company to introduce a shaped grain to the market, over 20-years ago. Many companies source grains instead of developing them internally."

Weiler has decades of bond technology experience allowing them to mix and match pairings from different abrasive manufacturers.

Mix & Match Tech

SwatyComet, headquartered in Maribor, Slovenia, dates back to 1879 and has a long tradition of providing high quality abrasive products. Now as a part of Weiler, the organization started in aerospace applications in North America and is ready to focus its efforts in gear manufacturing.

Weiler has decades of experience with its bond technology. While many of the larger companies develop their own grain technology, Weiler has partnerships with different vendors in the industry.

"We can look at all these different abrasive technologies and identify which one works best with our bond technology," said Boudreau. "This gives us the ability to create unique pairings from different abrasive manufacturers into our grinding wheels. We can also determine what the most cost effective solution is available for our customer's application."

Smarter Wheels

On the focus within Industry 4.0 one additional feature of grinding wheels is the automatic data transfer of the tool information like module, no. of starts, pressure angle, allowable cutting speed, etc. into the grinding machine. "Maybe the solution is an integrated RFQ chip or data matrix code printed on the wheel. Both are a real challenge on vitrified bonded wheels, due to the surface structure and manufacturing process of the wheels. The wheel manufacture should seek a smart solution," Mehr said.

Norton | Saint-Gobain has recently been investigating this challenge and is looking to work closely with customers on projects related to smart tags. They are working to integrate RFID tags with grinding wheels for better identification and inventory management.

Also recently launched, the new Norton 4Sight system is a Process Monitoring and Diagnostic System which can remotely monitor machine operations and the grinding process allowing customers to collect real-time data to monitor process performance and optimize productivity.

The Future for Grinding Wheels

In Mehr's opinion, a further grinding time reduction will not happen in the next 3–5 years. "Actually, the new abrasives like 3M Cubitron II or Norton Quantum are already developed. Also the bonding systems are designed for these abrasives. The trend for a finer surface roughness will lead to use of finer grain sizes in the finishing cut. To be still powerful in the roughing cut the demand on segmented grinding worms (with a roughing and finishing zone) will increase. A further focus should be on the Industry 4.0 topics like the gear data exchange format for the communication between the machine and the tool," Mehr said.

Further advance of abrasive grit and compound material will allow higher stock removal rates. Compound technology will increase mechanical strength of grinding wheels allowing higher cutting speeds and benefitting productivity. In generating grinding there will be more applications with combination of different grinding wheel sections for conventional roughing

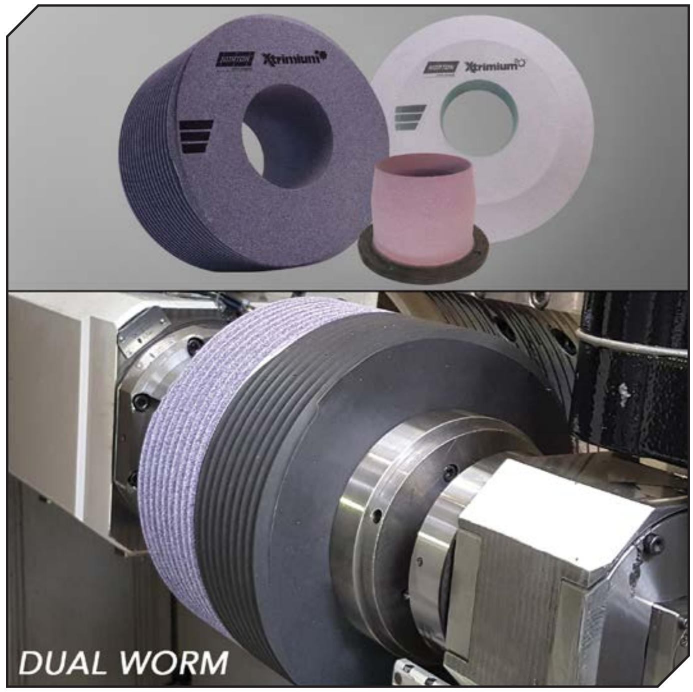
The trend for a finer surface roughness will lead to use finer grain sizes in the finishing cut, according to Andreas Mehr, Liebherr grinding and shaping technology developer.

and polish grinding.

For Schalaster at Klingelnberg, the basic trend will remain the same: grinding wheels that will increase productivity and provide better surface finish and increased tool life up to the physical limits of the equipment. "The costly control of heat treating to achieve constant stock and spacing for gear grinding may also be reduced due to the increased performance of the grinding process," he added.

Boudreau brings the topic of speed back into the conversation when looking into the crystal ball.

"A few years ago machines were grinding at 40 meters-per-second, than 50 and 60 and 80 will eventually be the norm," Boudreau said. "I'm sure we'll find our way to 100–120 meters-per-second for the surface speed of wheels down the road."



Substantial savings in wheel costs and productivity via the elimination of wheel swapping can be achieved with the Norton | Saint-Gobain design.

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Why Select Gear Grinding with cBN?

Phil Plainte Sr., Application Engineer, Norton|Saint-Gobain

The global economy is driving demand for precision gears in a wide range of applications and industries. Along with increased demand, pricing pressure has caused manufacturers to seek out lower cost solutions for reducing overhead and manufacturing costs, while still producing high quality gears. However, there are several challenges which must be addressed to achieve these savings.

For example, the consumption of material needed for the manufacturing of drive trains alone has a direct impact on producing more waste, thus increasing manufacturing cost and detrimentally effecting the environment.

A Conventional Approach

Eighty to ninety percent of all gears used in aerospace, automotive and land based applications are finish ground with conventional abrasives.

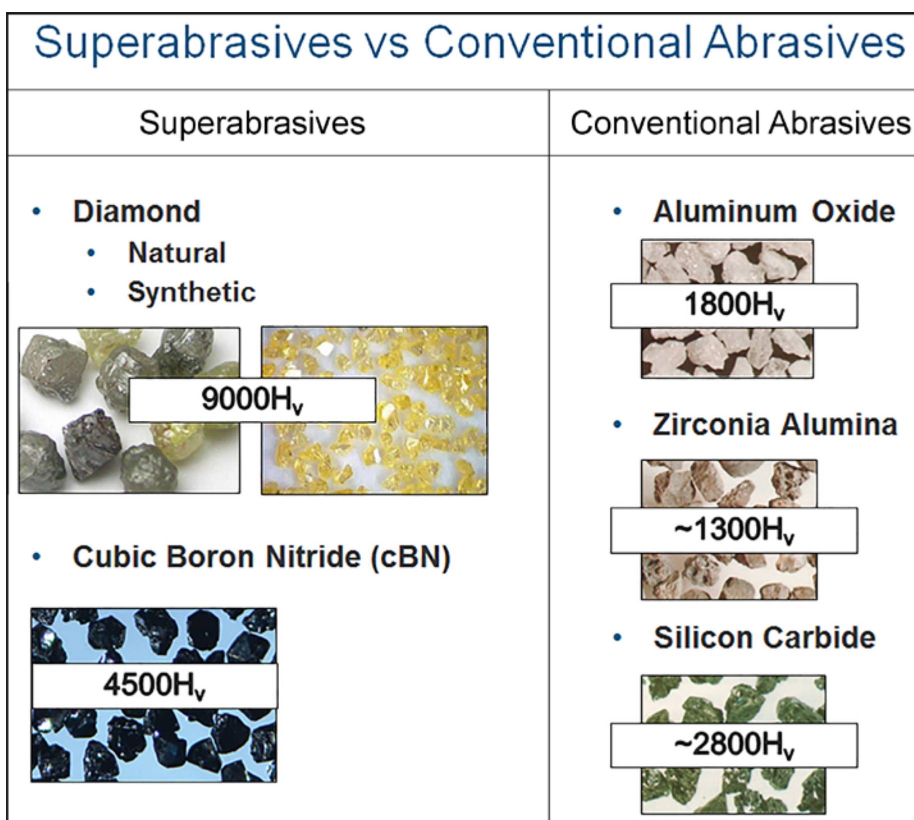
Grinding sludge (abrasive swarf which includes spent abrasive grains) is a by-product of grinding wheels. The typical large U.S. manufacture of automotive transmissions can go through 25,000 gallons of oil and create 32,000 pounds of used abrasive waste annually. A significant portion of this coolant soaked abrasive swarf is disposed of in landfills.

In high production gear manufacturing (such as automotive), a continuous generation grinding process is used. This efficient grinding process typically yields 40–80 parts per dress. With conventional abrasives, the average consumption of grinding wheels would typically be one to two wheels per week, per machine.

The Case for cBN

Cubic Boron Nitride (cBN) abrasive wheels, which are a specially engineered abrasive grain referred to as a superabrasive, typically yield 2,200–2,500 parts per dress with one wheel lasting as long as four to six months. In addition to the longer wheel life, the physical construction of cBN wheels is also very different. Whereas conventional wheels are made entirely of abrasives, cBN wheels have an aluminum core with only the outer rim containing the layer of abrasives - typically ⅜"–½". When the abrasives on the wheel are used up, the core can either be reused or recycled, while a conventional abrasive wheel stub would end up in a land fill.

Aluminum oxide ($Al0_2$) has been used in manufacturing for over 100 years to effectively finish grind parts. In the mid 1980's Norton|Saint-Gobain introduced a new abrasive grain, which is a sintered ceramic grain that micro fractures as it grinds, leading to better performance and longer wheel life than the A/O wheels. cBN was invented by GE in 1957 and is considered a superabrasive. Like conventional abrasives, over time it has been improved by GE and other superabrasive producers.



Transferring Heat

Being much harder than conventional abrasives, cBN resists dulling–stays sharper longer during the grinding process, which results in a significant improvement in wheel life. It features excellent thermal conductivity characteristics for grinding applications, allowing the heat generated during the grinding process to transfer out and away from the grind zone. cBN has approximately 40 times higher heat transfer rate than that of aluminum oxide (Ref. 1).

Additionally, the thermal diffusivity of cBN is almost two orders of magnitude greater than that of aluminum oxide (Ref. 2).

Further work by GE suggests that in grinding with aluminum oxide, about 63% of the heat generated goes into the work piece, while with cBN grinding only 4% goes into the work piece. The study at GE suggests cBN grinding of carburized parts and hardened parts can impact additional residual compressive stress to the part surface. These stresses may be as little as 30% greater to as much as 250% greater than the heat treated surface stresses (Ref. 3).

Less tensile stress and more compressive stress equals stronger gear teeth. Therefore, cBN provides excellent wear resistant and thermal transfer qualities which result in a very robust grind, beneficial to the surface integrity of the gear tooth and gear.

Baseline Specification:	A80H8V0058
Test #1 Specification:	CBN
MACHINE:	Rieshauer

Technical Summary				
	Compare Baseline	**to** Test Spec 1	BENEFIT	
Grind Contact time per part	78.61	78.61		Seconds
Percent Scrap				%
Parts per Wheel	6526	233301	**226,775**	Parts per Wheel
Contact Time per Year	90166	90166		Hours
Annual wheel usage	633	18	**615**	Wheels per year
Abrasive Change Time Per Year (All Steps)	949.5	27.0	**923**	Hours

Economic Summary				
	Baseline	**Test Spec 1**	**BENEFIT**	
Abrasive Cost per Year	$344,043	$195,398	$148,645	Total Abrasive $/Yr
Machine time cost per year	$1,843,557	$1,217,167	$626,390	Machine time $/Yr
Cost of Scrap				Scrap $/Yr
Finishing Cost per Year	$2,073,824	$2,073,824		Machine $/Yr
Abrasive Change Costs per Year	$21,839	$621	$21,218	Abrasive Change $/Yr
Total cost per year	$2,209,439	$1,413,186	**$796,252**	Total Costs $/Yr
Total cost per part	**$0.5351**	**$0.3422**	**$0.1928**	Dollars Per Unit
Cost Savings per part			**36.0%**	Savings per Unit %
Total Benefit/Cost Down, All Categories			**$796,252**	**Savings $**

Impact to the Bottom Line & More

Recent field tests show that cBN wheels can produce as much as 2,200–2,500 parts per dress.

This increase in productivity can offer a significant reduction in manufacturing costs. The field case study (see chart above) shows bottom line impact to a large gear manufacturer.

In addition to the cost advantages, the generation of grinding sludge by using cBN wheels is significantly reduced, lessening the impact to the environment. Also, by nearly eliminating spent abrasive grit from the machine, maintenance costs are reduced and machine life is extended. The reduction in the generation of grinding sludge on a yearly basis can result in significant cost savings and reduce material going to landfills. As waste disposal costs continue to rise, reducing the waste going to the landfill will become even more important.

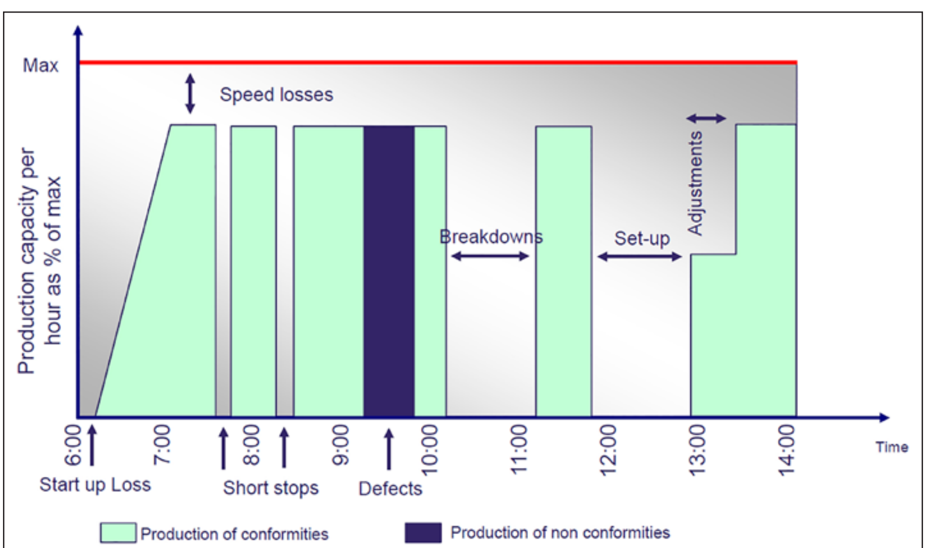
There are other economic savings to be realized. When using cBN grinding wheels, less time is spent dressing the wheel, allowing increased machine uptime for grinding gears.

Gear quality is improved by the inherent benefits of grinding with cBN adding to the compressive residual stress of the gear tooth. Additionally, cBN helps to transmit heat much the way copper transmits electricity, by pulling the heat out of the grinding zone.

Extended dress frequency means more time in the grind cycle. In a conventional grinding process and grind cycle, a wheel has a break-in period after dress. The efficiency of the grind cycle and part quality drops when the wheel requires dressing or reconditioning.

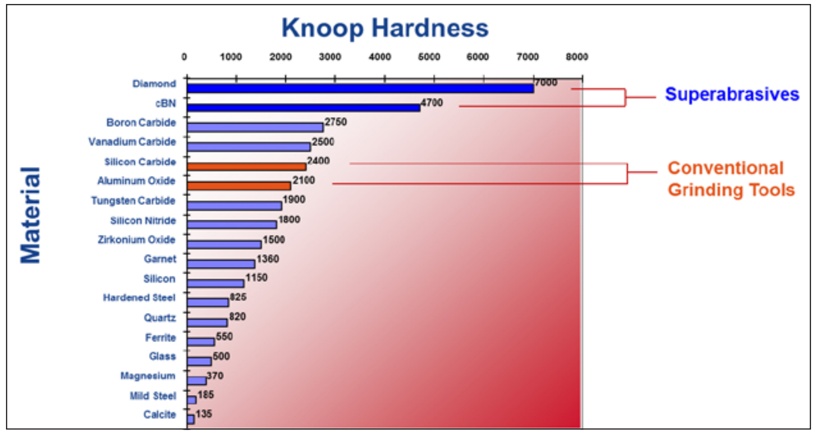
cBN excels at providing long periods of peak cutting performance and high part quality. This has a direct impact on CPK, which is the measure of quality and the ability to hold the process within a certain tolerance bandwidth, and OEE (Overall Equipment Effectiveness) which is the measurement of efficiency and quality in a manufacturing environment.

As shown in the chart (to the left), OEE provides a simple way to look at process improvement in a production environment. More quality parts are produced when grinding without interruptions for longer periods of time.



Compared to the conventional abrasives like Aluminum Oxide and Ceramic Seeded Gel/Norton Quantum, cBN is significantly harder. Dressing and conditioning the cBN wheel requires a different approach than with conventional abrasives.

For example, when dressing threaded vitrified cBN grinding wheels, the dress compensation amount (which is the radial in-feed of the diamond roll into the cBN wheel face) are greatly reduced as compared to conventional wheel dress amounts to re-establish the form of the grinding wheel.



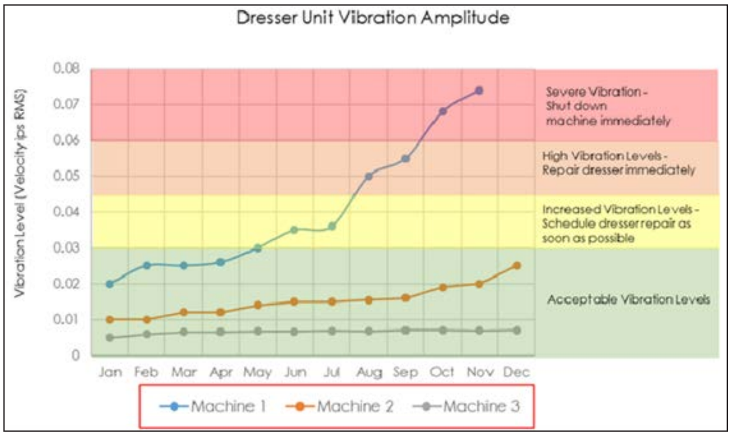
Wheel construction difference

With conventional abrasives, infeed would be .001"–.002" per pass whereas with cBN wheels it would be a fraction of this amount. During the initial dressing period, operators dress a newly installed wheel aggressively, often dressing .020"–.030" of the wheel face. A cBN wheel requires only a fraction of this infeed. The usable abrasive depth of a cBN wheel is typically .250"–.375", so wheel manufacturers need to make certain the wheel face and thread form are close to operating tolerances.

Care needs to be taken when dressing a cBN wheel. Aligning the dresser with the face of the wheel is critical to prevent wheel chipping, and to reduce the total dress amount required for the machine to produce good quality parts.

Continuous gear generation machines use a threaded wheel to generate the involute form on a gear tooth. As continuous generation machines have

Diamond dressing rolls thread gear wheels.



evolved, efficient dressing features have improved. Faster grinding methods have also been developed by introducing multiple starts or multiple wheel threads along the face of the wheel. By introducing diamond rolls with multiple ribs to complement the cBN wheels, dressing times have been significantly reduced.

Often times, the number of "starts" on a wheel dictates the numbers of ribs on a dress roll. These multi-start rib rolls add efficiency to the dressing process, but can also add pressure on the rotary truing device spindle and spindle bearings. To be successful with cBN wheels, a solid, good quality rotary truing device is required. A rotary truing device that is old and worn can cause issues.

During a cBN grind test on a Reischauer RZ400, it was discovered through vibration analysis that the bearings were nearing the end of their life. The vibrations in the spindle bearings had been transmitted into the cBN wheel face, resulting in the vibration showing up in gear tooth inspection of the lead and profile.

This demonstrates the importance of having a rotary dressing unit in good condition when profiling a cBN wheel. In order to lower the dressing pressure, a single rib diamond roll should be considered.

Clear Benefits with cBN

The economic benefits of using cBN wheels in high production environments such as automotive applications are significant. The benefits of using

cBN wheels in continuous generation gear grinding can also be found in shops that grind large internal spur and helical gears using a simple cBN form wheel. Machine builders like Höfler, Gleason, and Kapp sell machines that grind both external and internal spur gears. Grinding an internal spur or helical gear requires an internal attachment which looks like a bicycle fork with a much smaller wheel fitted to the machine.

These smaller conventional wheels typically have a much shorter life (lower G ratio) and require more dress cycles than in external grinding. To extend dress cycles, increasing the wheel life by as much as 100 percent, cBN wheels are the ideal choice. This often means one dress cycle will allow the grinding wheel to complete the gear without any additional dressing, whereas using a conventional grinding wheel in the same application could require more than one wheel to complete the job.

For gear manufacturers, cBN wheels can provide better quality gears with higher compressive residual stress, and allow greater throughput with less dress time and wheel changes. The absence of grinding swarf floating around in the machines promises longer machine life and fewer repairs. Coolant systems run cleaner, requiring less maintenance, filter paper and service. Lower abrasive consumption reduces tooling cost. Less waste going to landfills reduces costs and helps to protect the environment. All of these factors have an impact on the bottom line, helping gear manufacturers remain globally competitive and eco-friendly.

References

1. *Manufacturing Engineering* February 1994 cBN Grinding.
2. ***Gear Technology*** September 10, 1988 Johnson and Ratterman GE Enhanced Product Performance Through cBN Grinding.
3. Dodd H.P, K.V. Kumar. Technology Fundamentals of cBN Bevel Gear Finish Grinding.

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Admire its Purity

As gear manufacturing techniques become more precise and demanding, there is a growing demand for cleaner, higher quality steel.

Alex Cannella, Associate Editor

Steel cleanliness is becoming increasingly important. Luckily, we can already do better.

Accuracy is tight these days. Minute imperfections of only a few microns at any step of the process can be the difference between a gear that functions for years and one that fails critically in testing.

That includes the very first step: acquiring materials. According to Buddy Damm, scientist for advanced steel solutions at TimkenSteel, nonmetallic inclusions just 10 microns in diameter — thinner than a hair — can be enough to eventually trigger a gear's failure if you're unlucky enough to get one right near the gear's surface, where stresses are highest. In the past, when demands haven't been as stringent, such minute imperfections weren't as noticeable and a steel's purity wasn't scrutinized too strictly. But that's all starting to change, and many steel suppliers are developing methods for producing cleaner steel.

That all starts by taking a hard look at some of the current standards we use to rate a steel's cleanliness, many of which are aging and leave a little bit to be desired. ASTM E45, for example, is a standard that has been giving guidance on inclusions in steel for decades. It is worth noting that ASTM E45 does see revisions every few years, including in 2018, but according to Damm, the standard is being outpaced by evolving metrology machinery today.

"It doesn't give you a lot of information and detail about the statistical nature of the inclusion content in the steel," Damm said. "And not only does it not give you any statistical details, it's not a very discriminating measuring technique anymore."

TimkenSteel isn't the only company going above and beyond what standards decree. Lily Kamjou, senior specialist, power trains, industry solutions development at Ovako, has run into similar issues, pointing to ISO 6336 as vague and not having kept up with modern manufacturing techniques. As demands on steel quality continue to rise, Kamjou has found that many jobs just demand more than what baseline standards and guidelines suggest.

"If you just ask for it according to the ISO standard, it's very likely that you won't get that performance level that you're counting on," Kamjou said. "It doesn't really match the material demands. That's something we run into quite a lot."

And if you don't get the material quality you're looking for, it can exacerbate already excrutiating lead times by forcing you to redo prototypes. But that's where Ovako comes in. One of their major selling points is the personal relationship the company tries to build with customers early in the prototyping process. By trying to get involved early, Ovako's experts not only have an

opportunity to share their expertise beyond the basics of what official standards demand, but also can get their steel in the manufacturer's hands quickly enough to give them a chance to perform multiple prototyping trials.

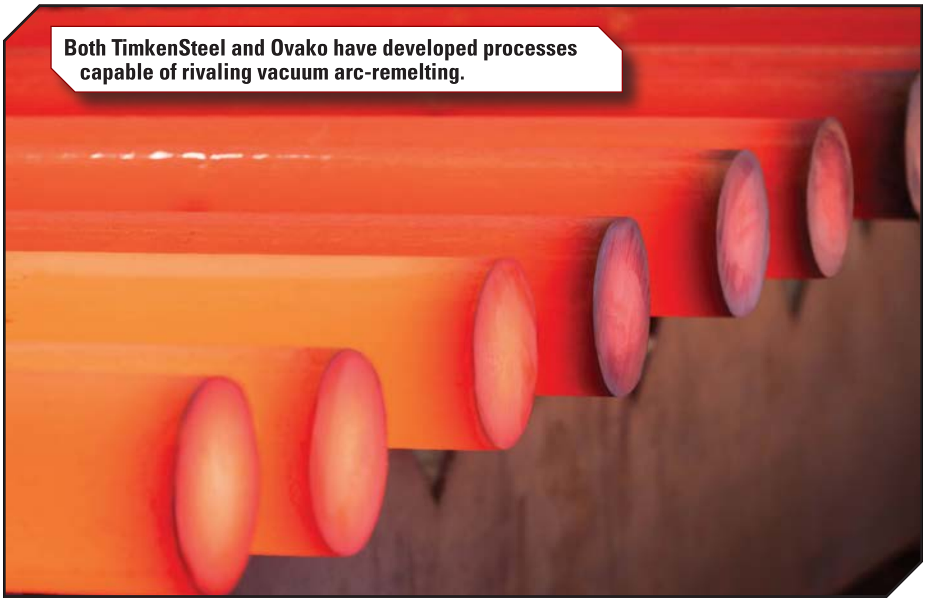
"If we can get involved at an early stage, we can make sure that we can supply the prototype material needed to do all the different testing," Kamjou said. "Which is from the end point of view, crucial because it can be such a waste of time waiting for prototypes for a year or longer than that. But also, making sure that the material performance level is what you're actually asking for. It's very easy to ask something in theory that looks good on paper, but the reality is very, very different from what we've learned over the years working with this industry."

Both TimkenSteel and Ovako have also been focused on improving the affordability of high-end, cutting edge steel. Ovako through the high-fatigue resistant IQ- and BQ-steel families and TimkenSteel through their new Ultrapremium advanced air-melted and vacuum-refined steel-making process that is the culmination of ten years of effort and study at the company.

"This is the steelmaking practice that we evolved over the past ten years," Damm said. "It's a combination of a lot of careful manufacturing processes when making the steel and then a lot of careful testing to verify the inclusion content and to provide our customers with a statistically relevant data set about the inclusion population in the steel. That's Ultrapremium. It's our top tier of clean steel practice."

Ultrapremium is impressive in that it already goes above and beyond even premium aircraft standards such as AMS 2300 and 2304, two of the most stringent standards around, for steel cleanness. But in addition, Ultrapremium can be done at a fraction of the cost and with better lead time than other methods of producing similarly clean steel such as vacuum arc re-melting (VAR).

Currently, vacuum arc-remelting is one primary way steel suppliers produce such clean steel. It's a lengthy and costly process that involves passing a high electric current through a solid steel electrode into a vacuum furnace. The steel electrode is slowly melted by the electric arc passing from the electrode tip to the newly forming liquid steel pool, which resolidifies in a water-cooled copper mold. This process continues slowly upwards incrementally, continuously melting the bottom until it's worked through the entire electrode. The whole process is time intensive and can only handle limited batch sizes, which means premium steels often get price tags to match their quality. According to Damm, you'll be paying three to five times more than average for vacuum melted steel.


Both TimkenSteel and Ovako have developed processes capable of rivaling vacuum arc-remelting.

The prime issue with these standards, and the primary reason TimkenSteel and Ovako compare themselves to vacuum arc-remelting, is that the current standards decree steel cleanness according to the process by which they were made, not the actual statistics of how pure they are. If you vacuum arc-remelt your steel, it gets a different rating than if you use a different process. This made a sort of roundabout sense during a time when vacuum arc-remelting was the only process capable of reaching a certain quality of cleanness, but now that companies like Ovako and TimkenSteel have developed competing processes that the standards don't account for, these processes are producing steel as clean or even cleaner than the strictest standards demand, but are still given a lower grade in the existing system.

But not only are processes like TimkenSteel's or Ovako's capable of competing with vacuum arc-remelting, they're also faster and can be produced in large-scale production quantities. Damm pointed out that TimkenSteel is capable of treating up to 240,000 pounds of steel in one heat using the Ultrapremium process. Faster and higher volume production gives TimkenSteel the ability to sell these high cleanness steels at a more affordable price.

So what do you get with all of this purified, high-grade steel? One primary advantage we've already touched on is improved endurance and reliability, but another major advantage is improved power density — sometimes even up to a 30% improvement. That means gears capable of handling 30% heavier loads or, conversely, being capable of handling the same load with a considerably smaller gearset.

In general, material suppliers are seeing power density as an increasingly important area to focus on. Numerous customers are looking to reduce the size of their products without compromising strength or durability. In particular, the aerospace and automotive racing fields are interested in improving power density for lightweighting purposes. Lighter planes and rockets require less fuel to propel themselves, and a lighter racing car obviously takes less effort to go faster. And starting with lightweight, premium materials that tout superior potential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power density is an easy, if perhaps more costly, way to improve that metric.

According to Elias Löthman, application engineer, industry solutions development at Ovako, that focus on lightweighting is one of the main reasons steel purity has come into the spotlight. Previously, the focus wasn't as important, as manufacturers could just upsize their gears to compensate for any deficiencies in the steel, but now that products are shrinking again, the easy option is less and less applicable, and now the pressure is shifting onto steel suppliers, as well.

"Before there hasn't really been issues because you've allowed yourself to make them big and bulky," Löthman said. "But now when the restrictions are getting more demanding and the space is getting smaller, then these things become issues."

"Steel hasn't really been important up until now because they can just make everything bigger or they could just throw after treatments at it," Kamjou added. "But now with increasing demands, it's putting pressure on steel, as well."

Steel purity isn't the only path to achieving improved power density. There's also the option of developing an alloy, as in the case of QuesTek Innovations' Ferrium line, a carburizable steel alloy which can deliver a 20% increase in power density. The Ferrium line is primarily designed to appeal to manufacturers looking to lightweight components.

"C64 is one of the highest-performance carburizable steels available today," Jeff Grabowski, manager of business development at QuesTek, said. "It's displacing some of these legacy alloys like X53 and 9310 that have been in use for many decades."

QuesTek's Ferrium lines provide high surface hardness, fatigue resistance, and perhaps most interestingly, high temperature resistance, one of the line's most unique and important selling points. Ferrium C61 and C64 are capable of maintaining their strength above 500 degrees Fahrenheit where legacy alloys would soften and fail.

"The high temperature stability of Ferrium C61 and C64 is due to the high tempering temperature and the stability of the main strenghtening phase, M2C carbides, at those temperatures," Grabowski said. "The strengthening carbides do not coarsen nor dissolve until about 50 degrees below the tempering temperature of 925-950 degrees Celsius."

And thanks to its high temperature resistance, Ferrium is also being tested for use in helicopter applications — specifically for oil-out performance.

Oil-out refers to conditions where a gear has to operate without any oil or other form of lubrication, most commonly because failure or damage has caused the oil to drain from the system. This rapidly becomes a problem for gears, as without lubrication, friction between the gears increases, and when friction increases, it produces a significant amount of heat. And when exposed to that heat, gears expand, causing the friction to worsen, and the situation continues to spiral until the gears tear themselves apart.

As we reported on almost two years ago, oil-out performance has become a renewed focus for some corners of the aerospace industry. The military, in particular, is interested in pushing a gear's endurance as far as possible, as in the event of damage in battle, aircraft may need to make it back to safety under these exact conditions, and with operational ranges extending as technology improves, they'll need as much time as possible to do so.

For some gears, the whole process can lead to a critical failure in as little as a minute. Previously, the upper limit of how long a gear could be expected to last had been 30 minutes. According to Grabowski, gears made with Ferrium have survived tests for 85. And considering heat is the primary driver of gear failure in an oil-out situation, it's no surprise that QuesTek's Ferrium line is appearing in these tests, or that it's performing so well.

QuesTek's Ferrium line is also being tested for use in additive manufacturing, which has the potential to finally provide a strong enough material to make 3D printed gears viable.

"We're taking one of our Ferrium steels — Ferrium C64 — and we've atomized it and we've done prints," Grabowski said. "And we're showing good static properties, strength and toughness and elongation, and we're just now in the next six months going to be looking at fatigue performance of additive gears."

One last innovation on this front comes from TimkenSteel's *Endurance* steels, which includes a trio of patent-pending steel grades that Damm claims can improve a gearset's power density by 20–30%. They were named American Metal Market's Best Product Innovation of the Year in 2018 and boast an excessively high degree of strength and toughness, with a yield strength ranging from 180 to 210 KSI and toughness going from 35 to over 60 ft.-lbs. And if that's not enough, it's also possible to apply TimkenSteel's Ultrapremium process to an *Endurance* steel for even further improvements to power density. These new steels offer a 25% to 40% increase in both strength and toughness over conventional gear steels like 8620, 4320 and similar.

"Both of these techniques, the Ultrapremium very clean steel or the *Endurance* high-strength, high-toughness steels offer real opportunities by themselves for improved power density," Damm said. "And by combining the two of them, you would get further incremental improvement."

No doubt, incremental improvement will continue to be the name of the game in the future, both for manufacturers looking for improved power density and for steel suppliers looking for newer and better products to offer. But right now, there isn't much incremental about a 30% jump — an entire step change — in power density. If you're looking for ways to shrink your own products down or have them handle heavier loads, consider looking at your materials. You might just find an opportunity for improvement.

For more information:

Ovako
+46 8-622-1300
www.ovako.com

QuesTek Innovations LLC
(847) 328-5800
www.questek.com

TimkenSteel
(330) 471-6832
www.timkensteel.com

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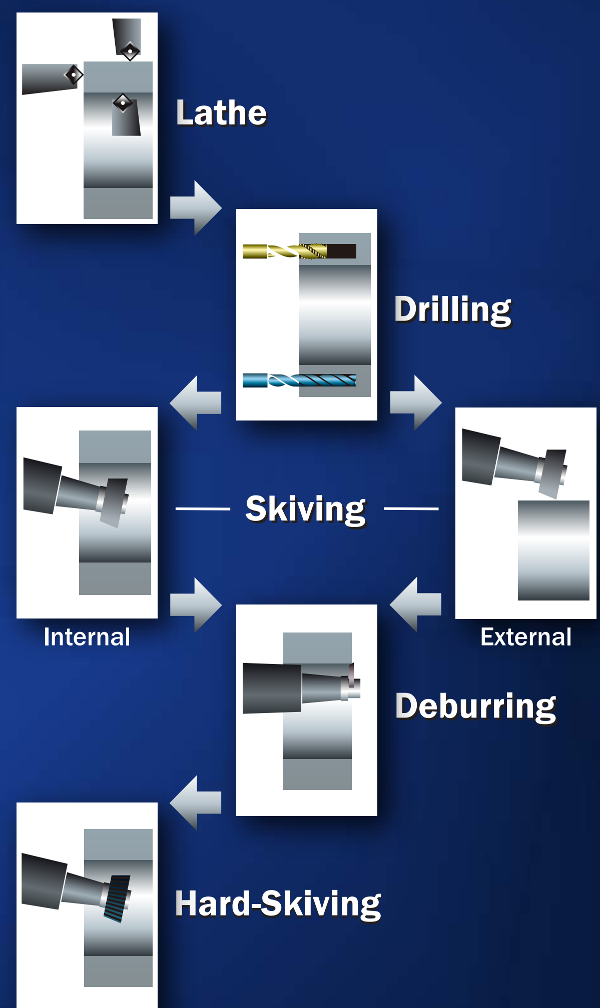
Multi-Function Machine to Include Skiving



- High Efficiency Gear Skiving & Integrated Process Reduce Machining Time
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Nachi America Inc.

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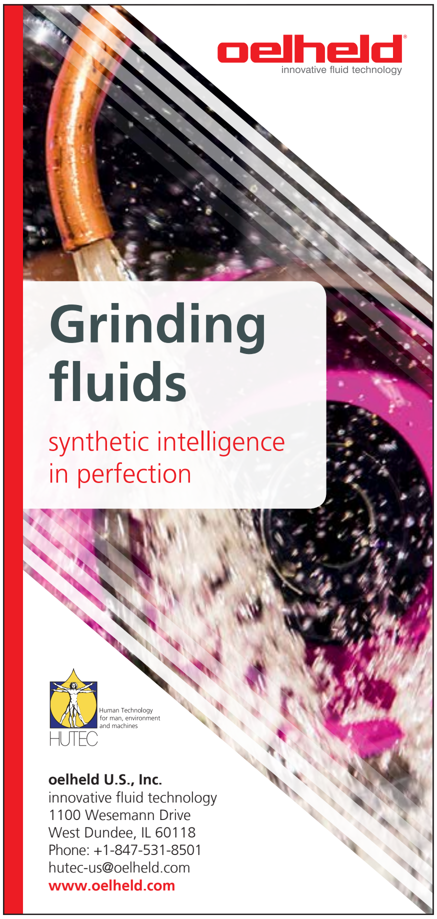
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Grinding fluids
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HUTEC
oelheld U.S., Inc.
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1100 Wesemann Drive
West Dundee, IL 60118
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www.oelheld.com


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24 / 7 Customer Service: 800-547-1527
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WE ARE A LITTLE EDGY......
When it comes to your productivity
SNC 30
Gear manufacturers need tools returned quickly. We sharpen your perishable assets to meet or surpass original sharpening specifications... rapidly. That is what we do.
Enabling our customers to continually cut teeth since 1999.
• HOB SHARPENING
• SKIVE CUTTER SHARPENING
• BROACH SHARPENING
• STRIPPING & RECOATING
Index Technologies
Gear Tool Reconditioning
WWW.GALLENCO.COM
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Fax: 216-642-8837 • Email: gallen@gallenco.com
5755 Canal Road, Valley View, OH 44125


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HARD JAWS
JAW NUTS
FULLGRIP JAWS
CUSTOM JAWS
VISE JAWS
JAW BORING RING
JAW FORCE GAGE
CHUCK GREASE
COLLECT PADS & COLLECT JAWS
Dillon Manufacturing, Inc.
2115 Progress Drive,
Springfield, Ohio 45505
ISO 9001:2015 - Sold through distributors
P 800.428.1133
F 800.634.6480
dillonmfg.com
sales4@dillonmfg.com

About This Directory

The 2018 *Gear Technology* Buyers Guide was compiled to provide you with a handy resource containing the contact information for significant suppliers of machinery, tooling, supplies and services used in gear manufacturing.

BOLD LISTINGS throughout the Buyers Guide indicate that a company has an advertisement in this issue of ***Gear Technology***.

But Wait! Where are the Gear Manufacturers Listed?

If you are looking for suppliers of gears, splines, sprockets, gear drives or other power transmission components, see our listing of this issue's power transmission component advertisers on page 53. In addition, you will find our comprehensive directory in the December 2018 issue of *Power Transmission Engineering* as well as in our online directory at *www.powertransmission.com.*

Handy Online Resources

The Gear Industry Buyers Guide – The listings printed here are just the basics. For a more comprehensive directory of products and services, please visit our website, where you'll find each of the categories here broken down into sub-categories: *www.geartechnology.com/dir/*

The Power Transmission Engineering Buyers Guide – The most comprehensive online directory of suppliers of gears, bearings, motors, clutches, couplings, gear drives and other mechanical power transmission components, broken down into sub-category by type of product manufactured: *www.powertransmission.com/directory/*

How to Get Listed in the Buyers Guide

Although every effort has been made to ensure that this Buyers Guide is as comprehensive, complete and accurate as possible, some companies may have been inadvertently omitted. If you'd like to add your company to the directory, we welcome you. Please visit *www.geartechnology.com/getlisted.php* to fill out a short form with your company information and Buyers Guide categories. These listings will appear online at *www.geartechnology.com*, and those listed online will automatically appear in next year's printed Buyers Guide

CUTTING TOOLS

All of the suppliers listed here are broken down by category (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com.*

2L Inc.
www.2Linc.com

A.L. Tooling cc
www.altooling.co.za

ANCA, Inc.
www.anca.com

Accu-Cut Diamond Tool Co.
www.accucutdiamond.com

Acedes Gear Tools
www.acedes.co.uk

Addison & Co. Ltd.
www.addison.co.in

Advent Tool and Manufacturing Inc.
www.advent-threadmill.com

Advico
www.advico.co.uk

Ajax Tool Supply
www.ajaxtoolsupply.com

Alliance Broach & Tool
www.alliancebroach.com

Allied Machine & Engineering Corp.
www.alliedmachine.com

American Broach & Machine Co.
www.americanbroach.com

Anderson Cook Inc.
www.andersoncook.com

Apex Broaching Systems
www.apexbroach.com

Ash Gear & Supply
www.ashgear.com

BTS Broaching Tools
www.brostakimsanayi.com.tr

Banyan Global Technologies LLC
www.banyangt.com

Broach Masters/Universal Gear Co.
1605 INDUSTRIAL DRIVE
AUBURN, CA 95603
Phone: (800) 563-3442
Fax: (530) 885-8157
sales@broachmasters.com
www.broachmasters.com

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Broaching Machine Specialties
www.broachingmachine.com

Canada Broach
www.canadabroach.com

Capital Tool Industries
www.capital-tool.com

Carbide Tool Services, Inc.
www.carbidetool.com/

Carborundum Universal Ltd.
www.cumiabrasives.com

Century Precision Co., Ltd.
www.cty.co.kr

Ceramtec North America
www.ceramtec.us

Cold Forming Technology
www.coldformingtechnology.com

Colonial Tool Group
www.colonialtool.com

Comco Inc.
www.comcoinc.com

Continental Diamond Tool Corporation
www.cdtusa.net

D.C. Morrison Company
www.dcmorrison.com

DTR Corp. (formerly Dragon Precision Tools)
1865A HICKS ROAD
ROLLING MEADOWS, IL 60008
Phone: (847) 375-8892
Fax: (224) 220-1311
alex@dragon.co.kr
www.dragon.co.kr
SEE OUR AD P27

Dathan Tool & Gauge Co. Ltd.
www.dathan.co.uk

Diametal AG
www.diametal.ch

Dianamic Abrasive Products Inc.
www.dianamic.com

ESGI Tools Pvt. Ltd.
esgitools.com

Eagle Tool Company Inc.
www.eaglebroach.com

Eltool Corp.
www.eltool.com

Eltro Services, Inc.
www.eltroservices.com

Emuge Corp.
www.emuge.com

Engineered Tools Corp.
www.engineeredtools.com

FHUSA-TSA
www.fhusa-tsa.com

Fassler by Daetwyler Industries
faessler.daetwyler.com/en/

Federal Broach & Machine
www.federalbroach.com

Forst Technologie GmbH & Co. KG
www.forst-online.de

Friedrich Gloor Ltd.
www.gloorag.ch

Fuji Machine America Corp.
www.fujimachine.com

Galaxy Sourcing Inc.
www.galaxysourcing.com

General Broach Company
www.generalbroach.com

German Machine Tools of America
www.gmtamerica.com

Gleason Corporation
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com
SEE OUR AD P37, 91

Gleason Cutting Tools Corporation
1351 WINDSOR RD.
LOVES PARK, IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com
SEE OUR AD P37, 91

Gleason Works (India) Private Ltd.
PLOT NO. 37
DODDENAKUNDI INDUSTRIAL AREA
WHITEFIELD RD., MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com
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Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
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Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greg Allen Company
www.gallenco.com

Guardair Corporation
www.guardair.com

Guven Bronz Metal
www.guvendokum.com

Hanik Corporation
www.hanikcorp.com

Harbin Tool Works
NO.29 XINNONG ROAD
NAN GANG DISTRICT HARBIN
CHINA
Phone: 86-451-86702277
Fax: 86-451-86700684
peter@hrbtool.com
www.hrbtool.com
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HobSource Inc.
www.hobsource.com

Ingersoll Cutting Tools
www.ingersoll-imc.com

International Tool Machines (ITM)
www.itmfl.com

Interstate Tool Corp.
itctoolcorp.com

Kennametal Inc.
www.kennametal.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

Kinefac Corporation
www.kinefac.com

Kingsford Broach & Tool Inc.
www.kingsfordbroach.com

Klingelnberg AG
BINZMÜHLESTRASSE 171
CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
Fax: +(41) 44-2781594
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SALINE, MI 48176
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www.klingelnberg.com
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info@klingelnberg.com
www.klingelnberg.com
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Knuth Machine Tools USA, Inc.
www.knuth-usa.com

Koepfer America
koepferamerica.com

LMT USA
www.lmt-fette.com

Lalson Tools Corporation
www.lalsoncuttingtools.com

Leistritz Advanced Technology Corp.
165 CHESTNUT STREET
ALLENDALE, NJ 07401
Phone: (201) 934-8262
Fax: (201) 934-8266
staff@leistritzcorp.com
www.leistritzcorp.com
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Liebherr America
1465 WOODLAND DR.
SALINE, MI 48176
Phone: (734) 429-7225
Fax: (734) 429-2294
info.lgt@liebherr.com
www.liebherr.com
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Liebherr-Verzahntechnik GmbH
KAUFBEURER STRASSE 141
D-87437 KEMPTEN
GERMANY
Phone: +(49) 831-786-0
Fax: +(49) 831-7861279
info.lvt@liebherr.com
www.liebherr.com
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Longevity Coatings
www.longevitycoatings.com

Luren Precision
www.luren.com.tw/en/index.html

Machine Tool Solutions, Inc.
machtoolinc.com

Maheen Enterprises
www.maheenbroaches.com

Maxwell Tools Co. USA
www.maxwelltools.com

Maxwell Tools Company
www.maxwelltools.com

Miller Broach
www.millerbroach.com

Mitsubishi Heavy Industries America
MACHINE TOOL DIVISION
46992 LIBERTY DRIVE
WIXOM, MI 48393
Phone: (248) 669-6136
Fax: (248) 669-0614
brenda_motzell@mhiahq.com
www.mitsubishigearcenter.com
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Mitsubishi Materials USA
11250 SLATER AVENUE
FOUNTAIN VALLEY, CA 92708
Phone: (714) 352-6100
Fax: (714) 668-1321
crivas@mmus.com
www.mmus.com
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Modern Gearing
www.moderngearing.com

Moncktons Machine Tools, LLC
www.mmtproductivity.com/

Mutschler Edge Technologies
mutschleredgetech.com

Nachi America Inc.
715 PUSHVILLE RD.
GREENWOOD, IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com
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Norton | Saint-Gobain
1 NEW BOND STREET.
P.O. BOX 15008
WORCESTER, MA 01606
Phone: 254-918-2313
Fax: 254-918-2314
www.nortonabrasives.com
SEE OUR AD P35,49

ORT Italia
www.ortitalia.com

Ohio Broach & Machine Co.
www.ohiobroach.com

PDM Engineering Pvt. Ltd.
www.pdmengg.net

Parker Industries Inc.
www.parkerind.com

Philadelphia Carbide Co.
www.philacarbide.com

Pinpoint Laser Systems
pinpointlaser.com

Pioneer Broach Co.
www.pioneerbroach.com

PlasmaRoute CNC
www.cncplasmacutterinc.com

Polygon Solutions
www.polygonsolutions.com

Productivity Inc.
www.productivity.com/

QC American
www.qcamerican.com

R.A. Heller
www.raheller.com

Rotec Tools Ltd.
www.rotectools.com

Russell Holbrook & Henderson
www.tru-volute.com

S.S.Tools
www.sstools.net

SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

SWG Solutions
www.swgsolutions.com

Saazor
www.saazor.de

Samputensili S.p.A.
www.samputensili.com

Sandvik Coromant
www.sandvik.coromant.com

Schnyder SA
SEE OUR AD P4
JAKOBSTRASSE 52
CH-2504 BIEL
SWITZERLAND
Phone: +(41)(32) 344-0406
Fax: +(41)(32) 344-0404
george.boon@schnyder.com
www.schnyder.com

Seco Tools Inc.
www.secotools.com/us

Shape-Master Tool Company
www.shapemastertool.com

Slater Tools Inc.
www.slatertools.com

Slone Gear International, Inc.
www.slonegear.com

Star Cutter Co.
www.starcutter.com

Star SU LLC
SEE OUR AD IFC-1,41
5200 PRAIRIE STONE PARKWAY, SUITE 100
HOFFMAN ESTATES, IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com

Steelmans Broaches Pvt. Ltd.
www.steelmans.com

Sunnen Products Company
www.sunnen.com

Super Hobs & Broaches Pvt. Ltd.
www.supercuttingtools.com

Techcellence
www.broachindia.com

Titanium Coating Services Inc.
www.pvdamerica.com

Ty Miles, Inc.
www.tymiles.com

U.S. Equipment
www.usequipment.com

United Tool Supply Ltd.
www.unitedtoolsupply.com

V W Broaching Service, Inc.
www.vwbroaching.com

Vargus USA
www.vargususa.com

Walter USA, LLC
www.walter-tools.com

Watkins Mfg. Inc.
www.saw-lutions.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Wolverine Broach Co., Inc.
www.wolverinebroach.com

Yash International
www.yashtools.com

GEAR BLANKS & RAW MATERIAL

All of the suppliers listed here are broken down by category (bar stock, forgings, gear steel, plastic resins, etc.) at *www.geartechnology.com*.

A. Finkl & Sons Co.
www.finkl.com

Accurate Specialties Inc.
www.accuratespecialties.com

Aksan Steel Forging
www.aksanforging.com

All Metals & Forge Group, LLC
www.steelforge.com

American Friction Welding
www.teamafw.com

Anihas Castings
www.anihas.com

ArcVac ForgeCast Ltd.
www.arcvacsteel.com

Atlas Bronze
SEE OUR AD P21
445 BUNTING AVE.
TRENTON, NJ 08611
Phone: 609-599-1402
sales@atlasbronze.com
www.atlasbronze.com

Aviva Metals
www.avivametals.com/

BGH Specialty Steel Inc.
www.bgh.de

Bharat Forge Ltd.
www.bharatforge.com

Boltex Manufacturing
www.boltex.com

Brooker Bros. Forging Co.
www.brookerbrosforgings.com

Buehler - An ITW Company
www.buehler.com

CFS Machinery Co. Ltd.
www.dropforging.net

Canton Drop Forge
www.cantondropforge.com

Castalloy
www.castalloycorp.com

Celanese
www.celanese.com

Compressed Gas Technologies Inc.
www.nitrogen-generators.com

Concast Metal Products
www.concast.com

Cornell Forge
www.cornellforge.com

Crucible Industries LLC
www.crucible.com

DSM Engineering Plastics
www.dsm.com

Dayton Forging and Heat Treating
www.daytonforging.com

Deco Products Company
www.decoprod.com

DuPont
plastics.dupont.com

Dura-Bar
www.dura-bar.com

Earle M. Jorgensen Co.
www.emjmetals.com

ElectroHeat Induction
www.electroheatinduction.com

Ellwood City Forge
www.ellwoodcityforge.com

Erasteel Inc.
www.erasteel.com

Eutectix, LLC
eutectix.com

Excel Gear
SEE OUR AD P18
11865 MAIN STREET
ROSCOE, IL 61073
Phone: (815) 623-3414
Fax: (815) 623-3314
Chinn@excelgear.com
www.excelgear.com

Fomas USA
www.fomasgroup.com

Forging Solutions LLC
www.forging-solutions.com

Fox Valley Forge
www.foxvalleyforge.com

Fuji Machine America Corp.
www.fujimachine.com

Galaxy Sourcing Inc.
www.galaxysourcing.com

Guven Bronz Metal
www.guvendokum.com

Hunter Chemical LLC
www.hunterchem.com

IMT Forge Group including Clifford-Jacobs Forge
www.imtforgegroup.com

Intech Corporation
www.intechpower.com

Interstate Tool Corp.
itctoolcorp.com

Kuraray America, Inc.
www.kuraray.com

Lalson Tools Corporation
www.lalsoncuttingtools.com

Larson Forgings
www.larsonforgings.com

Lefere Forge
www.lefereforge.com

Mackeil Ispat & Forging Ltd.
mackeilforgings.com

Maguire Technologies
www.maguiretech.com

Martin Tool & Forge
www.martinsprocket.com

Masternet Ltd.
www.masternetltd.com

Maxwell Tools Co. USA
www.maxwelltools.com

McInnes Rolled Rings
SEE OUR AD P23,46
1533 EAST 12TH STREET
ERIE, PA 16511
Phone: (800) 569-1420 or (814) 459-4495
Fax: (814) 459-8443
sales@mcrings.com
mcinnesrolledrings.com

McKees Rocks Forgings
www.mckeesrocksforgings.com

Midwest Themal-Vac Inc.
www.mtvac.com

Moore-Addison Precision Plastic Blanking
www.mooreaddison.com

Mosey Manufacturing Co. Inc.
www.moseymfg.com

National Bronze Mfg. Co.
www.nationalbronze.com

Ovako AB
www.ovako.com

PCK Buderus India
www.pck-buderus.com

Parag Casting Co.
www.paragcasting.com

Patriot Forge
www.patriotforge.com

Penticton Foundry Ltd.
www.pentictonfoundry.com

Perry Technology Corporation
www.perrygear.com

Presrite Corporation SEE OUR AD P40
3665 E. 78TH STREET
CLEVELAND, OH 44105
Phone: (216) 441-5990
Fax: (216) 441-2644
www.presrite.com

QSC Forge & Flange
www.qscforge.com

QuesTek Innovations LLC
www.questek.com

Ralf Schaffer
www.specialsteel-forgings.com

Reade Advanced Materials
www.reade.com

Renishaw Inc.
www.renishaw.com

Rewitec GmbH
www.rewitec.com

Rotek Incorporated
www.rotek-inc.com

SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

Schmiedewerke Groeditz GmbH
www.stahl-groeditz.de

Scot Forge
www.scotforge.com

Sedlock Companies
www.sedlockcompanies.com

Sensor Products Inc.
www.sensorprod.com

Southwest Metal Products Ltd.
www.southwestmetal.com

Spectrum Machine Inc.
www.spectrummachine.com

Steuby Manufacturing Company, Inc.
www.steubymfg.com

Sunbelt-Turret Steel. Inc.
www.sunbeltturretsteel.com

TimkenSteel Corporation
www.timkensteel.com

UMC - United Metals Co.
www.umcmetals.com

United Cast Bar, Inc.
www.unitedcastbar.com

Viking Forge
www.viking-forge.com

Voestalpine High Performance Metals
www.voestalpine.com

Walker Forge
www.walkerforge.com

Watkins Mfg. Inc.
www.saw-lutions.com

Willman Industries Inc.
www.willmanind.com

Yarde Metals
www.yarde.com

Yash International
www.yashtools.com

GEAR MACHINES

All of the suppliers listed here are broken down by category (hobbing machines, bevel gear machines, shaping machines, broaching machines, etc.) at *www.geartechnology.com.*

ANCA, Inc.
www.anca.com

Abtex Corp.
www.abtex.com

Accu-Cut Diamond Tool Co.
www.accucutdiamond.com

Acme Manufacturing Co.
www.acmemfg.com

Advico
www.advico.co.uk

Affolter
www.rotectools.com

Alliance Broach & Tool
www.alliancebroach.com

American Broach & Machine Co.
www.americanbroach.com

Anderson Cook Inc.
www.andersoncook.com

Apex Broaching Systems
www.apexbroach.com

BTS Broaching Tools
www.brostakimsanayi.com.tr

Banyan Global Technologies LLC
www.banyangt.com

Barber-Colman, Div of Bourn & Koch
www.bourn-koch.com

Bates Technologies, LLC
www.batestech.com

Becker GearMeisters, Inc.
www.maagmachines.com

Bourn & Koch Inc. SEE OUR AD P3
2500 KISHWAUKEE STREET
ROCKFORD, IL 61104
Phone: (815) 965-4013
Fax: (815) 965-0019
sales@bourn-koch.com
www.bourn-koch.com

Breton USA
www.bretonusa.com

Broaching Machine Specialties
www.broachingmachine.com

Buderus Schleiftechnik GmbH
www.buderus-schleiftechnik.de

C & B Machinery
www.cbmachinery.com

CNC Center
www.cnccenter.com

Capital Tool Industries
www.capital-tool.com

Chamfermatic Inc.
www.chamfermatic.com

Clemco Industries Corp.
www.clemcoindustries.com

Cleveland Deburring Machine Co.
cdmcmachine.com

Colonial Tool Group
www.colonialtool.com

Comco Inc.
www.comcoinc.com

Compressed Gas Technologies Inc.
www.nitrogen-generators.com

D.C. Morrison Company
www.dcmorrison.com

DMG MORI USA
www.dmgmori-usa.com

DVS Universal Grinding GmbH
www.ugrind.de

Danobat Machine Tool Co. Inc.
www.danobatusa.com

Dianamic Abrasive Products Inc.
www.dianamic.com

Donner+Pfister AG
www.dpag.ch

Drake Manufacturing Services Co., LLC
www.drakemfg.com

EMAG L.L.C.
www.emag.com

Electronics Inc.
www.electronics-inc.com

Eltro Services, Inc.
www.eltroservices.com

Engineered Abrasives
www.engineeredabrasives.com

Erwin Junker Machinery, Inc.
www.junker-group.com

FFG - Modul
www.star-su.com

Fassler by Daetwyler Industries faessler.daetwyler.com/en/

Federal Broach & Machine
www.federalbroach.com

Fellows Machine Tools
www.bourn-koch.com

Felsomat USA Inc.
www.felsomat.com

Forst Technologie GmbH & Co. KG
www.forst-online.de

Fuji Machine America Corp.
www.fujimachine.com

Gear Consulting Group
www.gearconsultinggroup.com

Gearspect s.r.o.
www.gearspect.com

Gehring L.P.
www.gehring.de

General Broach Company
www.generalbroach.com

Georg Kesel GmbH & Co. KG
www.kesel.com

German Machine Tools of America
www.gmtamerica.com

Gleason Corporation SEE OUR AD P37, 91
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com

Gleason Works (India) Private Ltd. SEE OUR AD P37, 91
PLOT NO. 37
DODDENAKUNDI INDUSTRIAL AREA
WHITEFIELD RD., MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com

Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greg Allen Company
www.gallenco.com

HÖFLER - A Brand of KLINGELNBERG
www.hofler.com

HARO Technologies
harotechnologies.com

Haas Multigrind LLC
www.multigrind.com

Hamai Co. Ltd.
www.hamai.com

Hanik Corporation
www.hanikcorp.com

Hans-Juergen Geiger Maschinen-Vertrieb GmbH
www.geiger-germany.com

Hartech
www.hartech.com.tw

Havlik International Machinery Inc.
www.havlikinternational.com

Heller Machine Tools
www.heller-machinetools.com

IMPCO Microfinishng
www.impco.com

ITW Heartland SEE OUR AD P20
1205 36TH AVENUE WEST
ALEXANDRIA MN 56308
Phone: (320) 762-0138
Fax: (320) 762-5645
info@itwheartland.com
www.itwheartland.com

Index Corporation
us.index-traub.com

Index-Werke GmbH & Co. KG Hahn & Tessky
www.index-traub.com/gearing

International Tool Machines (ITM)
www.itmfl.com

Involute Gear & Machine Company
www.involutegearmachine.com

J. Schneeberger Corp.
www.schneeberger-us.com

JRM International, Inc
www.jrminternational.com

James Engineering
www.james-engineering.com

Kapp Technologies SEE OUR AD P17, 40
2870 WILDERNESS PLACE
BOULDER, CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

Kinefac Corporation
www.kinefac.com

Klingelnberg AG SEE OUR AD BACK COVER
BINZMÜHLESTRASSE 171
CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
Fax: +(41) 44-2781594
info@klingelnberg.com
www.klingelnberg.com

Klingelnberg America Inc. SEE OUR AD BACK COVER
118 E. MICHIGAN AVENUE, SUITE 200
SALINE, MI 48176
Phone: (734) 470-6278
Fax: (734) 316-2158
kla.info@klingelnberg.com
www.klingelnberg.com

Klingelnberg GmbH SEE OUR AD BACK COVER
PETERSTRASSE 45
HUECKESWAGEN 42499
GERMANY
Phone: +(49) 2192-810
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com

Knuth Machine Tools USA, Inc.
www.knuth-usa.com

Koepfer America
koepferamerica.com

Lambda Technologies
www.lambdatechs.com

Leistritz Advanced Technology Corp. SEE OUR AD P30
165 CHESTNUT STREET
ALLENDALE, NJ 07401
Phone: (201) 934-8262
Fax: (201) 934-8266
staff@leistritzcorp.com
www.leistritzcorp.com

Liebherr America SEE OUR AD P5
1465 WOODLAND DR.
SALINE, MI 48176
Phone: (734) 429-7225
Fax: (734) 429-2294
info.lgt@liebherr.com
www.liebherr.com

Liebherr-Verzahntechnik GmbH SEE OUR AD P5
KAUFBEURER STRASSE 141
D-87437 KEMPTEN
GERMANY
Phone: +(49) 831-786-0
Fax: +(49) 831-7861279
info.lvt@liebherr.com
www.liebherr.com

Luren Precision
www.luren.com.tw/en/index.html

MPT Manufacturing Process Technologies
www.mptinc.com

Machine Tool Builders SEE OUR AD P7
7723 BURDEN ROAD
MACHESNEY PARK, IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
aminer@machinetoolbuilders.com
www.machinetoolbuilders.com

Mazak Corporation
www.mazakusa.com

Meccanica Nova Corporation
www.novagrinders.com

Meister Abrasives USA
www.meister-abrasives.com/USA

Miller Broach
www.millerbroach.com

Mitsubishi Heavy Industries America SEE OUR AD P8
MACHINE TOOL DIVISION
46992 LIBERTY DRIVE
WIXOM, MI 48393
Phone: (248) 669-6136
Fax: (248) 669-0614
brenda_motzell@mhiahq.com
www.mitsubishigearcenter.com

Mutschler Edge Technologies
mutschleredgetech.com

Nachi America Inc. SEE OUR AD P12,39
715 PUSHVILLE RD.
GREENWOOD, IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

Nagel Precision
www.nagelusa.com

Normac, Inc.
www.normac.com

ORT Italia
www.ortitalia.com

Ohio Broach & Machine Co.
www.ohiobroach.com

Okuma America Corporation
www.okuma.com

PTG Holroyd
www.holroyd.com

Parker Industries Inc.
www.parkerind.com

Penta Gear Metrology LLC SEE OUR AD P17
6161 WEBSTER STREET
DAYTON, OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com

Phoenix Inc.
www.phoenix-inc.com

Pioneer Broach Co.
www.pioneerbroach.com

Pittler T&S GmbH SEE OUR AD P13
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63128
GERMANY
Phone: +49-6074-4873-0
Fax: +49-6074-4873-291
christian.rhiel@pittler.de
www.pittler.de

PlasmaRoute CNC
www.cncplasmacutterinc.com

Praewema Antriebstechnik GmbH
www.praewema.de

Precision Finishing Inc.
www.precisionfinishinginc.com

Preco Inc.
www.precoinc.com

Prime Technologies
www.gear-testers.com

QC American
www.qcamerican.com

Röders GmbH
www.roeders.de

Ravjeet Engineering Specialty Ltd.
www.ravjeet.com

Redin Production Machine
www.redinmachine.com

Reishauer AG SEE OUR AD P19
INDUSTRIESTRASSE 36
CH-8304 WALLISELLEN
SWITZERLAND
Phone: +(41) 44-832-22-11
Fax: +(41) 44-832-23-90
info@reishauer.com
www.reishauer.com

Reishauer Corporation SEE OUR AD P19
1525 HOLMES ROAD
ELGIN, IL 60123
Phone: (847) 888-3828
Fax: (847) 888-0343
usa@reishauer.com
www.reishauer.com

Roberts Sinto Corp.
www.robertssinto.com

Rotec Tools Ltd.
www.rotectools.com

Rotek Incorporated
www.rotek-inc.com

Russell Holbrook & Henderson
www.tru-volute.com

SETCO Precision Spindles
www.setcousa.com

SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

Saacke North America, LLC
www.saacke-usa.com

Samputensili S.p.A.
www.samputensili.com

SerWeMa GmbH & Co. KG
www.serwema.de

Star Cutter Co.
www.starcutter.com

Star SU LLC SEE OUR AD IFC-1,41
5200 PRAIRIE STONE PARKWAY, SUITE 100
HOFFMAN ESTATES, IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com

Steelmans Broaches Pvt. Ltd.
www.steelmans.com

Sunnen Products Company
www.sunnen.com

Surface Finishing Equipment Co.
www.sfecindia.net

Surplex GmbH
www.surplex.com

TECO Werkzeugmaschinen GmbH & Co.
www.teco-germany.com

Tianjin No.1 Machine Tool Works
www.tmtw.com

Toolink Engineering
www.toolink-eng.com

Ty Miles, Inc.
www.tymiles.com

U.S. Equipment
www.usequipment.com

Ultramatic Equipment Co.
ultramatic-equipment.com

WFL Millturn Technologies, Inc
www.wfl-usa.com

WMZ - Werkzeugmaschinenbau Ziegenhain GmbH
www.wmz-gmbh.de

WardJet
www.wardjet.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Westminster Machine Tools Ltd.
www.wmtg.co.uk

Wheelabrator
www.wheelabratorgroup.com

Willrich Precision Instrument Company
willrich.com

Wolverine Broach Co., Inc.
www.wolverinebroach.com

Yieh Chen Machinery
www.yiehchen.com

GRINDING WHEELS & ABRASIVE TOOLS

All of the suppliers listed here are broken down by category (diamond wheels, grinding wheels, honing stones, etc.) at *www.geartechnology.com*.

2L Inc.
www.2Linc.com

3M Abrasives
www.3m.com/Abrasives

Abtex Corp.
www.abtex.com

Accu-Cut Diamond Tool Co.
www.accucutdiamond.com

Ajax Tool Supply
www.ajaxtoolsupply.com

Alliance Broach & Tool
www.alliancebroach.com

Banyan Global Technologies LLC
www.banyangt.com

Bates Technologies, LLC
www.batestech.com

Brighton Laboratories
www.brightonlabs.com

CGW - Camel Grinding Wheels
www.cgwcamel.com

Carborundum Universal Ltd.
www.cumiabrasives.com

Cleveland Deburring Machine Co.
cdmcmachine.com

Comco Inc.
www.comcoinc.com

Continental Diamond Tool Corporation
www.cdtusa.net

DTR Corp. (formerly Dragon Precision Tools)
1865A HICKS ROAD
ROLLING MEADOWS, IL 60008
Phone: (847) 375-8892
Fax: (224) 220-1311
alex@dragon.co.kr
www.dragon.co.kr

SEE OUR AD P27

DVS Tooling GmbH
www.dvs-tooling.de

DiaTech Tools India Pvt. Ltd.
www.diatechtools.com

Diametal AG
www.diametal.ch

Diamond Abrasive Products
www.diamondabrasiveproducts.com

Dianamic Abrasive Products Inc.
www.dianamic.com

Dr. Kaiser Diamantwerkzeuge
www.drkaiser.de

ESGI Tools Pvt. Ltd.
esgitools.com

FFG - Modul
www.star-su.com

Fassler by Daetwyler Industries
faessler.daetwyler.com/en/

Gear Resource Technologies Inc.
www.gear-resource.com

Gehring L.P.
www.gehring.de

Gleason Corporation
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com

SEE OUR AD P37, 91

Gleason Cutting Tools Corporation
1351 WINDSOR RD.
LOVES PARK, IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com

SEE OUR AD P37, 91

Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com

SEE OUR AD P37, 91

Graff Diamond Products
www.graffdiamond.com

Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greg Allen Company
www.gallenco.com

Hermes Abrasives Ltd.
www.hermesabrasives.com

Interstate Tool Corp.
itctoolcorp.com

Involute Gear & Machine Company
www.involutegearmachine.com

J. Schneeberger Corp.
www.schneeberger-us.com

JRM International, Inc
www.jrminternational.com

Kapp Technologies
2870 WILDERNESS PLACE
BOULDER, CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com

SEE OUR AD P17, 40

Klingelnberg AG
BINZMÜHLESTRASSE 171
CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
Fax: +(41) 44-2781594
info@klingelnberg.com
www.klingelnberg.com

SEE OUR AD BACK COVER

Klingelnberg America Inc.
118 E. MICHIGAN AVENUE, SUITE 200
SALINE, MI 48176
Phone: (734) 470-6278
Fax: (734) 316-2158
kla.info@klingelnberg.com
www.klingelnberg.com

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Klingelnberg GmbH
PETERSTRASSE 45
HUECKESWAGEN 42499
GERMANY
Phone: +(49) 2192-810
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com

SEE OUR AD BACK COVER

Knuth Machine Tools USA, Inc.
www.knuth-usa.com

Koepfer America
koepferamerica.com

Lambda Technologies
www.lambdatechs.com

Liebherr America
1465 WOODLAND DR.
SALINE, MI 48176
Phone: (734) 429-7225
Fax: (734) 429-2294
info.lgt@liebherr.com
www.liebherr.com

SEE OUR AD P5

Liebherr-Verzahntechnik GmbH
KAUFBEURER STRASSE 141
D-87437 KEMPTEN
GERMANY
Phone: +(49) 831-786-0
Fax: +(49) 831-7861279
info.lvt@liebherr.com
www.liebherr.com

SEE OUR AD P5

Longevity Coatings
www.longevitycoatings.com

Luren Precision
www.luren.com.tw/en/index.html

Marposs Corporation
www.marposs.com

Meister Abrasives USA
www.meister-abrasives.com/USA

Modern Gearing
www.moderngearing.com

Mutschler Edge Technologies
mutschleredgetech.com

Nagel Precision
www.nagelusa.com

Naxos-Diskus Schleifmittelwerke GmbH
www.naxos-diskus.de

Norton | Saint-Gobain
1 NEW BOND STREET
P.O. BOX 15008
WORCESTER, MA 01606
Phone: 254-918-2313
Fax: 254-918-2314
www.nortonabrasives.com

SEE OUR AD P35,49

Osborn International
www.osborn.com

PTG Holroyd
www.holroyd.com

Particular Technology, Inc.
www.particulartechnology.com

Philadelphia Carbide Co.
www.philacarbide.com

Precision Spindle & Accessories Inc.
www.precisionspindleinc.com

QC American
www.qcamerican.com

Radiac Abrasives
www.radiac.com

Ravjeet Engineering Specialty Ltd.
www.ravjeet.com

RedLine Tools
www.redlinetools.com

Redin Production Machine
www.redinmachine.com

Reishauer AG
INDUSTRIESTRASSE 36
CH-8304 WALLISELLEN
SWITZERLAND
Phone: +(41) 44-832-22-11
Fax: +(41) 44-832-23-90
info@reishauer.com
www.reishauer.com
SEE OUR AD P19

Reishauer Corporation
1525 HOLMES ROAD
ELGIN, IL 60123
Phone: (847) 888-3828
Fax: (847) 888-0343
usa@reishauer.com
www.reishauer.com
SEE OUR AD P19

Rex-Cut Products, Inc.
www.rexcut.com

S.L. Munson & Company
www.slmunson.com

Samputensili S.p.A.
www.samputensili.com

Schnyder SA
JAKOBSTRASSE 52
CH-2504 BIEL
SWITZERLAND
Phone: +(41)(32) 344-0406
Fax: +(41)(32) 344-0404
george.boon@schnyder.com
www.schnyder.com
SEE OUR AD P4

Sitab S.r.l.
www.sitab-abrasives.com

Star Cutter Co.
www.starcutter.com

Star SU LLC
5200 PRAIRIE STONE PARKWAY, SUITE 100
HOFFMAN ESTATES, IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com
SEE OUR AD IFC-1,41

Steelmans Broaches Pvt. Ltd.
www.steelmans.com

Stella Keramik GmbH
www.stella-gruppe.de

Stone Tucker Instruments Inc.
www.stone-tucker.com

Sunnen Products Company
www.sunnen.com

Suresh Mehta Associates
www.sureshmehta.com

Toolink Engineering
www.toolink-eng.com

Ultramatic Equipment Co.
ultramatic-equipment.com

Vargus USA
www.vargususa.com

Weldon Solutions
www.weldonsolutions.com

Yash International
www.yashtools.com

HEAT TREATING EQUIPMENT & SUPPLIES

All of the suppliers listed here are broken down by category (batch furnaces, continuous furnaces, induction heating equipment, ovens, etc.) at *www.geartechnology.com.*

A&A Coatings
www.thermalspray.com

AFC-Holcroft
www.afc-holcroft.com

Abbott Furnace Company
www.abbottfurnace.com

Advanced Nitriding Solutions
www.ans-ion.net

Ajax Tocco Magnethermic
1745 OVERLAND AVE NE
WARREN, OH 44483
Phone: 330-372-8511
Fax: 330-372-8608
sales@ajaxtocco.com
www.ajaxtocco.com
SEE OUR AD P43,51

Aksan Steel Forging
www.aksanforging.com

Ambrell Precision Induction Heating
www.ambrell.com

Avion Manufacturing Company Inc.
www.avionmfg.com

Bega Special Tools
www.bega.nl

Byington Steel Treating
www.byingtonsteel.com

C.I. Hayes
www.cihayes.com

Cascade TEK
www.cascadetek.com

Compressed Gas Technologies Inc.
www.nitrogen-generators.com

Contour Hardening, Inc.
www.contourhardening.com

DAM HÃ¤rtetechnik GmbH
www.stopoffpaints.com

DK Surface Hardening
www.dksurfacehardening.com

Davron Technologies
www.davrontech.com

Duffy Company, The
www.duffycompany.com

ECM USA
9505 72ND AVE. SUITE 400
PLEASANT PRAIRIE WI 53158
Phone: (262) 605-4810
info@ecm-usa.com
www.ecm-usa.com
SEE OUR AD P31,50

EFD Induction Inc.
www.efdinduction-usa.com

East Coast Induction
www.eastcoastind.com

Eldec Induction USA, Inc.
www.eldec-usa.com

ElectroHeat Induction
www.electroheatinduction.com

Eltro Services, Inc.
www.eltroservices.com

Euclid Heat Treating
www.euclidheattreating.com

FPM Heat Treating
www.fpmht.com

Flame Treating Systems, Inc.
www.flametreatingsystems.com

Fredericks Company - Televac
www.frederickscompany.com

Furnaces, Ovens & Baths, Inc.
www.fobinc.com

GH Induction Atmospheres
www.gh-ia.com

Gleason Corporation
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com
SEE OUR AD P37, 91

Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Grieve Corporation, The
www.grievecorp.com

Heatbath/Park Metallurgical
www.heatbath.com

Heavy Carbon Co., LLC
www.heavycarbon.com

Houghton International
www.houghtonintl.com

IHI Ionbond Inc.
ionbond.com

Induction Tooling, Inc.
www.inductiontooling.com

Inductoheat Inc.
www.inductoheat.com

Inductotherm Corp.
www.inductotherm.com

Infrared Heating Technologies
www.infraredheating.com

Ionitech Ltd.
www.ionitech.com

Ipsen, Inc.
984 IPSEN RD.
CHERRY VALLEY, IL 61016
Phone: (800) 727-7625
Fax: (815) 332-4549
sales@ipsenusa.com
www.IpsenUSA.com
SEE OUR AD IBC, 50

J.L. Becker, A Gasbarre Furnace Group Company
www.jlbecker.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

Klingelnberg AG
BINZMÜHLESTRASSE 171
CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
Fax: +(41) 44-2781594
info@klingelnberg.com
www.klingelnberg.com
SEE OUR AD BACK COVER

Klingelnberg GmbH
PETERSTRASSE 45
HUECKESWAGEN 42499
GERMANY
Phone: +(49) 2192-810
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com
SEE OUR AD BACK COVER

Koncar Termotehnika d.o.o.
koncar-termotehnika.hr

Lucifer Furnaces, Inc.
www.Luciferfurnaces.com

Machine Tool Solutions, Inc.
machtoolinc.com

Metallurgical High Vacuum Corp.
www.methivac.com

Motultech
www.motul.com

National Heat Treat
nationalheattreat.com

Nisha Engineers (India)
www.nishagroup.com

Nitrex Inc. - Chicago Operations
www.nitrex.com

Nitrex Inc. - Indiana Operations
www.nitrex.com

Nitrex Inc. - Michigan Operations
www.nitrex.com

Nitrex Inc. - West Coast Operations
www.nitrex.com

Nitrex Metal Inc.
www.nitrex.com

Penta Gear Metrology LLC
6161 WEBSTER STREET
DAYTON, OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com
SEE OUR AD P17

PhoenixTM
www.phoenixtm.com

Pillar Induction
www.pillar.com

Plus Furnace
www.plusfurnace.com

Preco Inc.
www.precoinc.com

Premier Furnace Specialists Inc.
www.premierfurnace.com

Pro-Beam USA
www.pro-beam.com

Pyromaitre
www.pyromaitre.com

Radyne Corporation
www.radyne.com

Regal Products, Inc.
www.regalproducts.com

Roberts Sinto Corp.
www.robertssinto.com

Rubig US, Inc.
www.rubig.com

SECO/Vacuum Technologies LLC
180 MERCER STREET
MEADVILLE, PA 16335
Phone: 814-332-8520
Fax: 814-724-1407
doug.glenn@secovacusa.com
www.secovacusa.com
SEE OUR AD P33

SMS Elotherm North America
www.techinduction.com

SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

Seco/Warwick Corp.
www.secowarwick.com

Seco/Warwick Europe S.A.
www.secowarwick.com

Sinterite, A Gasbarre Furnace Group Company
www.sinterite.com

Solar Manufacturing
1983 CLEARVIEW ROAD
SOUDERTON, PA 18964
Phone: (267) 384-5040
Fax: (267) 384-5060
info@solarmfg.com
www.solarmfg.com
SEE OUR AD P50

Stack Metallurgical Services, Inc.
www.stackmet.com

Surface Combustion
www.surfacecombustion.com

TM Induction Heating
www.tminductionheating.com

ZRIME
www.zrime.com.cn

Zion Industries
www.zioninduction.com

HEAT TREATING SERVICES

All of the suppliers listed here are broken down by category (carburizing, nitriding, induction hardening, etc.) at *www.geartechnology.com.*

300 Below, Inc.
www.300below.com

ALD Thermal Treatment, Inc.
www.aldtt.net

Accurate Steel Treating, Inc.
www.accuratesteeltreating.com

Advanced Heat Treat Corp.
www.ahtweb.com

Advanced Nitriding Solutions
www.ans-ion.net

Ajax Tocco Magnethermic
1745 OVERLAND AVE NE
WARREN, OH 44483
Phone: 330-372-8511
Fax: 330-372-8608
sales@ajaxtocco.com
www.ajaxtocco.com
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Akron Steel Treating Company
www.akronsteeltreating.com

Aksan Steel Forging
www.aksanforging.com

American Metal Treating Co.
www.americanmetaltreating.com

American Metal treating, Inc.
www.americanmetaltreatinginc.com

Ampere Metal Finishing
www.amperemetal.com

Applied Process
www.appliedprocess.com

Applied Thermal Technologies
www.appliedthermaltechnologies.com

Avion Manufacturing Company Inc.
www.avionmfg.com

BG&S Peening and Consulting LLC
www.peening-consultants.com

BOS Services Company
www.bosheattreating.com

Bennett Heat Treating & Brazing Co., Inc.
www.bennettheat.com

Best Technology Inc.
www.besttechnologyinc.com

Bluewater Thermal Solutions
www.bluewaterthermal.com

Bodycote Thermal Processing - Highland Heights
www.bodycote.com

Bodycote Thermal Processing - Melrose Park
www.bodycote.com

Boltex Manufacturing
www.boltex.com

Braddock Metallurgical
www.braddockmt.com

Burlington Engineering, Inc
www.burlingtoneng.com

Byington Steel Treating
www.byingtonsteel.com

CST-Cincinnati Steel Treating
www.steeltreating.com

Cambridge Heat Treating Inc.
www.cambridgeheattreating.com

Cascade TEK
www.cascadetek.com

Certified Steel Treating
www.certifiedsteeltreat.com

Chicago Flame Hardening
www.cflame.com

Cleveland Deburring Machine Co.
cdmcmachine.com

Complete Heat Treating
www.completeht.com

Continental Heat Treating, Inc.
www.continentalht.com

Contour Hardening, Inc.
www.contourhardening.com

Cryogenic Institute of New England, Inc.
www.nitrofreeze.com

Cryoplus Inc.
www.cryoplus.com

Curtiss-Wright Surface Technologies
www.cwst.com

DK Surface Hardening
www.dksurfacehardening.com

Dayton Forging and Heat Treating
www.daytonforging.com

Duffy Company, The
www.duffycompany.com

ECM USA
9505 72ND AVE. SUITE 400
PLEASANT PRAIRIE WI 53158
Phone: (262) 605-4810
info@ecm-usa.com
www.ecm-usa.com
SEE OUR AD P31,50

EFD Induction Inc.
www.efdinduction-usa.com

ERS Engineering Corp.
www.ersengine.com

Eagle Tool Company Inc.
www.eaglebroach.com

East-Lind Heat Treat, Inc.
www.eastlind.com

Eldec Induction USA, Inc.
www.eldec-usa.com

ElectroHeat Induction
www.electroheatinduction.com

Eltro Services, Inc.
www.eltroservices.com

Engineered Heat Treat, Inc.
www.ehtinc.com

Erasteel Inc.
www.erasteel.com

Euclid Heat Treating
www.euclidheattreating.com

FPM Heat Treating
www.fpmht.com

Felsomat USA Inc.
www.felsomat.com

Flame Metals Processing Corporation
www.flamemetals.com

Flame Treating Systems, Inc.
www.flametreatingsystems.com

Forst Technologie GmbH & Co. KG
www.forst-online.de

General Metal Heat Treating, Inc.
www.generalmetalheat.com

General Surface Hardening Inc.
www.gshinc.net

Gleason Corporation
SEE OUR AD P37, 91
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com

Härterei Reese Bochum GmbH
www.hardening.com

Heat Treating Services Corporation of America
www.htsmi.com

Hi TecMetal Group
www.htg.cc

Horsburgh & Scott Co.
www.horsburgh-scott.com

Hudapack Metal Treating
www.hudapack.com

IHI Ionbond Inc.
ionbond.com

IMT Forge Group including Clifford-Jacobs Forge
www.imtforgegroup.com

Induction Hardening Specialists
inductionhardeningspecialists.com

Induction Services, Inc.
www.inductionservicesinc.com

Induction Tooling, Inc.
www.inductiontooling.com

Inductoheat Inc.
www.inductoheat.com

Industrial Hard Carbon LLC
industrialhardcarbon.com

Industrial Metal Finishing, Inc.
www.indmetfin.com

Infrared Heating Technologies
www.infraredheating.com

Ionic Technologies Inc.
www.ionic-tech.com

Ionitech Ltd.
www.ionitech.com

Irwin Automation Inc.
www.irwinautomation.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

Klingelnberg AG
SEE OUR AD BACK COVER
BINZMÜHLESTRASSE 171
CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
Fax: +(41) 44-2781594
info@klingelnberg.com
www.klingelnberg.com

Klingelnberg GmbH
SEE OUR AD BACK COVER
PETERSTRASSE 45
HUECKESWAGEN 42499
GERMANY
Phone: +(49) 2192-810
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com

Kowalski Heat Treating
www.khtheat.com

Lalson Tools Corporation
www.lalsoncuttingtools.com

Lambda Technologies
www.lambdatechs.com

Mackeil Ispat & Forging Ltd.
mackeilforgings.com

Magnum Induction
www.magnuminduction.com

McLeod and Norquay Ltd.
www.mcleodandnorquay.com

Metallurgical Processing, Inc.
www.mpimetaltreating.com

Metallurgical Solutions, Inc.
www.met-sol.com

Metlab
www.metlabheattreat.com

Mid-South Metallurgical
www.midsouthmetallurgical.com

Midwest Themal-Vac Inc.
www.mtvac.com

Nachi America Inc.
SEE OUR AD P12,39
715 PUSHVILLE RD.
GREENWOOD, IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

National Heat Treat
nationalheattreat.com

Nisha Engineers (India)
www.nishagroup.com

Nitrex Inc. - Chicago Operations
www.nitrex.com

Nitrex Inc. - Indiana Operations
www.nitrex.com

Nitrex Inc. - Michigan Operations
www.nitrex.com

Nitrex Inc. - Nevada Operations
www.nitrex.com

Nitrex Inc. - West Coast Operations
www.nitrex.com

Nitrex Metal Inc.
www.nitrex.com

Oerlikon Balzers - PPD Division
www.oerlikon.com

Ohio Vertical Heat Treat
www.ov-ht.com

Ovako AB
www.ovako.com

Paulo
www.paulo.com

Penna Flame Industries
www.pennaflame.com

Penticton Foundry Ltd.
www.pentictonfoundry.com

Peters Heat Treating
www.petersheattreat.com

Pillar Induction
www.pillar.com

Precision Finishing Inc.
www.precisionfinishinginc.com

Precision Heat Treating Co.
www.precisionheat.net

Precision Pump and Gear Works
www.ppg-works.com

Preco Inc.
www.precoinc.com

Pro-Beam USA
www.pro-beam.com

Rex Heat Treat
www.rexht.com

Rockford Heat Treaters
www.rockfordheattreaters.com

Rotek Incorporated
www.rotek-inc.com

Rubig US, Inc.
www.rubig.com

SMS Elotherm North America
www.techinduction.com

SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

SWD Inc.
www.swdinc.com

Sedlock Companies
www.sedlockcompanies.com

Solar Atmospheres
SEE OUR AD P26,52
1969 CLEARVIEW ROAD
SOUDERTON, PA 18964
Phone: 855-934-3284
Fax: (215) 723-6460
info@solaratm.com
www.solaratm.com

Specialty Steel Treating Inc.
www.sst.net

Spectrum Thermal Processing
www.spectrumtp.com

Stack Metallurgical Services, Inc.
www.stackmet.com

Sun Steel Treating Inc.
www.sunsteeltreating.com

Super Systems Inc.
www.supersystems.com

Thermetco Inc.
www.thermetco.com

Thermex Metal Treating Ltd.
www.thermexmetal.com

Thermtech
www.thermtech.net

TimkenSteel Corporation
www.timkensteel.com

Titanium Coating Services Inc.
www.pvdamerica.com

Treat All Metals, Inc.
www.treatallmetals.com

United Gear and Assembly, Inc.
www.ugaco.com

VaporKote, Inc.
www.vaporkote.com

WPC Treatment Co., Inc.
www.wpctreatment.com

Willman Industries Inc.
www.willmanind.com

ZRIME
www.zrime.com.cn

Zion Industries
www.zioninduction.com

INSPECTION EQUIPMENT

All of the suppliers listed here are broken down by category (gages, CMMs, analytical gear inspection machines, bevel gear testers, etc.) at *www.geartechnology.com*.

A.G. Davis - AA Gage
www.agdavis.com

ABTech Inc.
www.abtechmfg.com

Accu-Cut Diamond Tool Co.
www.accucutdiamond.com

Advent Tool and Manufacturing Inc.
www.advent-threadmill.com

Advico
www.advico.co.uk

Ajax Tool Supply
www.ajaxtoolsupply.com

Aksan Steel Forging
www.aksanforging.com

Alliance Broach & Tool
www.alliancebroach.com

American Stress Technologies, Inc.
www.astresstech.com

Andec Mfg. Ltd.
www.andec.ca

Anthony Best Dynamics Ltd
www.abd.uk.com

Ash Gear & Supply
www.ashgear.com

Avalon International Corporation
www.avalongateway.com

Becker GearMeisters, Inc.
www.maagmachines.com

Borescopes-R-Us
www.borescopesrus.com

Bourn & Koch Inc.
2500 KISHWAUKEE STREET
ROCKFORD, IL 61104
Phone: (815) 965-4013
Fax: (815) 965-0019
sales@bourn-koch.com
www.bourn-koch.com
SEE OUR AD P3

Broach Masters/Universal Gear Co.
1605 INDUSTRIAL DRIVE
AUBURN, CA 95603
Phone: (800) 563-3442
Fax: (530) 885-8157
sales@broachmasters.com
www.broachmasters.com
SEE OUR AD P14

Buehler - An ITW Company
www.buehler.com

CN Technical Services Ltd (CN Tech)
www.cntech.co.uk

CNC Center
www.cnccenter.com

Capital Tool Industries
www.capital-tool.com

Carl Zeiss Industrial Metrology LLC
www.zeiss.com/metrology

Celanese
www.celanese.com

Certified Comparator Products (CCP)
www.certifiedcomparator.com

Comtorgage Corporation
www.comtorgage.com

DK Surface Hardening
www.dksurfacehardening.com

Dino-Lite
www.dinolite.us

Donner+Pfister AG
www.dpag.ch

Drewco Workholding
www.drewco.com

Dyer Company
dyergage.com

Erwin Junker Machinery, Inc.
www.junker-group.com

Euro-Tech Corporation
www.eurotechcorp.com

FARO Technologies, Inc.
www.faro.com

FHUSA-TSA
www.fhusa-tsa.com

FPM Heat Treating
www.fpmht.com

Flexbar Machine Corporation
www.flexbar.com

Foerster Instruments Incorporated
foerstergroup.com

Fredericks Company - Televac
www.frederickscompany.com

Frenco GmbH
www.frenco.de

Fuji Machine America Corp.
www.fujimachine.com

Furnaces, Ovens & Baths, Inc.
www.fobinc.com

Gear Consulting Group
www.gearconsultinggroup.com

Gearspect s.r.o.
www.gearspect.com

Gleason Corporation
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com
SEE OUR AD P37, 91

Gleason Metrology Systems
300 PROGRESS ROAD
DAYTON, OH 45449
Phone: (937) 859-8273
Fax: (937) 859-4452
gleason-metrology@gleason.com
www.gleason.com
SEE OUR AD P37, 91

Gleason Works (India) Private Ltd.
PLOT NO. 37
DODDENAKUNDI INDUSTRIAL AREA
WHITEFIELD RD., MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com
SEE OUR AD P37, 91

Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
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Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greg Allen Company
www.gallenco.com

HITEC Sensor Developments
www.hitecorp.com

Hanik Corporation
www.hanikcorp.com

Hansford Sensors
www.hansfordsensors.com/us/

Hexagon Metrology
www.hexagonmetrology.us

HobSource Inc.
www.hobsource.com

Hydra-Lock Corporation
www.hydralock.com

ITW Heartland
1205 36TH AVENUE WEST
ALEXANDRIA MN 56308
Phone: (320) 762-0138
Fax: (320) 762-5645
info@itwheartland.com
www.itwheartland.com
SEE OUR AD P20

Innovative Analytical Solutions
www.steelanalyzer.com

Interstate Tool Corp.
itctoolcorp.com

Involute Gear & Machine Company
www.involutegearmachine.com

Kapp Technologies
2870 WILDERNESS PLACE
BOULDER, CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com
SEE OUR AD P17, 40

Khemka Broach & Spline Gauge
www.khemkabroach.com

Klingelnberg AG
BINZMÜHLESTRASSE 171
CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
Fax: +(41) 44-2781594
info@klingelnberg.com
www.klingelnberg.com
SEE OUR AD BACK COVER

Klingelnberg America Inc.
118 E. MICHIGAN AVENUE, SUITE 200
SALINE, MI 48176
Phone: (734) 470-6278
Fax: (734) 316-2158
kla.info@klingelnberg.com
www.klingelnberg.com
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Klingelnberg GmbH
PETERSTRASSE 45
HUECKESWAGEN 42499
GERMANY
Phone: +(49) 2192-810
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com
SEE OUR AD BACK COVER

Koepfer America
koepferamerica.com

LDB Corporation
ldbcorp.com

Lambda Technologies
www.lambdatechs.com

Liebherr America
1465 WOODLAND DR.
SALINE, MI 48176
Phone: (734) 429-7225
Fax: (734) 429-2294
info.lgt@liebherr.com
www.liebherr.com
SEE OUR AD P5

MPT Manufacturing Process Technologies
www.mptinc.com

MRO Electric and Supply
www.mroelectric.com/

Magnetic Inspection Laboratory
www.milinc.com

Maheen Enterprises
www.maheenbroaches.com

Mahr Inc.
www.mahr.com

Marposs Corporation
www.marposs.com

Miller Broach
www.millerbroach.com

Mitutoyo America Corporation
www.mitutoyo.com

The Modal Shop
www.modalshop.com

Modern Gearing
www.moderngearing.com

Mutschler Edge Technologies
mutschleredgetech.com

Nachi America Inc. SEE OUR AD P12,39
715 PUSHVILLE RD.
GREENWOOD, IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

Newage Testing Instruments
www.hardnesstesters.com

Ono Sokki Technology, Inc.
www.onosokki.net

Optical Gaging Products, Inc. (OGP)
www.ogpnet.com

PCE Instruments
www.pce-instruments.com/english

Parker Industries Inc.
www.parkerind.com

Penta Gear Metrology LLC SEE OUR AD P17
6161 WEBSTER STREET
DAYTON, OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com

Phase II
www.phase2plus.com

Pinpoint Laser Systems
pinpointlaser.com

Pioneer Broach Co.
www.pioneerbroach.com

PlasmaRoute CNC
www.cncplasmacutterinc.com

Precision Devices, Inc.
www.predev.com

Precision Gage Co., Inc.
www.precisiongageco.com

Prime Technologies
www.gear-testers.com

Proceq USA, Inc.
www.proceq-usa.com

Promess Inc.
www.promessinc.com

Proto Manufacturing SEE OUR AD P24
12350 UNIVERSAL DRIVE
TAYLOR, MI 48180
Phone: (313) 965-2900
Fax: (734) 946-0974
info@protoxrd.com
www.protoxrd.com

Quality Solutions
www.qs-hardnesstester.com

Quality Vision Services (QVS)
www.qvsi.com

RAM Optical Instrumentation, Inc.
www.ramoptical.com

Ravjeet Engineering Specialty Ltd.
www.ravjeet.com

Renishaw Inc.
www.renishaw.com

Reska Spline Products Co.
www.reskasplinegauge.com

Russell Holbrook & Henderson
www.tru-volute.com

S.S.Tools
www.sstools.net

SMS Elotherm North America
www.techinduction.com

SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

Samputensili S.p.A.
www.samputensili.com

Schnyder SA SEE OUR AD P4
JAKOBSTRASSE 52
CH-2504 BIEL
SWITZERLAND
Phone: +(41)(32) 344-0406
Fax: +(41)(32) 344-0404
george.boon@schnyder.com
www.schnyder.com

Sensor Products Inc.
www.sensorprod.com

SerWeMa GmbH & Co. KG
www.serwema.de

Slone Gear International, Inc.
www.slonegear.com

Spline Gage Solutions
splinegagesolutions.com

Star Cutter Co.
www.starcutter.com

Star SU LLC SEE OUR AD IFC-1,41
5200 PRAIRIE STONE PARKWAY, SUITE 100
HOFFMAN ESTATES, IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com

Stone Tucker Instruments Inc.
www.stone-tucker.com

Stotz Gaging Co.
www.stotz-usa.com

Stresstech Oy
www.stresstech.com

Sunnen Products Company
www.sunnen.com

Super Hobs & Broaches Pvt. Ltd.
www.supercuttingtools.com

Surplex GmbH
www.surplex.com

TECO Werkzeugmaschinen GmbH & Co.
www.teco-germany.com

Techcellence
www.broachindia.com

TechnoMax Inc.
www.technomax-j.com

Tianjin No.1 Machine Tool Works
www.tmtw.com

Tokyo Technical Instruments USA Inc.
www.tti-geartec.jp

USA Borescopes
www.USABorescopes.com

United Calibration Corp.
www.tensiletest.com

United Tool Supply
www.united-tool.com

View Micro-Metrology
www.viewmm.com

WMZ - Werkzeugmaschinenbau Ziegenhain GmbH
www.wmz-gmbh.de

Wenzel America SEE OUR AD P11
28700 BECK RD.
WIXOM, MI 48393
Phone: (248) 295-4300
Fax: (248) 773-7565
inquiries@wenzelamerica.com
www.wenzelamerica.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Westport Gage
www.westportcorp.com

Willrich Precision Instrument Company
willrich.com

Zoller Inc.
www.zoller-usa.com

LUBRICANTS

All of the suppliers listed here are broken down by category (coolants, gear greases, gear oils, plastic gear lubricants, etc.) at *www.geartechnology.com*.

A.W. Chesterton
chestertonlubricants.chesterton.com/en-us

Aarna Lube Private Ltd.
www.aarnalube.com

Aerospace Lubricants, Inc.
www.aerospacelubricants.com

American Chemical Technologies, Inc.
www.americanchemtech.com

American Refining Group, Inc.
www.amref.com

Avalon International Corporation
www.avalongateway.com

BASF
www.basf.com/lubes

BFK Solutions LLC
bfksolutions.com

Blaser Swisslube Inc.
www.blaser.com

Bodycote Thermal Processing - Melrose Park
www.bodycote.com

Brighton Laboratories
www.brightonlabs.com

Byington Steel Treating
www.byingtonsteel.com

Carborundum Universal Ltd.
www.cumiabrasives.com

Castrol Industrial North America Inc.
www.castrol.com/industrial

Chemtool Inc.
www.chemtool.com

Cimcool Fluid Technology
www.cimcool.com

Cortec Corporation
www.cortecvci.com

Daubert Cromwell
www.daubertcromwell.com

Des-Case Corporation
descase.com

Dillon Chuck Jaws SEE OUR AD P43,62
2115 PROGRESS DRIVE
SPRINGFIELD, OH 45505
Phone: (800) 428-1133
Fax: (800) 634-6480
sales4@dillonmfg.com
www.dillonmfg.com

Etna Products, Inc.
www.etna.com

ExxonMobil Oil Corp.
www.mobilindustrial.com

Fuchs Lubricants Company
www.fuchs.com

General Magnaplate
www.magnaplate.com

Hangsterfer's Laboratories
www.hangsterfers.com

Heatbath/Park Metallurgical
www.heatbath.com

Hoffmann Filter Corporation
www.hoffmannfilter.com

Houghton International
www.houghtonintl.com

Hydrotex
www.hydrotexlube.com

Industrial Speciality Lubricants Co. (ISLUB)
www.islub.com

Isel Inc.
www.iselinc.com

Klüber Lubrication North America L.P.
www.klubersolutions.com

Lubegard/International Lubricants Inc.
www.lubegard.com

Lubrication Engineers
www.lelubricants.com

ML Lubrication Inc.
www.ml-lubrication.com

Microsurface Corporation
www.ws2coating.com

Moncktons Machine Tools, LLC
www.mmtproductivity.com/

Motultech
www.motul.com

Nye Lubricants
www.nyelubricants.com

Particular Technology, Inc.
www.particulartechnology.com

PetroChoice
www.PetroChoice.com

Petronomics Mfg. Group, Inc.
www.petronomics.com

Productivity Inc.
www.productivity.com/

RedLine Tools
www.redlinetools.com

SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

SWD Inc.
www.swdinc.com

Shell Lubricants
www.shellus.com

Summit Industrial Products
www.klsummit.com

Sunnen Products Company
www.sunnen.com

Syn-Tech Ltd.
www.syn-techlube.com

Tecsia Lubricants USA
www.tecsialube.com

Texas Refinery Corp.
www.texasrefinery.com

TheLubricantStore.com
www.thelubricantstore.com

United Tool Supply Ltd.
www.unitedtoolsupply.com

Voelker Sensors, Inc.
www.vsi-oil.com

Whitmore
whitmores.com

MACHINE TOOLS

All of the suppliers listed here are broken down by category (milling machines, turning machines, grinding machines, etc.) at *www.geartechnology.com*.

2L Inc.
www.2Linc.com

A&A Coatings
www.thermalspray.com

ADF Systems Ltd.
www.adfsys.com

ANCA, Inc.
www.anca.com

Accu-Cut Diamond Tool Co.
www.accucutdiamond.com

Acieta
www.acieta.com/robotics-products/gripper-systems/

Acme Manufacturing Co.
www.acmemfg.com

Advico
www.advico.co.uk

Aksan Steel Forging
www.aksanforging.com

Alliance Broach & Tool
www.alliancebroach.com

Almco Finishing & Cleaning Systems
www.almco.com

American Broach & Machine Co.
www.americanbroach.com

Ampere Metal Finishing
www.amperemetal.com

Andec Mfg. Ltd.
www.andec.ca

Arbortech Corporation
www.arbortech.com

BFK Solutions LLC
bfksolutions.com

BTS Broaching Tools
www.brostakimsanayi.com.tr

Balanstar Corp
www.balanstar.com

Barber-Colman, Div of Bourn & Koch
www.bourn-koch.com

Bates Technologies, LLC
www.batestech.com

Becker GearMeisters, Inc.
www.maagmachines.com

Best Technology Inc.
www.besttechnologyinc.com

Bohle Machine Tools, Inc.
www.bmtbohle.com

Breton USA
www.bretonusa.com

Brighton Laboratories
www.brightonlabs.com

Broaching Machine Specialties
www.broachingmachine.com

Buderus Schleiftechnik GmbH
www.buderus-schleiftechnik.de

C & B Machinery
www.cbmachinery.com

CNC Center
www.cnccenter.com

CNC Design Pty Ltd
www.cncdesign.com

Capital Equipment LLC
www.capitalequipment.com

Capital Tool Industries
www.capital-tool.com

Carborundum Universal Ltd.
www.cumiabrasives.com

Castrol Industrial North America Inc.
www.castrol.com/industrial

Cleaning Technologies Group/Ransohoff
www.ctgclean.com

Clemco Industries Corp.
www.clemcoindustries.com

Cleveland Deburring Machine Co.
cdmcmachine.com

Colonial Tool Group
www.colonialtool.com

Comco Inc.
www.comcoinc.com

Cortec Corporation
www.cortecvci.com

Cosen Saws USA
www.cosensaws.com

Creative Automation, Inc.
www.cautomation.com

Crest Ultrasonics Corp.
www.crest-ultrasonics.com

Curtiss-Wright Surface Technologies
www.cwst.com

D.C. Morrison Company
www.dcmorrison.com

DMG MORI USA
www.dmgmori-usa.com

DVS Universal Grinding GmbH
www.ugrind.de

Danobat Machine Tool Co. Inc.
www.danobatusa.com

Daubert Cromwell
www.daubertcromwell.com

Des-Case Corporation
descase.com

Diskus Werke Schleiftechnik GmbH
www.diskus-werke.de

Drake Manufacturing Services Co., LLC
www.drakemfg.com

Duffy Company, The
www.duffycompany.com

EDAC Machinery
www.edacmachinery.com

EMAG L.L.C.
www.emag.com

Eagle PLC
www.eagleplc.com

ElectroHeat Induction
www.electroheatinduction.com

Eltro Services, Inc.
www.eltroservices.com

Engineered Abrasives
www.engineeredabrasives.com

Erwin Junker Machinery, Inc.
www.junker-group.com

Euro-Tech Corporation
www.eurotechcorp.com

FPM Heat Treating
www.fpmht.com

Felsomat USA Inc.
www.felsomat.com

Firbimatic Metal Cleaning Division
www.metalcleaning-firbimatic.com

Flexbar Machine Corporation
www.flexbar.com

Foerster Instruments Incorporated
foerstergroup.com

Forst Technologie GmbH & Co. KG
www.forst-online.de

Fuji Machine America Corp.
www.fujimachine.com

Furnaces, Ovens & Baths, Inc.
www.fobinc.com

GH Induction Atmospheres
www.gh-ia.com

GMN USA LLC
www.gmnusa.com

Galomb Inc.
www.injectionmolder.net

Gehring L.P.
www.gehring.de

General Broach Company
www.generalbroach.com

General Magnaplate
www.magnaplate.com

Gleason Corporation
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com
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Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
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GoHz Inc.
www.gohz.com

Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greenerd Press & Machine Co. Inc.
www.greenerd.com

Guardair Corporation
www.guardair.com

HARO Technologies
harotechnologies.com

HPI Processes, Inc.
www.hpipro.com/

Haas Multigrind LLC
www.multigrind.com

Hans-Juergen Geiger Maschinen-Vertrieb GmbH
www.geiger-germany.com

Hardinge Inc.
www.hardinge.com

Havlik International Machinery Inc.
www.havlikinternational.com

Heatbath/Park Metallurgical
www.heatbath.com

Heiko Machine Tools
www.heikomachine.com

Heller Machine Tools
www.heller-machinetools.com

Hines Industries
www.hinesindustries.com

HobSource Inc.
www.hobsource.com

Hoffmann Filter Corporation
www.hoffmannfilter.com

Hy-Pro Filtration
www.hyprofiltration.com

IHI Hauzer Techno Coating B.V.
www.hauzer.nl

IHI Ionbond Inc.
ionbond.com

IMPCO Microfinishng
www.impco.com

Index Corporation
us.index-traub.com

Index-Werke GmbH & Co. KG Hahn & Tessky
www.index-traub.com/gearing

Industrial Hard Carbon LLC
industrialhardcarbon.com

International Tool Machines (ITM)
www.itmfl.com

Interstate Tool Corp.
itctoolcorp.com

Ion Vacuum (IVAC) Technologies Corp.
www.ivactech.com

J. Schneeberger Corp.
www.schneeberger-us.com

Jenfab
www.jenfab.com

K+S Services, Inc.
www.k-and-s.com

KGK International Corp.
www.kgki.com

Kennametal Inc.
www.kennametal.com

Kinefac Corporation
www.kinefac.com

Klingelnberg AG
BINZMÜHLESTRASSE 171
CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
Fax: +(41) 44-2781594
info@klingelnberg.com
www.klingelnberg.com
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Klingelnberg America Inc.
118 E. MICHIGAN AVENUE, SUITE 200
SALINE, MI 48176
Phone: (734) 470-6278
Fax: (734) 316-2158
kla.info@klingelnberg.com
www.klingelnberg.com
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Klingelnberg GmbH
PETERSTRASSE 45
HUECKESWAGEN 42499
GERMANY
Phone: +(49) 2192-810
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com
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Knuth Machine Tools USA, Inc.
www.knuth-usa.com

Kollmorgen
www.kollmorgen.com/en-us/home/

Kwikmark Inc.
www.kwikmark.com

Lafert North America
www.lafertna.com

Lambda Technologies
www.lambdatechs.com

Laser Tools Co.
www.lasertoolsco.com

Liebherr America
1465 WOODLAND DR.
SALINE, MI 48176
Phone: (734) 429-7225
Fax: (734) 429-2294
info.lgt@liebherr.com
www.liebherr.com
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Liebherr-Verzahntechnik GmbH
KAUFBEURER STRASSE 141
D-87437 KEMPTEN
GERMANY
Phone: +(49) 831-786-0
Fax: +(49) 831-7861279
info.lvt@liebherr.com
www.liebherr.com
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Longevity Coatings
www.longevitycoatings.com

Luren Precision
www.luren.com.tw/en/index.html

MPT Manufacturing Process Technologies
www.mptinc.com

MRO Electric and Supply
www.mroelectric.com/

Machine Tool Builders
7723 BURDEN ROAD
MACHESNEY PARK, IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
aminer@machinetoolbuilders.com
www.machinetoolbuilders.com
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Machine Tool Solutions, Inc.
machtoolinc.com

Mazak Corporation
www.mazakusa.com

Meccanica Nova Corporation
www.novagrinders.com

Meister Abrasives USA
www.meister-abrasives.com/USA

Metallurgical High Vacuum Corp.
www.methivac.com

Metallurgical Processing, Inc.
www.mpimetaltreating.com

Methods Machine Tools Inc.
www.methodsmachine.com

Miller Broach
www.millerbroach.com

Mitsubishi Heavy Industries America
MACHINE TOOL DIVISION
46992 LIBERTY DRIVE
WIXOM, MI 48393
Phone: (248) 669-6136
Fax: (248) 669-0614
brenda_motzell@mhiahq.com
www.mitsubishigearcenter.com
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Modern Gearing
www.moderngearing.com

Moncktons Machine Tools, LLC
www.mmtproductivity.com/

Mutschler Edge Technologies
mutschleredgetech.com

NTC America Corporation
www.ntcmc.com

Nachi America Inc.
715 PUSHVILLE RD.
GREENWOOD, IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com
SEE OUR AD P12,39

Nagel Precision
www.nagelusa.com

National Heat Treat
nationalheattreat.com

Normac, Inc.
www.normac.com

Oelheld U.S., Inc.
1100 WESEMANN DRIVE
WEST DUNDEE, IL 60118
Phone: (847) 531-8501
Fax: (847) 531-8511
hutec-us@oelheld.com
www.oelheld-us.com
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Oerlikon Balzers USA
www.oerlikon.com/balzers/us

Ohio Broach & Machine Co.
www.ohiobroach.com

Okuma America Corporation
www.okuma.com

PTG Holroyd
www.holroyd.com

Penna Flame Industries
www.pennaflame.com

Penta Gear Metrology LLC
6161 WEBSTER STREET
DAYTON, OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com
SEE OUR AD P17

Philadelphia Carbide Co.
www.philacarbide.com

Phoenix Inc.
www.phoenix-inc.com

Pinpoint Laser Systems
pinpointlaser.com

Pioneer Broach Co.
www.pioneerbroach.com

Pittler T&S GmbH
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63128
GERMANY
Phone: +49-6074-4873-0
Fax: +49-6074-4873-291
christian.rhiel@pittler.de
www.pittler.de
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PlasmaRoute CNC
www.cncplasmacutterinc.com

Praewema Antriebstechnik GmbH
www.praewema.de

Precision Finishing Inc.
www.precisionfinishinginc.com

Precision Spindle & Accessories Inc.
www.precisionspindleinc.com

Preco Inc.
www.precoinc.com

Pro-Beam USA
www.pro-beam.com

Promess Inc.
www.promessinc.com

QC American
www.qcamerican.com

Röders GmbH
www.roeders.de

R.A. Heller
www.raheller.com

RAM Optical Instrumentation, Inc.
www.ramoptical.com

Reade Advanced Materials
www.reade.com

Redin Production Machine
www.redinmachine.com

Renegade Parts Washers and Detergents
www.renegadepartswashers.com

Renishaw Inc.
www.renishaw.com

Rewitec GmbH
www.rewitec.com

Riten Industries, Inc.
www.riten.com

Roberts Sinto Corp.
www.robertssinto.com

Russell Holbrook & Henderson
www.tru-volute.com

SCHUNK
www.schunk.com

SETCO Precision Spindles
www.setcousa.com

SMS Elotherm North America
www.techinduction.com

SWD Inc.
www.swdinc.com

Samputensili S.p.A.
www.samputensili.com

Schutte LLC
www.schutteusa.com

SerWeMa GmbH & Co. KG
www.serwema.de

Slater Tools Inc.
www.slatertools.com

Slone Gear International, Inc.
www.slonegear.com

Star Cutter Co.
www.starcutter.com

Star SU LLC
5200 PRAIRIE STONE PARKWAY, SUITE 100
HOFFMAN ESTATES, IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com
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Stotz Gaging Co.
www.stotz-usa.com

Sunnen Products Company
www.sunnen.com

Super Hobs & Broaches Pvt. Ltd.
www.supercuttingtools.com

Surplex GmbH
www.surplex.com

TECO Werkzeugmaschinen GmbH & Co.
www.teco-germany.com

Titanium Coating Services Inc.
www.pvdamerica.com

Toolink Engineering
www.toolink-eng.com

Toolmex Corporation - Lathe group
www.toolmexlathes.com

Toshiba Machine Co.
www.toshiba-machine.com

Tribo Surface Engineering LLC
www.tribosurfaceengineering.com

Ty Miles, Inc.
www.tymiles.com

U.S. Equipment
www.usequipment.com

Ultramatic Equipment Co.
ultramatic-equipment.com

Ultrasonic LLC
www.ultrasonicllc.com

United Grinding
grinding.com

Usach Technologies Inc.
www.usach.com

VaporKote, Inc.
www.vaporkote.com

Venture Mfg. Co.
www.venturemfgco.com

View Micro-Metrology
www.viewmm.com

Voelker Sensors, Inc.
www.vsi-oil.com

WFL Millturn Technologies, Inc
www.wfl-usa.com

WMZ - Werkzeugmaschinenbau Ziegenhain GmbH
www.wmz-gmbh.de

WardJet
www.wardjet.com

Watkins Mfg. Inc.
www.saw-lutions.com

Weldon Solutions
www.weldonsolutions.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Westfalia Technologies
www.westfaliausa.com

Westminster Machine Tools Ltd.
www.wmtg.co.uk

Wheelabrator
www.wheelabratorgroup.com

Wolverine Broach Co., Inc.
www.wolverinebroach.com

Yaskawa Motoman
www.motoman.com

RESOURCES

All of the suppliers listed here are broken down by category (associations, education, publications, research institutes, etc.) at *www.geartechnology.com*.

AGMA - American Gear Manufacturers Association
www.agma.org

AMT - The Association for Manufacturing Technology
www.amtonline.org

ASM International
www.asminternational.org

American Bearing Manufacturers Association
www.americanbearings.org

American Wind Energy Association
www.awea.org

Balanstar Corp
www.balanstar.com

Banyan Global Technologies LLC
www.banyangt.com

Buderus Schleiftechnik GmbH
www.buderus-schleiftechnik.de

CTI - Car Training Institute
www.car-training-institute.com

DVS Tooling GmbH
www.dvs-tooling.de

Drive Systems Technology, Inc.
www.gear-doc.com

EES KISSsoft GmbH
www.ees-kisssoft.ch

FVA GmbH
www.fva-service.de

FZG
www.fzg.mw.tum.de

Forging Industry Association
www.forging.org

Gear Consulting Group
www.gearconsultinggroup.com

Gear Research Institute
APPLIED RESEARCH LABORATORY
PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PA 16802
Phone: (814) 865-5832
aci101@arl.psu.edu
www.gearresearch.org
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Gehring L.P.
www.gehring.de

Gleason Corporation
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com
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Gleason Cutting Tools Corporation
1351 WINDSOR RD.
LOVES PARK, IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com
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Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
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Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Guardair Corporation
www.guardair.com

Hannover Fairs USA
www.hfusa.com

The Herring Group Inc.
www.heat-treat-doctor.com

KISSsoft AG
ROSENGARTENSTRASSE 4
BUBIKON 8608
SWITZERLAND
Phone: 0041 (0)55 254 20 70
Fax: 0041 (0)55 254 20 71
info@KISSsoft.ag
www.KISSsoft.ag
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Kapp Technologies
2870 WILDERNESS PLACE
BOULDER, CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com
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Koepfer America
koepferamerica.com

Lafert North America
www.lafertna.com

Liebherr America
1465 WOODLAND DR.
SALINE, MI 48176
Phone: (734) 429-7225
Fax: (734) 429-2294
info.lgt@liebherr.com
www.liebherr.com
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Lubrication Engineers
www.lelubricants.com

Metal Powder Industries Federation (MPIF)
www.mpif.org

Noria Corporation
www.noria.com

Pittler T&S GmbH
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63128
GERMANY
Phone: +49-6074-4873-0
Fax: +49-6074-4873-291
christian.rhiel@pittler.de
www.pittler.de
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Praewema Antriebstechnik GmbH
www.praewema.de

Randall Publications LLC
www.geartechnology.com

Robert E. Smith, Consultant
gearman@rochester.rr.com

Suresh Mehta Associates
www.sureshmehta.com

Thors, LLC
www.thors.com

VDI
www.vdi.de

Virgo Communications & Exhibitions Pvt Ltd.
www.virgo-comm.com

West Michigan Spline, Inc.
www.westmichiganspline.com

SERVICES

All of the suppliers listed here are broken down by category (consulting, hob sharpening, gear engineering, tool coating, machine tool repair, etc.) at *www.geartechnology.com.*

A&A Coatings
www.thermalspray.com

ATS - Advanced Technology Services
www.advancedtech.com

Acedes Gear Tools
www.acedes.co.uk

Advanced Heat Treat Corp.
www.ahtweb.com

Airflow Sciences Corporation
www.airflowsciences.com/

Aksan Steel Forging
www.aksanforging.com

American Broach & Machine Co.
www.americanbroach.com

Ampere Metal Finishing
www.amperemetal.com

Andec Mfg. Ltd.
www.andec.ca

Anthony Best Dynamics Ltd
www.abd.uk.com

Apex Broaching Systems
www.apexbroach.com

BG&S Peening and Consulting LLC
www.peening-consultants.com

BTS Broaching Tools
www.brostakimsanayi.com.tr

Balanstar Corp
www.balanstar.com

Banyan Global Technologies LLC
www.banyangt.com

Barber-Colman, Div of Bourn & Koch
www.bourn-koch.com

Bates Technologies, LLC
www.batestech.com

Becker GearMeisters, Inc.
www.maagmachines.com

Best Technology Inc.
www.besttechnologyinc.com

Beyta Gear Service
0N230 COUNTY FARM ROAD
WINFIELD, IL 60190
Phone: (630) 209-1652
chuck@beytagear.com
www.beytagear.com
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Bill's Machine Repair
www.billsmachinerepair.com

Borescopes-R-Us
www.borescopesrus.com

Bourn & Koch Inc.
2500 KISHWAUKEE STREET
ROCKFORD, IL 61104
Phone: (815) 965-4013
Fax: (815) 965-0019
sales@bourn-koch.com
www.bourn-koch.com
SEE OUR AD P3

Broach Masters/Universal Gear Co.
1605 INDUSTRIAL DRIVE
AUBURN, CA 95603
Phone: (800) 563-3442
Fax: (530) 885-8157
sales@broachmasters.com
www.broachmasters.com
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Broaching Technologies, LLC
keyway-spline-broaching.com

Bruce Cox Engineering Corporation
www.bcoxengineering.com/

Buehler - An ITW Company
www.buehler.com

C & B Machinery
www.cbmachinery.com

CNC Center
www.cnccenter.com

CNC Design Pty Ltd
www.cncdesign.com

Canada Broach
www.canadabroach.com

Capital Tool Industries
www.capital-tool.com

Carbide Tool Services, Inc.
www.carbidetool.com/

Carl Zeiss Industrial Metrology LLC
www.zeiss.com/metrology

Cincinnati Gearing Systems Inc.
www.cincinnatigearingsystems.com

Curtiss-Wright Surface Technologies
www.cwst.com

Daubert Cromwell
www.daubertcromwell.com

Delta Inspection
www.deltainspect.com

Diametal AG
www.diametal.ch

Diehl Engineering Company, Inc. PS
www.diehlengineering.com

Dixitech CNC
www.dixitechcnc.com

Drive Systems Technology, Inc.
www.gear-doc.com

EES KISSsoft GmbH
www.ees-kisssoft.ch

EMAG L.L.C.
www.emag.com

Eagle Tool Company Inc.
www.eaglebroach.com

Eaglemaster Inc.
www.eaglemasterinc.com/

East-Lind Heat Treat, Inc.
www.eastlind.com

ElectroHeat Induction
www.electroheatinduction.com

Electronics Inc.
www.electronics-inc.com

Ellwood City Forge
www.ellwoodcityforge.com

Eltro Services, Inc.
www.eltroservices.com

Engineered Abrasives
www.engineeredabrasives.com

Estudio Piña
www.estudiopina.com

Excel Gear
11865 MAIN STREET
ROSCOE, IL 61073
Phone: (815) 623-3414
Fax: (815) 623-3314
Chinn@excelgear.com
www.excelgear.com
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FPM Heat Treating
www.fpmht.com

FVA GmbH
www.fva-service.de

Forst Technologie GmbH & Co. KG
www.forst-online.de

Framo Morat, Inc.
www.framo-morat.com

Frenco GmbH
www.frenco.de

Friedrich Gloor Ltd.
www.gloorag.ch

Furnaces, Ovens & Baths, Inc.
www.fobinc.com

GMN USA LLC
www.gmnusa.com

GWJ Technology GmbH
www.gwj.de

Gear Consulting Group
www.gearconsultinggroup.com

Gear Consulting Services of Cincinnati LLC
octave@fuse.net

Gehring L.P.
www.gehring.de

General Magnaplate
www.magnaplate.com

Gleason Corporation
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER, NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com
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Gleason Cutting Tools Corporation
1351 WINDSOR RD.
LOVES PARK, IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com
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Gleason Metrology Systems
300 PROGRESS ROAD
DAYTON, OH 45449
Phone: (937) 859-8273
Fax: (937) 859-4452
gleason-metrology@gleason.com
www.gleason.com
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Gleason Works (India) Private Ltd.
PLOT NO. 37
DODDENAKUNDI INDUSTRIAL AREA
WHITEFIELD RD., MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com
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Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
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GoHz Inc.
www.gohz.com

Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greg Allen Company
www.gallenco.com

Grindal Company
www.grindal.com

Hansford Sensors
www.hansfordsensors.com/us/

The Herring Group Inc.
www.heat-treat-doctor.com

HobSource Inc.
www.hobsource.com

Hydrotex
www.hydrotexlube.com

IHI Hauzer Techno Coating B.V.
www.hauzer.nl

IHI Ionbond Inc.
ionbond.com

IMPCO Microfinishng
www.impco.com

Index Technologies Inc.
5755 CANAL ROAD
VALLEY VIEW, OH 44125
Phone: 216 642 5900
Fax: 216 642 8837
galllen@gallenco.com
www.gallenco.com
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Industrial Hard Carbon LLC
industrialhardcarbon.com

Industrial Metal Finishing, Inc.
www.indmetfin.com

Innovative Analytical Solutions
www.steelanalyzer.com

Involute Gear & Machine Company
www.involutegearmachine.com

Ion Vacuum (IVAC) Technologies Corp.
www.ivactech.com

Jesse Garant Metrology Center
jgarantmc.com

K+S Services, Inc.
www.k-and-s.com

Kapp Technologies
2870 WILDERNESS PLACE
BOULDER, CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com
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Kinematics Manufacturing, Inc.
www.kinematicsmfg.com

Kingsford Broach & Tool Inc.
www.kingsfordbroach.com

Klingelnberg America Inc.
118 E. MICHIGAN AVENUE, SUITE 200
SALINE, MI 48176
Phone: (734) 470-6278
Fax: (734) 316-2158
kla.info@klingelnberg.com
www.klingelnberg.com
SEE OUR AD BACK COVER

Koepfer America
koepferamerica.com

Koro Sharpening Service
www.koroind.com

Lafert North America
www.lafertna.com

Lalson Tools Corporation
www.lalsoncuttingtools.com

Laser Tools Co.
www.lasertoolsco.com

Liebherr-Verzahntechnik GmbH
KAUFBEURER STRASSE 141
D-87437 KEMPTEN
GERMANY
Phone: +(49) 831-786-0
Fax: +(49) 831-7861279
info.lvt@liebherr.com
www.liebherr.com
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Longevity Coatings
www.longevitycoatings.com

Luren Precision
www.luren.com.tw/en/index.html

MATsolutions
www.matsolutions.com

MESYS AG
www.mesys.ag

MRO Electric and Supply
www.mroelectric.com/

MTI Systems, Inc.
www.mtisystems.com

Machine Tool Builders
7723 BURDEN ROAD
MACHESNEY PARK, IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
aminer@machinetoolbuilders.com
www.machinetoolbuilders.com
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Machine Tool Solutions, Inc.
machtoolinc.com

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ultramatic-equipment.com

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www.united-tool.com

United Tool Supply Ltd.
www.unitedtoolsupply.com

VFA Engineering Group
failure-analysis-durability.com

VaporKote, Inc.
www.vaporkote.com

Victrex Gear Solutions
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www.dontynesystems.com

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www.reskasplinegauge.com

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The Influence of a Grinding Notch on the Gear Bending Strength Rating

Ulrich Kissling and Ioannis Zotos

Symbols used in this paper:

Symbol	Description	Unit
	Symbols for the grinding notch	
Y_{Sg}	Stress correction factor for gears with grinding notch (ISO 6336)	
Y_S	Stress correction factor for gears without grinding notch (ISO 6336)	
t_g	Grinding notch depth	mm
ρ_g	Grinding notch radius	mm
h_{grind}*	Height of grinding tool	(in module)
ρ_{grind}*	Tip radius of grinding tool	(in module)
q	Grinding allowance q	mm
σ_{F0}	Nominal tooth root stress (without load factors K_A, K_V etc.)	
	Symbols for gear geometry	
z, b, m_n, …	All symbols according ISO21771 (Ref. 13)	

Introduction

To achieve the requested quality, most gears today are ground. The usual grinding process includes treating the gear flank but disengaging before reaching the root rounding area. If the gear is pre-manufactured with a tool without protuberance, then at the position where the grinding tool retracts from the flank a grinding notch in the tooth root area is produced. Such a notch may increase the bending stresses in the root area, thus reducing the strength rating.

The AGMA 2001 standard does not address this topic, but in ISO 6336-3, a rule to consider the stress increase due to a grinding notch is documented. The formulas presented are based on research done by Wirth in the 1970s. A recent discussion in the ISO Workgroup responsible for the development of this standard showed that a review of the formulas is necessary as it is presently, the method can be interpreted in two ways.

Modern FEM (finite element method) tools are well-adapted to calculate the stress in the root area, so it is possible to perform an FEM-based parametric study to compare the grinding notch effect as calculated by FEM with the formulas of the standard. Additionally, in Wirth's work some factors are given that are currently not considered in the standard; this is an additional topic of this investigation.

To make such a study possible, an option for an external FEM software was introduced in a calculation software for strength analysis (ISO 6336). The necessary data, such as the exact tooth form and the load at the highest point of single tooth contact, is transferred to the pre-processor, which automatically generates the mesh and calls the solver and the post-processor. The main results are the stress at the 30° (60° for internal gears) tangent point and the maximum stress found in the overall root area. The maximum stress is typically located at the position of the grinding notch.

For helical gears, according to the procedure given in ISO 6336-3, the tooth form of the equivalent spur gear is generated and used for the analysis. An additional topic of interest is the following: if a 3-D FEM analysis is useful for helical gears, how well will the results of the FEM correspond to the equivalent spur gear model used by ISO 6336? This is currently under investigation and will be published later.

In the parameter study for different gear geometries, the grinding allowance, the tip radius of the grinding wheel, the grinding process (generating and form grinding), and the grinding depth were varied. The results provide a good overview of the accuracy of the outcome of the two interpretation variants of the ISO method for the influence of the grinding notch — compared to FEM results. Based on the study, the best variant can be demonstrated. The formula used to obtain the grinding notch depth used in the ISO method is deduced and will be presented. The position of the notch on the tooth has an important influence, which can now be much better considered.

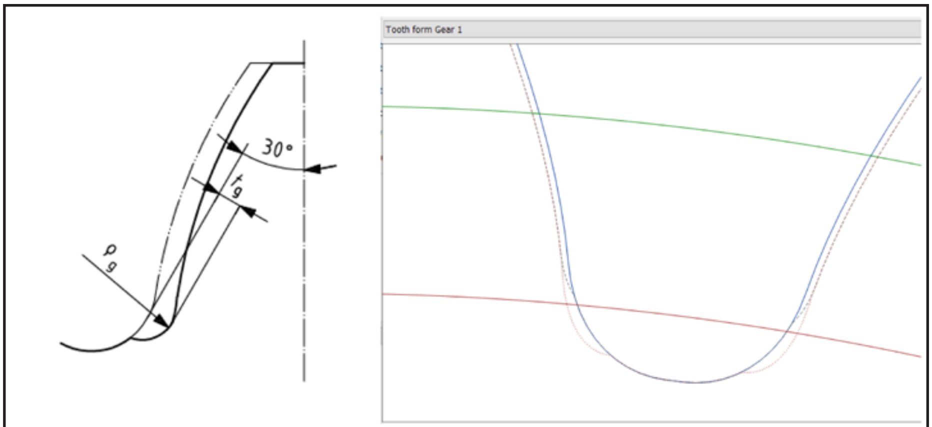
To get a high-torque capacity for today's gears in car transmissions, industrial gearboxes, or wind turbines, case-carburized steel materials are used. Such gears are pre-manufactured, then case-carburized and surface- hardened. The hardening process generates relatively large distortions of the gears due to the high temperatures during treatment. A gear having quality 7 (AGMA 2015) (Ref. 2) before treatment will typically rise to quality 9 afterwards. To realize a good contact pattern (for high-torque capacity) and low noise behavior, such gears must be reshaped by grinding (or a similar process).

Research on the Grinding Notch Effect

The effect of a grinding notch on the tooth bending load capacity was researched by Wirth (Ref. 1) at the FZG in Munich in the 1970s. Wirth made many measurements on gears with and without grinding notches and deduced S/N-curves. He tested gears with module 3 mm on a test bench, and other gears with module 8 mm were measured on a pulsator. Wirth deduced the stress in the tooth root with the photo-elastic method. Today, the preferred tool to analyze tooth root stress theoretically would be the FE method. But in the 1970s this method was not yet fully accepted, so Wirth used the photo-elastic method to investigate the stress. While the method can be used to indicate the position of the highest stress, the results obtained with this method are limited.

Wirth's test gears were ground on Maag grinding machines; the Maag dry grinding process was popular at that time but is clearly outdated today. The pre-manufacturing tools used are well-defined, but the shape obtained by the grinding process was documented by contrast pictures only, so the shape, position, and radius of the grinding notch on the different test gears can only be roughly estimated. A profile measurement documentation from an involute measuring machine is not available.

We tried to recalculate Wirth's test gears, but, as the exact tooth form after the grinding process is not defined as precisely as needed, this is unfortunately not possible. Therefore, it is not possible today to recalculate the test gears with an FEM analysis. So, Wirth's impressive research work is of little use today if we try to reproduce his findings with modern calculation methods.



Grinding notch parameters as displayed in ISO 6336-3 [4]

Blue: Premanufactured tooth form. Green dashed: Grinding the active flank area. Red dotted: Grinding to the center of the root rounding. Green circle: Reference diameter. Dark red circle: Base diameter.

Figure 1 A (left): grinding notch parameters; B (right): different positions of the grinding notch.

Consideration of the Grinding Notch Effect in ISO 6336-3

In the German DIN 3990-3 (Ref. 3) standard, a rule is included for the consideration of the stress increase due to a grinding notch; the same rule was later included in ISO 6336-3 (Ref. 4). Per the references, the method is based on a work performed by Puchner/Kamenski (Ref. 5), published some years earlier then Wirth's work. Puchner investigated the effect of a notch situated in the center of a bigger notch in general — not on gears. So basically, his results can be applied to the grinding notch case only if the normal to the 30° tangent point in the root rounding and normal to the 30° tangent point of the grinding notch coincide. Wirth (Ref. 1, pp, 6–7) documents the formulas as used 1975 in a working document for the ISO 6336-3 standard. But the formulas that were published in the first official ISO 6336 edition in 1996 are quite different from the equations as documented by Wirth. As a result, some changes were made later, based on the findings of Wirth and others.

The description of the grinding notch effect in ISO 6336-3 is not easily understood, unfortunately, and can be interpreted in various ways. With a grinding notch the stress concentration factor must be substituted by Y_{Sg}, according to Equation 1. The sketch (Fig. 1a) in ISO 6336-3 (Ref. 4) shows the two important parameters used in the grinding notch formula: 1) the maximum depth of grinding notch (t_g); and 2) the radius of grinding notch (ρ_g). The depth t_g is indicated as the distance between the 30° tangent at the pre-manufactured tooth form and the 30° tangent at the grinding notch.

$$Y_{Sg} = \frac{1.3 Y_S}{1.3 - 0.6\sqrt{\frac{t_g}{\rho_g}}} \quad (1)$$

There is no indication on how to calculate t_g and ρ_g in the standard. For a generating grinding process, the radius ρ_g can be calculated, as described in chapter 6 of ISO 6336-3, just using the tooth reference profile deduced from the grinding tool (using $h_{fP} = h_{aP0}$: tip height of the grinding tool; $\rho_{fP} = \rho_{aP0}$: tip radius of the grinding tool). The position of the point where the 30° tangent contacts the tooth (at the critical section) can be deduced with the tooth root chord s_{Fn}, the bending moment arm h_{Fe}, and the load direction angle α_{Fen}. These points must first be calculated for the pre-manufactured tooth and the grinding notch, then the distance between the 30° tangents through these points is the grinding notch depth t_g.

In a recent meeting of the ISO workgroup TC60/WG6, the calculation of the grinding notch effect was discussed. It became evident that two different interpretations were possible. Experts (Interpretation I) from the German gear industry claimed that t_g and ρ_g must be taken from the printout of the profile measuring machine. In that case, t_g will always approximately correspond to the grinding allowance, and the radius ρ_g, measured on the profile diagram, will be inaccurate because it is slightly changed due to the transformation in the profile measuring machine. The position of the grinding notch, whether higher up on the tooth or not, will then not be considered.

Other experts (Interpretation II) claim that the pre-manufactured tooth and the grinding notch form should be calculated, using t_g as the distance between the tangents described above. The well-known software *STplus* (Ref. 6), developed by FZG in Munich, and the software *KISSsoft* (Ref. 7) are using this method. The approach considers the position of the grinding notch, i.e. — the bigger the distance between notch (higher up) and gear root area, the smaller is t_g; therefore, the smaller the grinding notch factor becomes.

Both interpretations will yield the same result if the grinding notch is very deep in the root area, in the center of the root rounding (Fig. 1b, dotted line). But standard practice in grinding is to NOT do that; normally, only the active range of the tooth flank is ground. The grinder will emerge out of the flank shortly after the active root diameter (d_{Nf}) is reached (Fig. 1b, dashed line). Figure 1b (dashed line) shows a normal case of a gear having a tip clearance of $0.25{*}m_n$ to the meshing gear. The position of the usual grind notch is at a distance from the root rounding area. It is evident that

Interpretation I is on the safe side, but probably for most practical cases it is *too* conservative.

It is evident that the history of the development of Equation 1 as the interpretation of t_g in Figure 1 is not so clear. We therefore decided to calculate some typical gearsets — using Interpretation I and Interpretation II — and to also compare the results with an FEM approach.

Root Stress Calculation by 2-D Finite Element Method

To minimize the risk of errors by handling a big number of gear calculations in a calculation software according to ISO 6336 and in parallel with an FEM software, we decided to integrate directly an FEM calculation into the *KISSsoft* (Ref. 7) software, i.e. — a gearset is calculated according to ISO 6336, after which the tooth form is generated and then transmitted to an external FEM program. The FEM program selected is *code aster*, which has a wide user base and can be controlled through scripts (Ref. 10). For the same reasons, the program *Salome* (Ref. 11) was selected for the pre-processing (geometry handling and FE mesh generation).

The accuracy in the generated tooth profile is of great importance for the accurate calculation of stresses in gears, since even the smallest inaccuracies can lead to virtual stress concentration areas — thus influencing the results. For that reason we were based on the advanced tooth form calculation capabilities of *KISSsoft* (Ref. 7). Figure 2 presents the difference in the generated tooth form when using polygon lines vs. cubic splines to export the tooth form.

In the case of polygon lines, the highlighted areas result in stress peaks that do not represent real stresses (Fig. 2, right); hence it was decided to proceed using cubic splines for the tooth form export.

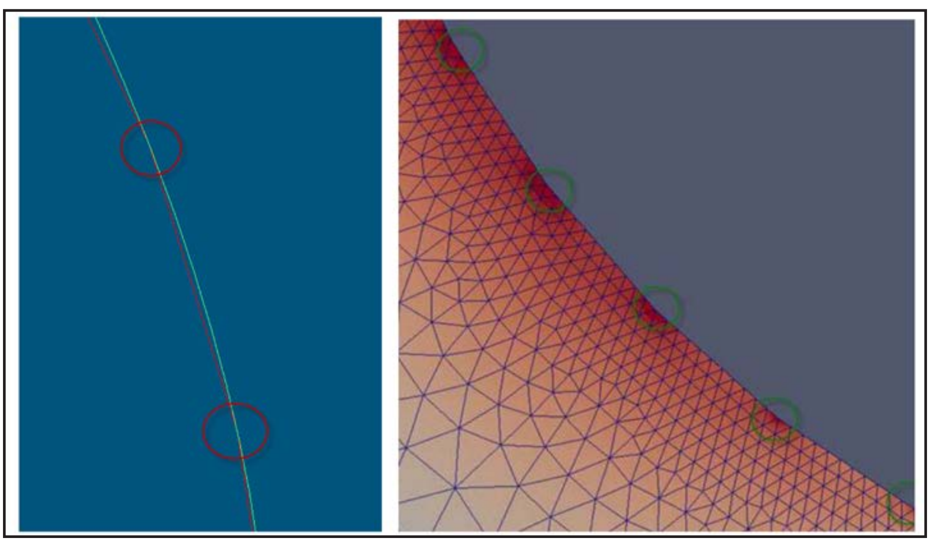


Figure 2 Polygon lines vs. cubic splines in tooth form export.

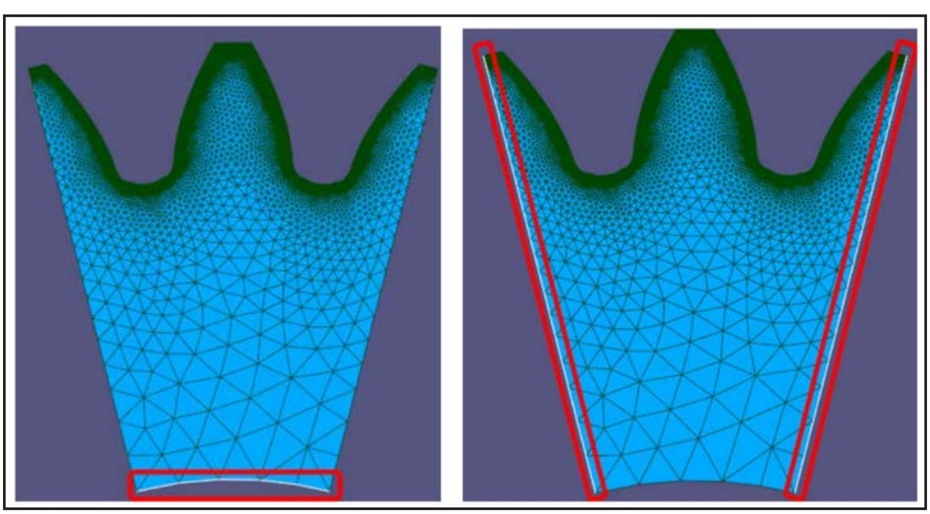


Figure 3 Two different options for clamping locations.

Regarding the analysis type used, it was decided to proceed in a first step with the 2-D plane stress assumption. That way, the computational time is shorter and more cases can be computed in a shorter time. Beyond that, 2-D plane stress is a common assumption for gear tooth stress analysis (Ref. 12); the smaller the gear face width, the closer to reality is this approximation.

For the FE mesh generation process, an automatic meshing procedure was selected based on the *NETGEN* algorithm. Since there was a need for the mesh generation to work flawlessly for many different cases, it was decided to prefer second-order triangular over quadrangle elements, since it is known that the latter option could result in highly distorted elements in case of abrupt geometry changes (as, for example, in the grinding notch area). The minimum and maximum element sizes were selected based on the normal module of the gear analyzed, whereas a mesh refinement was performed in the stress concentration areas. In order to reduce the size of the generated mesh, only a segment of three teeth of the complete gear is analyzed. That way we manage to reduce the calculation time without losing the information of the area surrounding the root of the loaded tooth. By choice of the user, the gear is clamped either in the inner diameter or at the sides of the segment analyzed (Fig. 3). Also, the mesh density can be selected by the user, i.e. — with 'very high density' about 24 nodes are generated in the root rounding area; the total number of elements is 4,000; other choices are 'high density' (17 nodes, 2,200 elements) and 'medium density' (10 nodes, 1,300 elements).

After the mesh generation is completed, specific nodes are moved to the exact location where results are to be extracted, such as at the 30° tangent point. Since in stress concentration areas (like the grinding notch), there is a high gradient in stresses and the exact location of the extracted result plays an important role (Fig. 4). The mesh refinement at the stress concentration, together with the selection of triangular elements and the performed mesh quality checks, guarantee that this node movement does not affect the accuracy of the resulting mesh.

Spur gears. Spur gears are ideal for a 2-D FEM analysis, because the load distribution over the face width is not a topic of this investigation. As in ISO 6336 (Ref. 4), the line load F_n/b ($F_n/b = F_t$ /cos $(\alpha_n)/b$) is applied at the outer point of single pair tooth contact (HPSTC). The load application angle α_{Fen} according to ISO is used. AGMA 908 (Ref. 8) allows, for spur gears, the choice between load application at tip or at HPSTC. For this investigation only the more accurate method with load application at HPSTC is used. The load angle ϕ_{nL} of AGMA is identical with α_{Fen} of ISO, so the applied load is also F_n/b.

Helical gears. For helical gears, both standards — ISO and AGMA — are converting the helical geometry into a virtual spur gear. The virtual gear is a spur gear having the same tooth form (tooth height and tooth thickness) as the helical tooth in the normal section. Then, to get the stresses, the same formulas are used as for native spur gears.

Therefore, for the FEM analysis we transform the gear geometry into the virtual spur gear (as given by the rules in ISO or AGMA). The tooth form of the virtual gear is then generated and transferred to the FEM procedure. The load, load position at HPSTC, and load angle in the FEM model are transferred, as described for the spur gears.

Calculating the bending stress in the root area, using the virtual spur gears for helical gears, is a certain simplification. That is why both the ISO and AGMA standards use an additional factor to compensate for the difference in stress obtained on the virtual spur gear and the effective stress in a helical gear. In ISO, the stress obtained on the virtual gear is multiplied with helix angle factor Y_β. In AGMA, the stress is multiplied by $1/(C_\psi {*} K_\psi)$ (C_ψ: helical overlap ratio, K_ψ: helix angle factor (Ref. 8)). Therefore, the stresses obtained by FEM in the documentation are multiplied with these factors to provide values that can be compared to the stresses, as given by ISO or AGMA.

It is clearly interesting to compare stresses obtained by the standard for helical gears with a 3-D/FEM analysis. That is why we decided to have an option in the software to generate data for a 3-D analysis, which is discussed further on.

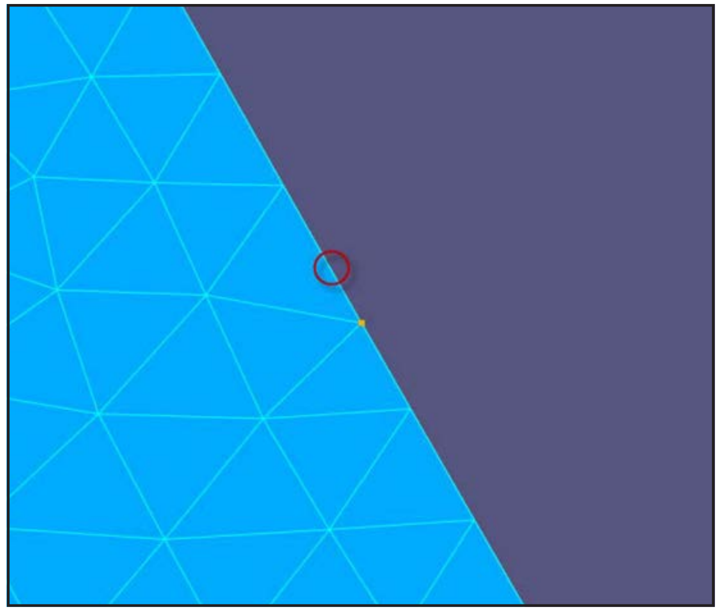


Figure 4 Initial and final location of moved node.

Table 1 Basic gearsets data

	Module	z_1	x_1	z_2	x_2	h_{aP}*	h_{fP}*	ρ_{fP}*	α_n	β
Set Ia	2 mm	12	0.3	varied	–0.3	1.0	1.25	0.38	20°	0°
Set Ib	2 mm	12	0.3	varied	0.0	1.0	1.25	0.38	20°	0°
Set Ic	2 mm	12	0.3	varied	+0.3	1.0	1.25	0.38	20°	0°
Set Id	2 mm	12	0.3	varied	–0.3	1.0	1.25	0.10	20°	0°
Set Ie	2 mm	12	0.3	varied	0.0	1.0	1.25	0.10	20°	0°
Set If	2 mm	12	0.3	varied	+0.3	1.0	1.25	0.10	20°	0°
	Module	z_1	x_1	z_2	x_2	h_{aP}*	h_{fP}*	ρ_{fP}*	α_n	β
Set 2a	6 mm	25	0.25	varied	0.0	1.0	1.25	0.38	20°	0°
Set 2b	6 mm	25	0.25	varied	0.0	1.0	1.25	0.10	20°	0°
Set 2c	6 mm	25	0.25	varied	0.0	1.0	1.25	0.10	25°	0°
Set 2d	6 mm	25	0.25	varied	0.0	1.0	1.25	0.10	20°	20°

Comparing Gear Stress According to ISO 6336 and AGMA 2101 with 2-D/FEM Results (on Gears without Grinding Notch)

The aim of this investigation is the evaluation of the grinding notch effect. Before performing this task we wanted to test the FEM method used with 'normal' tooth forms and compare the results with ISO 6336 and AGMA 2001. For a good test, we wanted to check a wide range of examples, but this is difficult as FEM calculations are time-consuming.

We therefore decided to integrate the entire calculation procedure in an *Excel* calculation in order to automatically calculate multiple variants and to control interesting inputs and outputs. This is possible using the *COM* interface of *KISSsoft* (Ref. 7). The *Excel* application permits us to load a gear pair example and then execute through dll-calls an ISO 6336, an AGMA 2001, and finally — a call of the tooth form calculator with appended FEM calculation.

Gear parameters can be changed automatically, step by step; the calculations can be performed and the results can be stored and displayed in an *Excel* graphic. We selected several basic gearsets (Table 1) and varied, with the *Excel* application, the tooth number of the gear (from 16 to 200 teeth) in six steps. Thus we obtained results from multiple gearsets and could verify the best possible FEM method.

In the graphics, the following results are displayed on the Y-axis:

- ***From FEM***: the maximum stress on the gear found in the root area, the stress at the 30° tangent point according ISO 6336, and the stress at the Lewis parabola point according AGMA908.
- ***From ISO 6336***: The nominal tooth root stress σ_{F0}.
- ***From AGMA 2001***: The nominal bending stress number σ_{F0} (equal to σ_F, if all K-factors are in unity)

On the X-axis, the tooth number of the gear is displayed.

The results displayed in Figure 5a–5f

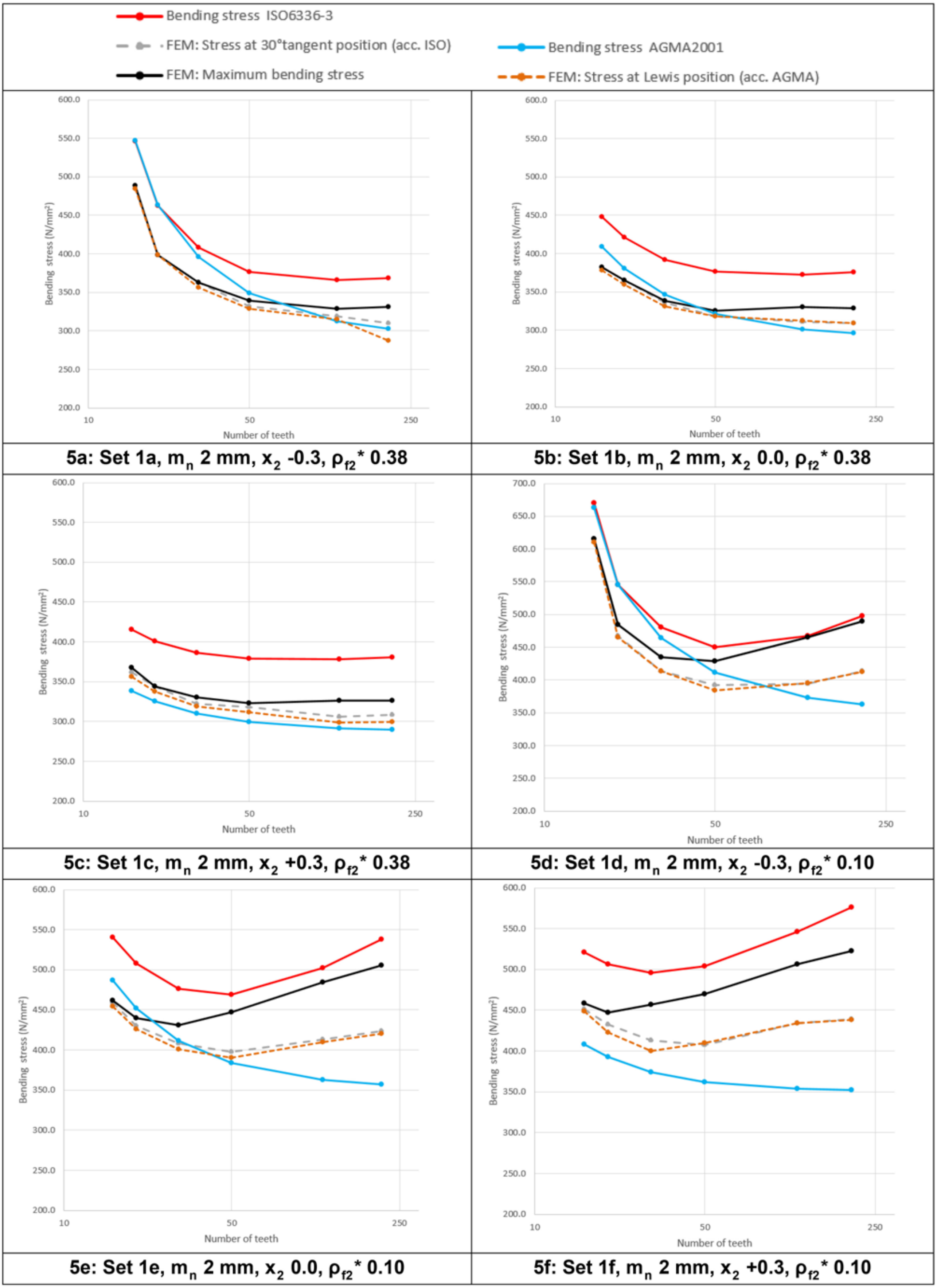


Figure 5 **Bending stress σ_{F0} results with module 2 mm gearsets.**

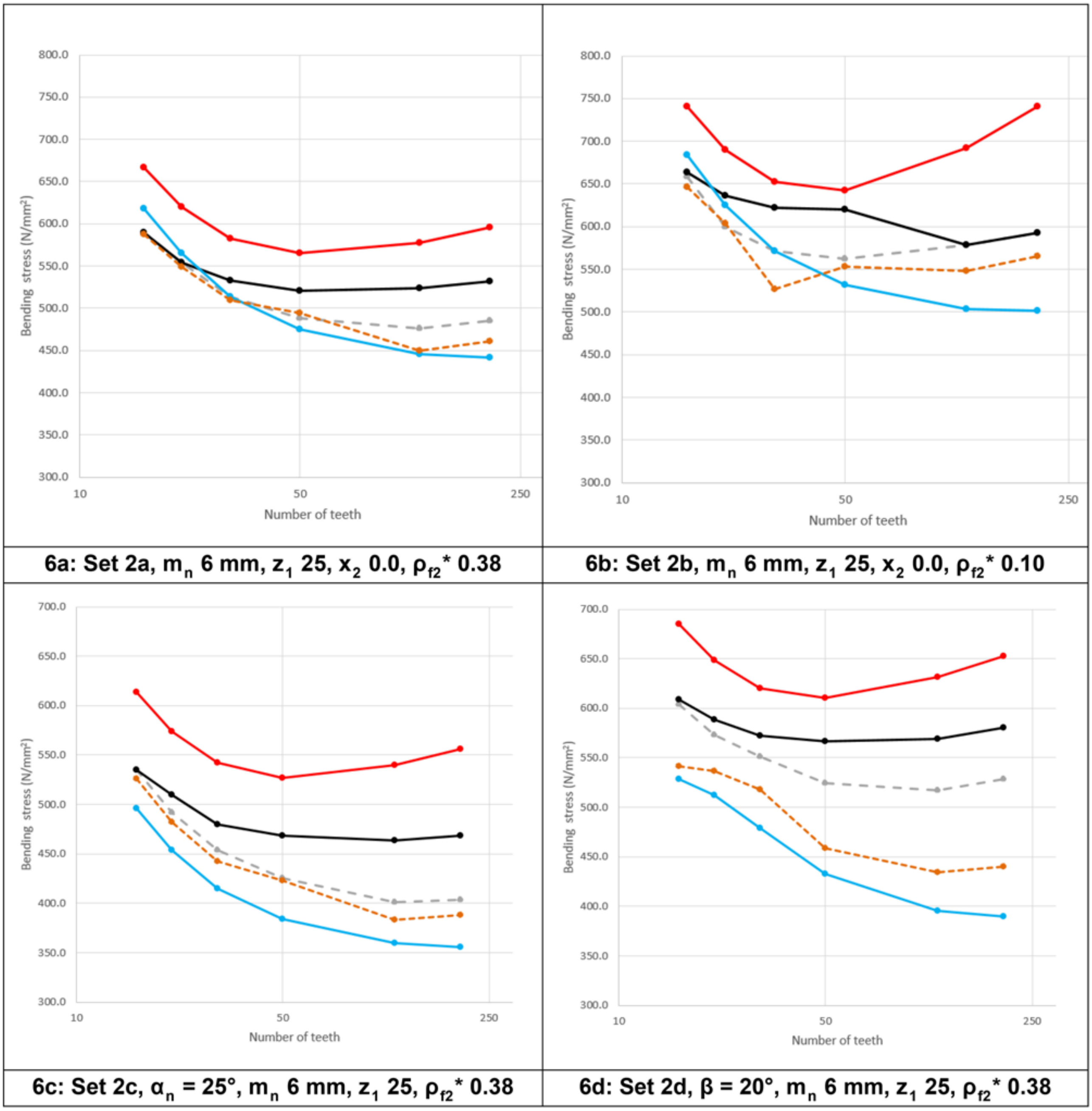


Figure 6 Bending stress results with module 6 mm gearsets.

and Figure 6a–6b are interesting. For example, the curve shapes over the gear tooth number for the maximum FEM stress and for the ISO stress are very similar. ISO stresses are always higher than the FEM results—between 5% to 15%, depending on the case. Therefore ISO values are on the safe side, which is reasonable for a simplified analytical method. In some cases the maximum FEM stress and the FEM stress found at the 30° tangent point are identical, which means that the highest stress found by FEM is located exactly at the 30° tangent point.

AGMA stresses compared to FEM results also show a relatively similar curve shape. But often, AGMA stresses are lower than the FEM results. We found AGMA stresses below FEM stresses specifically for:

- Higher profile shift, x
- Smaller root radius of the reference profile ρ_{FP}*
- Higher tooth number of the gear

AGMA results are probably too optimistic in these cases. And as the FEM stresses found at the Lewis parabola point (according AGMA) in most cases are a bit smaller than the stresses found at the 30° tangent point (according ISO), it seems that the 30° tangent is a better approach for the location of the section with highest stress. It must be noted that AGMA 908, with 'tip loading' instead of 'load at HPSTC,' gives much higher stresses; so 'tip loading' is on the safe side, but not 'load at HPSTC.'

It must be noted that we did not directly compare the FEM results with measured data on the tested gears because we know that ISO 6336-3 rules were tested with measurements (Ref. 12). So, we compared with analytical results obtained by ISO rules; this allowed us to

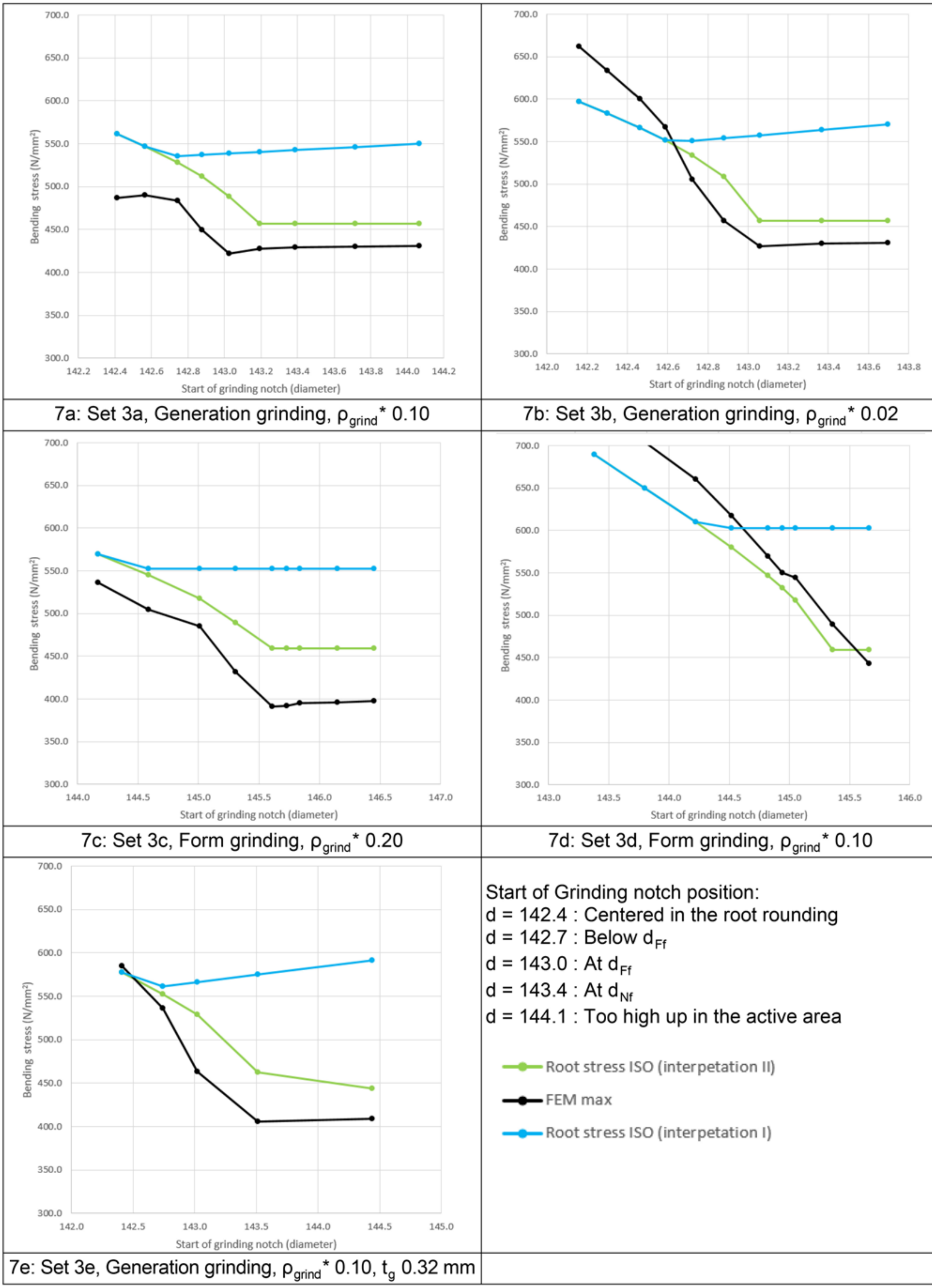


Figure 7 **Bending stress results with grinding notch position at different diameters.**

check a much higher number of examples. Overall, the tests confirmed that the FEM method is well-adapted to check and compare with stresses according ISO. Therefore, this method can be used for the grinding notch analysis.

Table 2 Basic gearsets data

	Module	z_1	x_1	z_2	x_2	h_{grind}*	P_{grind}*	Grinding	α_n	β	t_g
Set 3a	6 mm	25	0.25	76	–0.25	varied	0.10	generation	20°	0°	0.16 mm
Set 3b	6 mm	25	0.25	76	–0.25	varied	0.02	generation	20°	0°	0.16 mm
Set 3c	6 mm	25	0.50	76	–0.50	varied	0.20	form	20°	0°	0.16 mm
Set 3d	6 mm	25	0.50	76	–0.50	varied	0.10	form	20°	0°	0.16 mm
Set 3e	6 mm	25	0.25	76	–0.25	varied	0.10	generation	20°	0°	0.32 mm

Note: b = 44 mm, T_1 = 3600 Nm, Bending safety S_{F2} acc. ISO ca. 1.4
Grinding Allowance 0.16 mm; pre-manufacturing h_{aP}* = 1.32, ρ_{fP} = 0.38 (Ref. profile final tooth h_{fP}*=1.25)
FEM: Very high mesh density, clamped at the sides of the segment

Root Stress Calculation by 3-D Finite Element Method

It is very interesting to compare the results from the root stress calculation using a 3-D FEM approach with the results from the bending stresses calculation using the ISO and AGMA standards for helical gears.

But the grinding notch effect as explained in ISO 6336 is based on the equivalent spur gear, so 2-D FEM is best-fitted for this research. In this study the 3-D FEM results will not be used; they will be given in further publications.

Grinding Notch Effect Calculation by 2-D Finite Element Method

The application of the 2-D/FEM calculation, as previously discussed, provides good results and therefore will be used to investigate the grinding notch effect, as grinding notches, especially when form grinding is used, can be quite sharp. Therefore, all calculations were made with very high grid density.

To check the grinding notch effect, we calculated the same gearset (Table 2) with different grinding tool tip height (h_{grind}). So, the position of the grinding notch is varied, starting from a position near the root diameter (in the center of the root rounding), going higher up to the normally used positions (near the active root diameter), to a last point in the active flank range (which, in practice, should be avoided) (Fig. 8).

Generation grinding with two different grinding tip radii and form grinding with two different grinding tip radii is checked, including different grinding allowances (Table 2).

Different gearsets were analyzed, and an extract of the results is displayed (Fig. 7); the most important parameters to check are:

- The height of the grinding tool, h_{grind}
- The tip radius of the grinding tool, ρ_{grind}
- The grinding allowance, q

The radius of the grinding tool is producing the grinding notch radius ρ_g, which will be very different if generating grinding or form grinding is used. A grinding tool radius $\rho_{grind}=0$ will still produce a notch radius of (approximately) $\rho_g = 0.17 * m_n$ in a generating grinding process, but will produce a sharp edge when form grinding is used. The latter is bad practice and should be avoided. We checked generating grinding with tip radius on the tool $\rho_{grind}^* = 0.1$ and 0.02; form grinding with $\rho_{grind}^* = 0.2$ and 0.1.

The grinding allowance q used in most cases of the study is a standard value according DIN 3972 III, which is often applied in gear manufacturing. If the grinding is increased, then the notch radius ρ_g is unchanged, but the notch depth t_g is bigger, therefore increasing the notch effect. As displayed in Figure 7a and 7e, the stresses are higher in 7e with twice the grinding allowance q.

All the diagrams in Figure 7 show the maximum bending stress σ_{F0} in the root area, calculated with FEM and with the analytical method according ISO6336-3 for Interpretation I and Interpretation II, as discussed earlier. The FEM stresses in all gearsets are highest when the grinding notch is in the lowest position in the center of the root rounding (Fig. 8, right). The higher up the position of the notch,

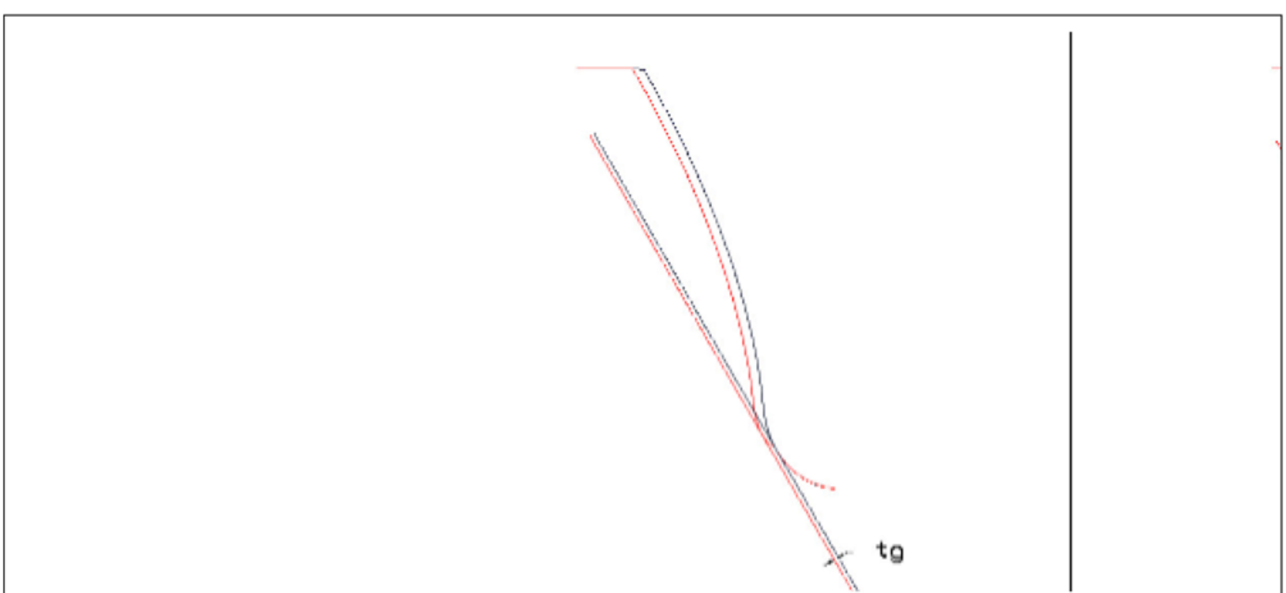


Figure 8 Grinding notch depth tg according to Interpretation II for a notch position in the d_{Nf} area (left) and for a notch position very low in the root rounding area (right).

the lower are the stresses. From a certain position on, the stresses are constant. Constant stress behavior indicates that the location of the maximum stress is no longer in the grinding notch — but in the root rounding area.

The analytical calculated stresses according ISO, using Interpretation I (constant t_g), demonstrate a very different behavior. The highest value is at the same position as the FEM stress, but with higher position of the notch, the stress first decreases a bit, but then remains constant and even starts to increase slightly (due to the fact that the grinding notch produced by generating grinding is decreasing with higher position of the tool).

The stresses according to ISO, using Interpretation II (t_g used, as indicated in Figure 8, left) is identical to the stress according to Interpretation I in the lowest notch position, but then it decreases significantly to become constant at a higher notch position — or very similar to the FEM results. We found similar behavior between FEM and Interpretation II in all gearsets we checked.

Also important to note is that, with few exceptions, the FEM stress is always lower than the Interpretation II stress, meaning that the ISO approach is on the safe side; the exceptions found are all cases where the notch is in a low position. As already mentioned, gears are normally not ground so deeply into the tooth rounding area.

The conclusion is that the use of Equation 1 for Y_{Sg} according to Interpretation II, yields realistic results; whereas, Interpretation I is greatly overestimating the notch effect when the notch is in a position just beyond the active flank area (the most-often-used procedure in manufacturing).

Conclusion

Depending on the pre-manufacturing process, often a so-called 'grinding notch' is created during grinding at the position where the grinding tool retracts from the flank. The maximum bending stress, which is normally in the tooth root rounding area, is increased due to a grinding notch. ISO 6336-3 disposes a method that considers the grinding notch effect. The application of this method is analyzed in this paper.

The investigation is made with an FEM tool, which is directly and automatically combined with a verification according to ISO 6336. Therefore, many different gearsets could be analyzed, comparing the maximum stress obtained in the FEM analysis with the stress calculated according ISO 6336. To validate the method, first a set of gears without a grinding notch were calculated; FEM, ISO 6336, and AGMA 2101 results are compared. The outcome is very satisfactory in that good agreement between FEM and ISO results was obtained. It is therefore evident that the method can also be used for the investigation of the grinding notch effect.

The grinding notch depth t_g used in the grinding notch formula in ISO 6336 can be interpreted in two ways. Interpretation I basically does not consider the position of the notch (in the tooth height direction), whereas Interpretation II considers the effective notch depth in dependency of the notch position. Many gearsets with different position of the grinding notch (generated by a different tip height of the grinding tool), different grinding tool tip radius, form and generating grinding processes, and different grinding allowance are analyzed. The FEM results confirmed that the stress increase through a grinding notch significantly depends on the notch position. The results according Interpretation II show good consistency with the FEM results. In contrast, Interpretation I results are overly conservative, partially showing even contradictory (unrealistic) stress values.

As the method to calculate the grinding notch depth t_g and the grinding notch radius ρ_g is not documented in ISO 6336-3, the formulas to obtain these values are explained.

Annex A: Formulas Used to Calculate the Grinding Notch Factor Y_{Sg}

In ISO 6336-3, only the equation for Y_{Sg} is documented, but there is no indication of how to get the notch depth t_g and radius ρ_g. For an outer gear, the notch geometry data can be obtained as follows: All symbols are according to the definitions in ISO 6336-3 (Ref. 4).

All data needed for the form factor Y_F (see previous Root Stress Calculation by 3-D Finite Element Method) (Ref. 4)) must be calculated twice — first for the pre-machining tool, and then for the grinding process.

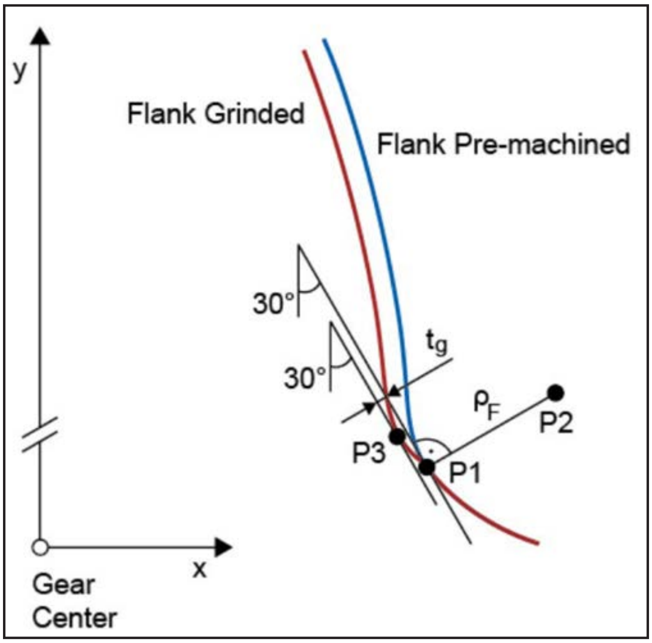


Figure 9 Grinding notch geometry points; P1: 30° tangent point of root rounding; P2: center of root rounding radius; P3: 30° tangent point of grinding notch.

Pre-machining tool data. A first calculation of Y_F with the basic rack profile data of the pre-machined gear — using the pre-machining manufacturing profile shift x_{Epre} — must be made to get s_{nF}, z_n, θ, G, ρ_{fPv}, ρ_F, according to ISO 6336-3.

Point P1 (x_1, y_1): $x_1 = S_{nF}/2$

$$y_{sFn}' = \frac{m_n}{2}\left[z_n \cos\left(\frac{\pi}{3}-\vartheta\right)+\left(\frac{G}{\cos\vartheta}-\frac{\rho_{fPv}}{m_n}\right)\right]$$

$$y_1 = y_{sFn}' + \frac{d}{2}\left(1-\frac{1}{(\cos\beta_b)^2}\right)$$

Point P2 (x_2, y_2): $x_2 = x_1 + \rho_F \cdot \cos\left(\frac{\pi}{3}\right)$

$$y_2 = y_2 + \rho_F \cdot \sin\left(\frac{\pi}{3}\right)$$

Grinding tool data (generation grinding). For a generating grinding process, a second calculation of Y_F with the basic rack profile corresponding to the grinding tool data (Fig. 10) — using the final manufacturing profile shift x_E, h_{grind} for h_{fP} and ρ_{grind} for ρ_{fP} — must be made to get s_n, F_g, ϑ_g, G_g, ρ_{fPvg}, ρ_{Fg}, according to ISO 6336-3.

Point P3 (x_3, y_3): $x_3 = S_{nFg}/2$

$$y_{sFng}' = \frac{m_n}{2}\left[z_n \cos\left(\frac{\pi}{3}-\vartheta_g\right)+\left(\frac{G_g}{\cos\vartheta_g}-\frac{\rho_{fPvg}}{m_n}\right)\right]$$

$$y_3 = y_{sFng}' + \frac{d}{2}\left(1-\frac{1}{(\cos\beta_b)^2}\right)$$

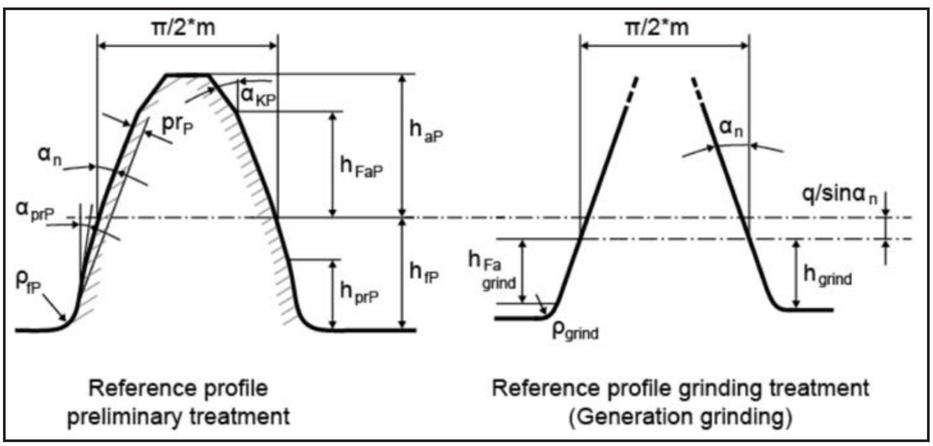


Figure 10 Definition of the gear reference profile for the grinding process.

Grinding notch data.

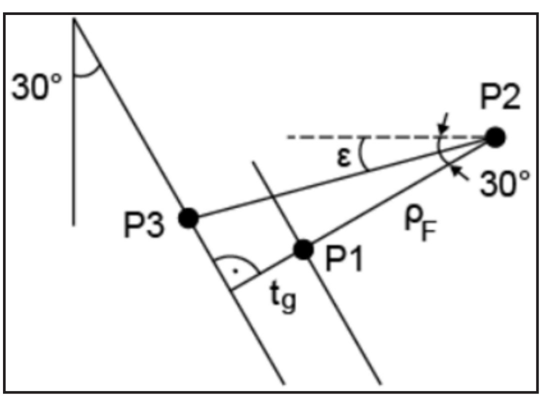


Figure 11 Grinding notch depth t_g.

With $\varepsilon = \arctan\left(\frac{y_2-y_3}{x_2-x_3}\right)$

we get angle $P1-P2-P3$ $\gamma = \frac{\pi}{6}-\varepsilon$

$$\overline{P_2P_3} = \sqrt{(x_2-x_3)^2+(y_2-y_3)^2}$$

Then the grinding notch geometry is obtained with:

$$t_g = \overline{P_2P_3}\cdot\cos(\gamma)-\rho_F \text{ and } \rho_g = \rho_{Fg}$$

In this paper, the formulas for outer gears using generating grinding are documented. The method to get the grinding geometry for form grinding is similar, but simpler, because the notch radius is equal to the grinding tool tip radius. For inner gears, both for generating and form grinding, a very similar approach can be used.

References

1. Wirth, X. "On the Impact of Grinding Notches in Surface Hardened Gears," Doctoral Thesis, 1977.
2. AGMA 2015-1-A01. *Accuracy Classification System — Tangential Measurements for Cylindrical Gears*, AGMA.
3. DIN 3990-3. *Load Capacity of Cylindrical Gears — Part 3*, 1987.
4. ISO 6336-3. *Calculation of Load Capacity of Spur and Helical Gears — Part 3: Calculation of Bending Strength*, 2007.
5. Puchner, 0. and A. Kamensky. "Stress Concentration and Notch Effect of Notches Included in a Bigger Notch Area," *Konstruktion* 24 (1972) 127-134.
6. *STplus* Cylindrical Gear Calculation software (developed by FZG Munich).
7. *KISSsoft* Calculation Programs, *www.KISSsoft.com*.
8. AGMA 908-B89. *Geometry Factors for Determining the Pitting Resistance and Bending Strength of*
9. *Spur, Helical and Herringbone Gear Teeth*, AGMA, 1989.
10. *www.code-aster.org*.
11. *www.salome-platform.org*.
12. Wright, A. "A Comparison of the Tooth-Root Stress and Contact Stress of an Involute Spur Gear Mesh as Calculated by FEM and AGMA Standards," Masters Thesis, Rensselaer Polytechnic Institute, June 2013.
13. Hirt, M. "Influence of the Gear Tooth Smoothing on the Stress and Resistance of Spur Gears," Doctoral
14. Thesis, TU München, 1974.
15. ISO 21771. *Gears — Cylindrical Involute Gears and Gear Pairs — Concept and Geometry*, 2007.

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PentacMono-RT: High-Performance Face Milling Cutter Heads

Dr. Hermann J. Stadtfeld

Past and Present Cutter Systems

Bevel and hypoid gears can be cut in a single indexing process (face milling) or in a continuous indexing process (face hobbing); both use cutter heads with a certain number of slot groups (equal blade groups) (Fig. 1). Each blade group consists of one to three blades assembled in the respective cutter head slots. In the case of three-blades-per-blade group, a rougher or bottom blade in each blade group roughs the convex and concave flank surfaces, as well as the root fillets and bottoms of a bevel gear. The second blade of each blade group is commonly an outside blade that finish-cuts the concave flank surfaces and the concave side root fillets. The third blade in each blade group is commonly an inside blade that finish-cuts the convex flank surfaces and the convex side root fillets,

A more common arrangement is the cutter head in Figure 1 with two-slots-per-blade group. The first blade of each blade group is an outside blade. The outside blades are tasked with roughing and finishing the concave flanks and the concave side of the root fillets, including a part of the root bottom of all slots on a bevel gear. The second blade of each blade group is an inside blade. The inside blades rough and finish the convex flanks and the convex side of the root fillets, including a part of the root bottom of all slots on a bevel gear. Figure 2 shows the chip removal arrangement where the outside blade removes a chip on the concave flank with a sharp side of the blade; the dull side of the blade has no cutting contact. The following inside blade removes a chip on the convex flank with the sharp side of the blade; here also the dull side of the blade has no cutting contact.

Another possibility is a cutter head with a single-blade-per-blade group. In such an arrangement the single-blade-type (full profile blade) will perform the roughing and finishing of the concave flanks, the concave root fillets, the root bottoms, the convex root fillets and the

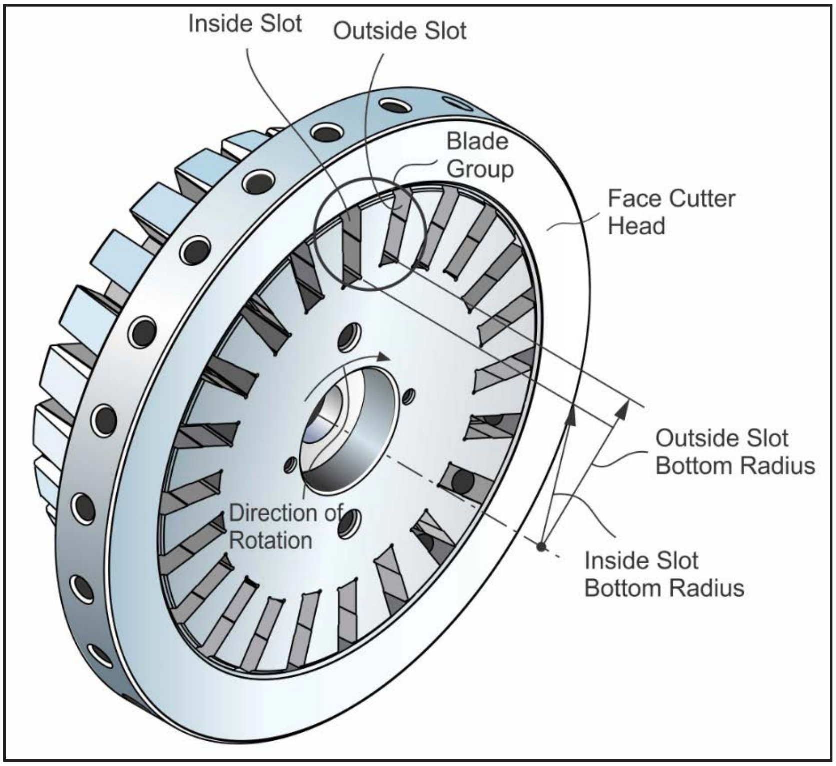

Figure 1 Face milling cutter head with rectangular blade slots (Ref. 1).

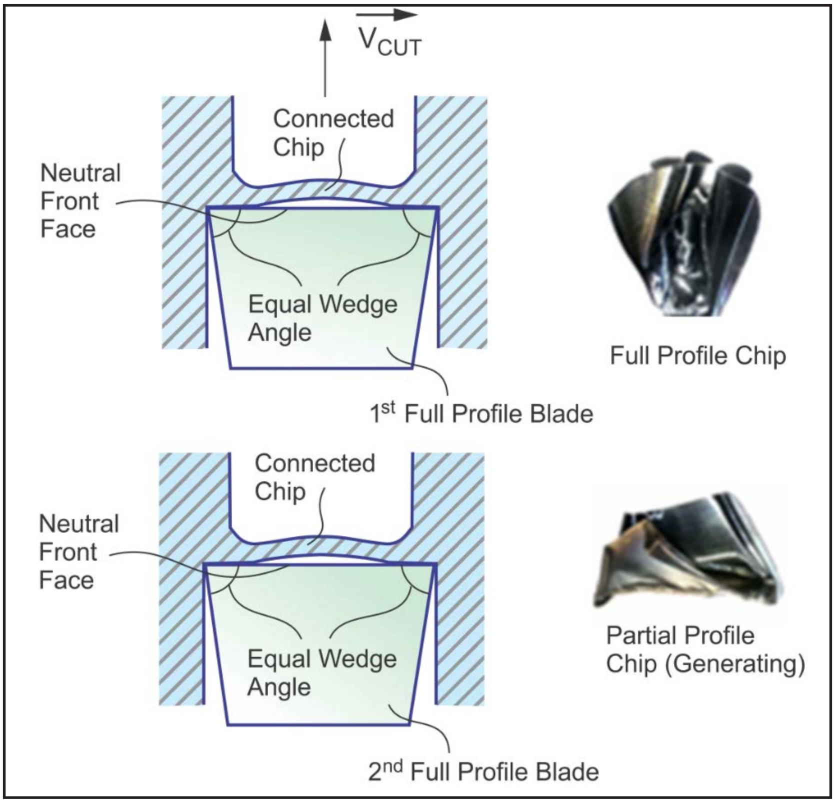

Figure 2 Outside blade and inside blade in cutting contact.

convex flanks of a bevel gear.

The single-blade-type cutter heads with full profile blades are only applied to face milled bevel gears that are cut in a completing process; this is because completing bevel gears show a parallel tooth slot width along the root bottom between toe and heel. The schematically shown cutting process in Figure 3, which only uses one blade type in order to manufacture both flanks of each gear slot, including the slot bottoms, has a number of disadvantages. The blade front face that connects both cutting edges (and in general is a plane surface) can only provide side rake angles of about zero degree for both cutting edges. With a side rake angle of zero degree (front face perpendicular to relative cutting velocity) the chip removal process must conduct more plasticization work in order to remove chips (rather than shearing the chips off with a sharp cutting edge that requires a positive side rake angle). Due to the cutting action around the entire blade profile, the chips from the two flanks are often a connected single chip (Fig. 3). Both zero side rake angle as well as connected chips lead to higher cutting forces and higher part temperature during the cutting and subsequently leads to lower part quality. Another disadvantage is that the connected outside-inside chips require a large space and are therefore not easily flowing away from the cutting area. Large, bulky chips are more likely to pack between consecutive blades, unlike smaller rolled chips like those produced with the outside-inside blade cutting system in Figure 2 that has a two-blades blade group.

The blade in Figure 4 used in the "single-blade-per-blade-group cutter head" comprises an outside cutting edge with an edge radius, an inside cutting edge with an inside edge radius, and a top width that spaces the two cutting edges in order to cut the correct slot width.

Obstacles Resulting from Full Profile Chip Formation

The bulky and large chips (Fig. 3) require a wide space between two preceding blades. In modern, high-productive cutter heads, the space between blades is limited, which causes chip flow problems. Particularly in front of the outside blades, chip flow is constrained because

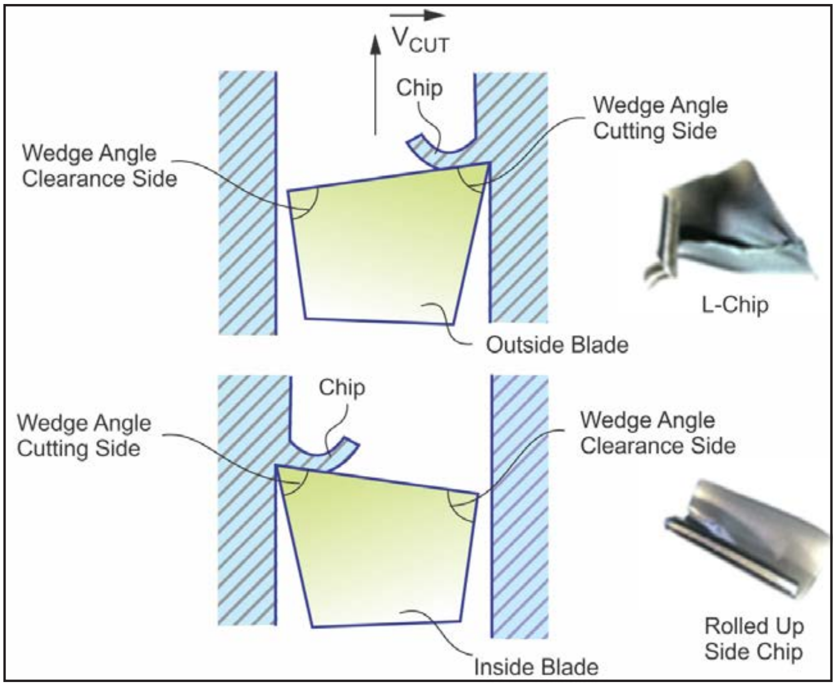

Figure 3 **Chip removal action with two consecutive full profile blades.**

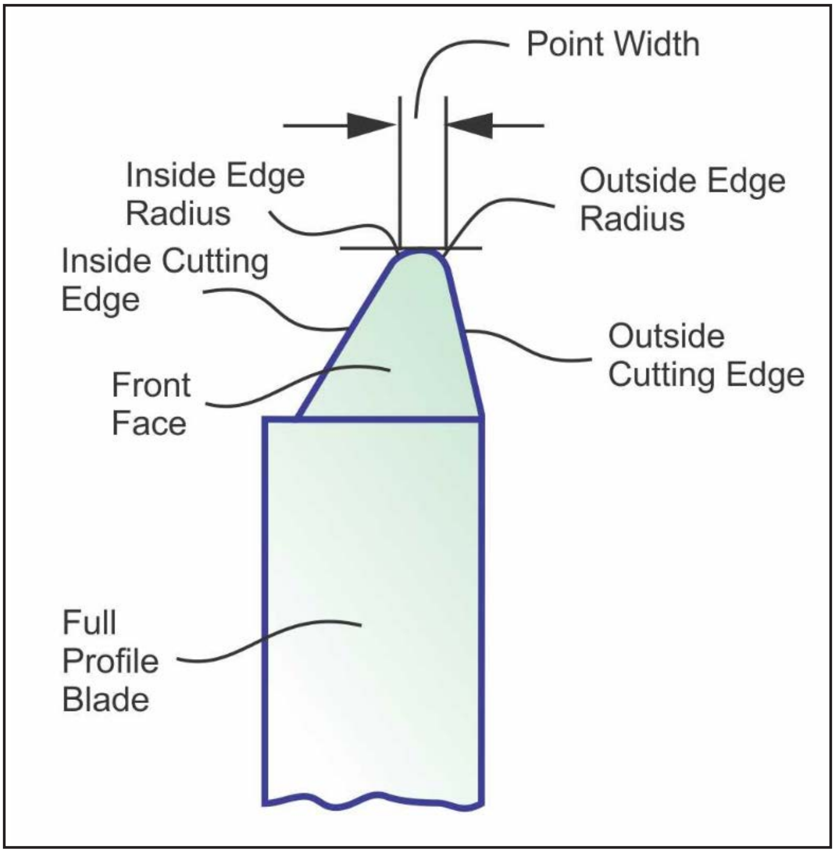

Figure 4 **Full profile stick blade with outside and inside cutting edge.**

the space is narrowing towards the outside of the cutter head. If the first chip is "caught" between two blades, then in the next revolution a new chip is developed in the same slot. Particularly when cutting Formate ring gears, the already-present chip and the newly cut chip cannot escape the gap between the blades because this gap is closed on both sides by the convex and the concave flank. Additional space is not available, which leads to a compression of both chips in order for both to fit in the given space. Each additional chip reduces the likelihood that the chips can leave the gap between the blades. Already the third and fourth chips can cause a situation like that shown in Figure 5.

Slight chip packing results in increased part temperature and reduced surface finish quality. If chip packing reaches the point shown in Figure 5, it will lead to a fatal end of the production because blades will break and the workholding—or even the machine—can be damaged.

Figure 5 Chip packing between two blades.

Reducing the feed or roll rates, or eliminating every other blade from the cutter head will, in most cases, solve the tool failure. However, it will in turn reduce productivity and therefore increase the cost-per-manufactured-part.

Part temperature in a high-speed, dry cutting process might be viewed as a problem, although certain compensations or corrections are available to reduce, for example, temperature growth-inflicted flank geometry deviations.

The process parameters in *PowerCutting* are chosen and optimized in order to remove the largest amount of process heat with the chips away from the part, the cutting tool, and from the machine components. Because of this, the temperature increase of the manufactured parts reaches a quasi-steady-state level after cutting of 5 to 10 parts. It is called a quasi-steady-state because after reaching this point, there first will be a very slow but steady increase of the part temperature that can be recognized after every 10 to 20 parts. Towards the end of the tool life a more rapid temperature increase can be noted which, along with other criteria, is a sign of the point where the cutter head should be exchanged.

Figure 6 indicates the differences of the average part temperature of a representative automotive-size Formate ring gear. Along with the increase of part temperature in the case of increasing cutting surface speed, the graphic in Figure 6 also reflects that the two-face blade system using inside and outside blades generates the lowest part temperatures. The reason is the 12° side rake angle that makes the blade appear very sharp, resulting in a high shearing component and a low cold forming component during chip formation.

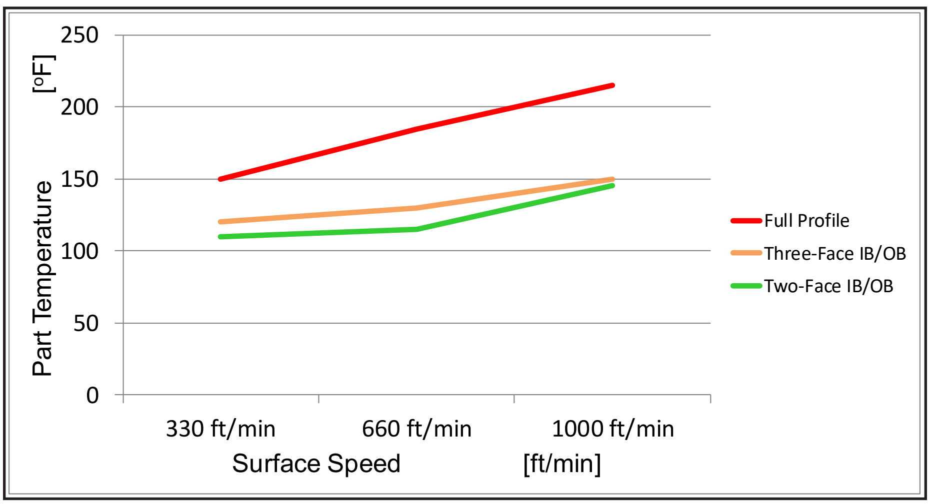

Figure 6 Part temperature versus cutting surface speed.

The highest average part temperatures are recorded in the case of a cutter head with full profile blades. The amount of "cold forming" or plasticization work that generates heat is higher than for two-face blades because of the zero degree side rake angle and the fact that the bulky chip, which is formed by the entire profile of the blade, is restricted in its flow; the chips cannot roll like the side-chips or L-chips created by the two-face inside and outside blade system. The crumbling of the bulky full profile chip requires additional energy that is converted to heat, as is evident in the recorded part temperature.

The temperature graph for the three-face blade system with inside and outside blades is slightly above the two-face graph. The side rake angles of about 4.5° cause a higher material plasticization work than the 12° two-face blades, but the chip can freely roll as side-chips or L-chips. The amount of plasticization work the three-face blade system performs is a desirable effect because the steel appears softer while it is sheared off and creates a better surface finish compared to the two-face cut parts.

The more significant problem is the growing temperature around the circumference of a pinion or a gear (Fig. 7). The heat that a single-indexing process generates is located in the area of the currently cut slot. If the temperature of a fresh-cut bevel gear should be recorded, it is necessary to choose a certain tooth or slot for the temperature measurement. Immediately after the cutting is finished, the temperature between the first cut slot and the last cut slot might vary more than 80°. The reason is that the highest temperature moves with the cutting zone around the part. The zone of the first cut slot has had the most time to cool down when the cutting reaches the last slot (adjacent to the first slot). The jump in temperature shown in Figure 7 results in a so-called "first-to-last error" in the tooth spacing that is difficult to correct entirely with a spacing compensation. A steady increase of this temperature jump during the cutting of a complete batch of parts can be noted, which would require frequent adjustment of the spacing compensation parameters. First-to-last spacing errors require a slowed down grinding cycle if the cut parts are ground after heat treatment.

Production measurements showed that a full profile blade system not only causes the highest average part temperature after cutting, but also generates the highest temperature step between the first and last cut slots compared with the inside-blade and outside-blade cutter systems.

Geometrical Aspects of Full Profile Blades

With a cutter system that only uses one kind of cutting blade, rather than three or two different blades arranged in blade groups, the logistical cost of blade blank storage, blade grinding, blade storage after grinding and cutter building is reduced to 50%, compared to an inside-blade and outside-blade cutter system. The cutter head has twice as many cutting edges for cutting the convex and the concave flanks and the same number of cutting edges cutting the root. In cases where cutting edge wear dominates over blade tip wear, the expected tool life of a full profile cutter head would be higher than the tool life of an outside-blade and inside-blade cutter head.

Higher cutting forces due to the restricted chip flow and vibrations induced by the full profile chip forming and crumbling work will adversely affect tool life, which is why the full profile blade system in practical applications does not show the anticipated tool life advantages versus the inside-blade and outside-blade cutter system.

Full profile blades can only be built to height. As shown in Figure 8, if the full profile blade was moved with the goal of re-positioning the outside cutting edge radially, then the inside cutting edge will also move radially by the same amount. This connection between inside-blade and outside-blade would only allow for a compromise in radial cutting edge position.

PentacMono — Design

A PentacMono blade (Fig. 9, center) is manufactured with an outside cutting edge that duplicates the pressure angle and shape of the full profile blade (Fig. 9, left), and has a tip edge radius that is identical to the outside edge radius of the

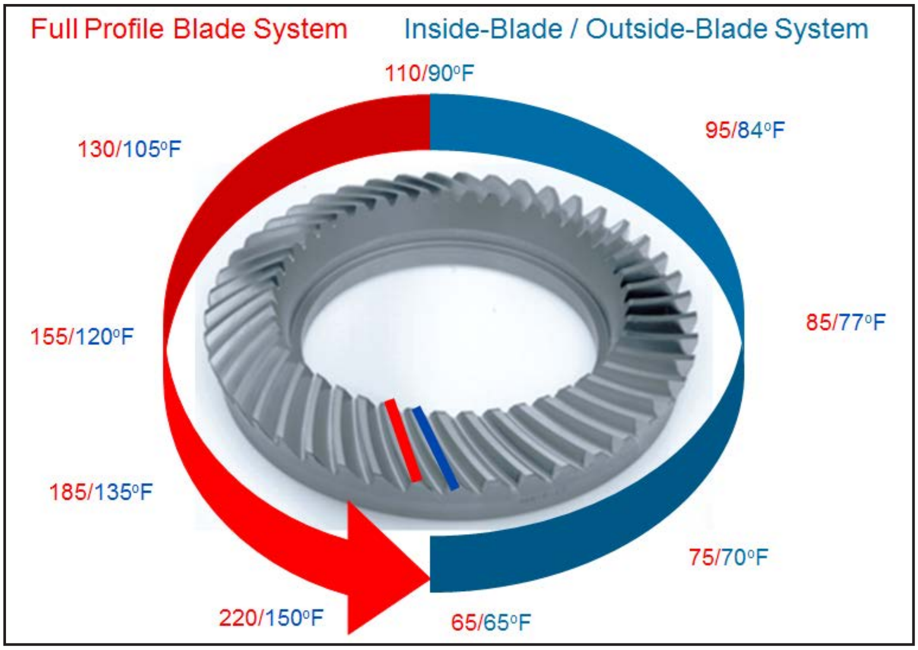

Figure 7 Temperature distribution of face milled workpieces.

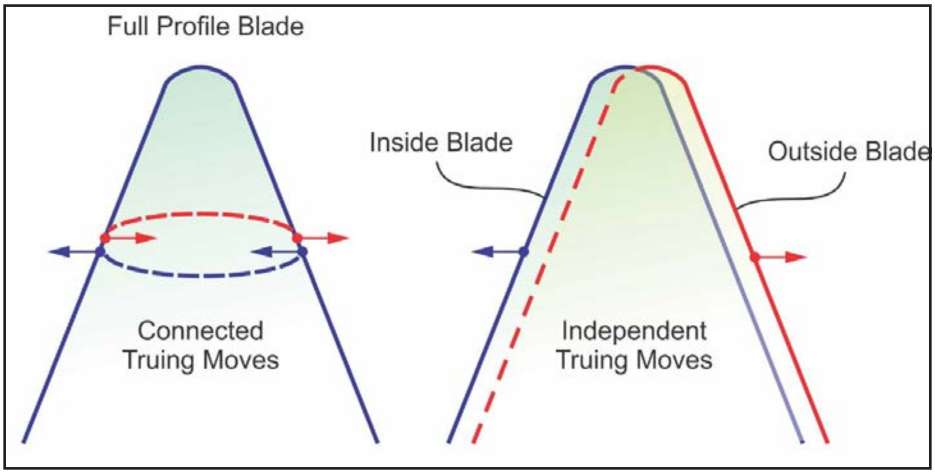

Figure 8 Radial truing only to a compromise runout value.

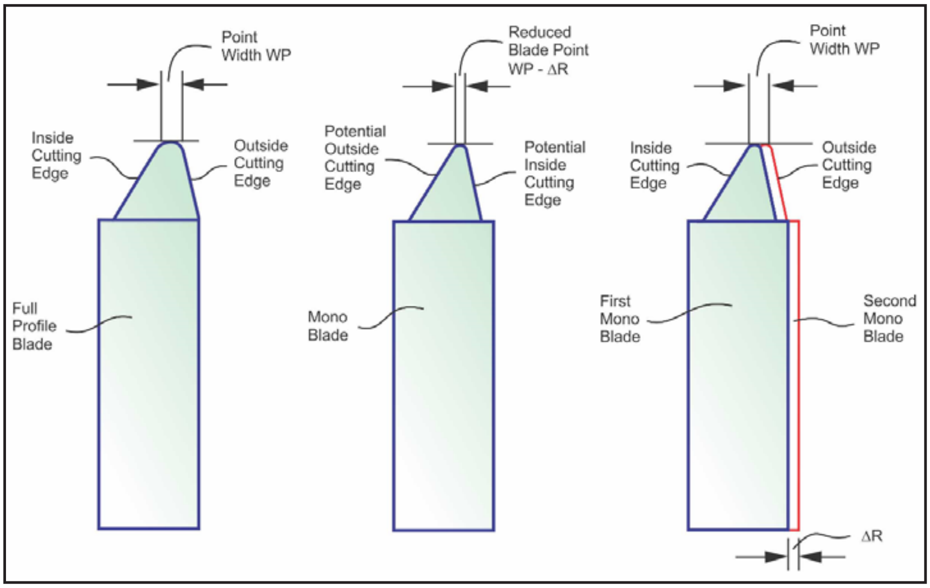

Figure 9 Comparison of full profile blade and two PentacMono blades.

full profile blade. The blade top width of the PentacMono blade is smaller than the top width of the full profile blade by an amount ΔR. Tip edge radius and cutting edge on the right side of the PentacMono blade are identical to the inside cutting edge of the full profile blade.

If two identical PentacMono blades are placed in a cutter head that has slot bottom radii for two consecutive blade slots that differ by the amount of ΔR (Fig. 9, right), then the slots cut with this cutter have the same width as the slots cut with the full profile cutter head.

The produced gear surface geometry is identical to the geometry produced by the full profile blade. Like the full profile blade, the PentacMono blade arrangement only requires one single type of blade in order to simultaneously cut, in a completing cutter head, the convex and the concave flanks, as well as the root fillets and root bottoms.

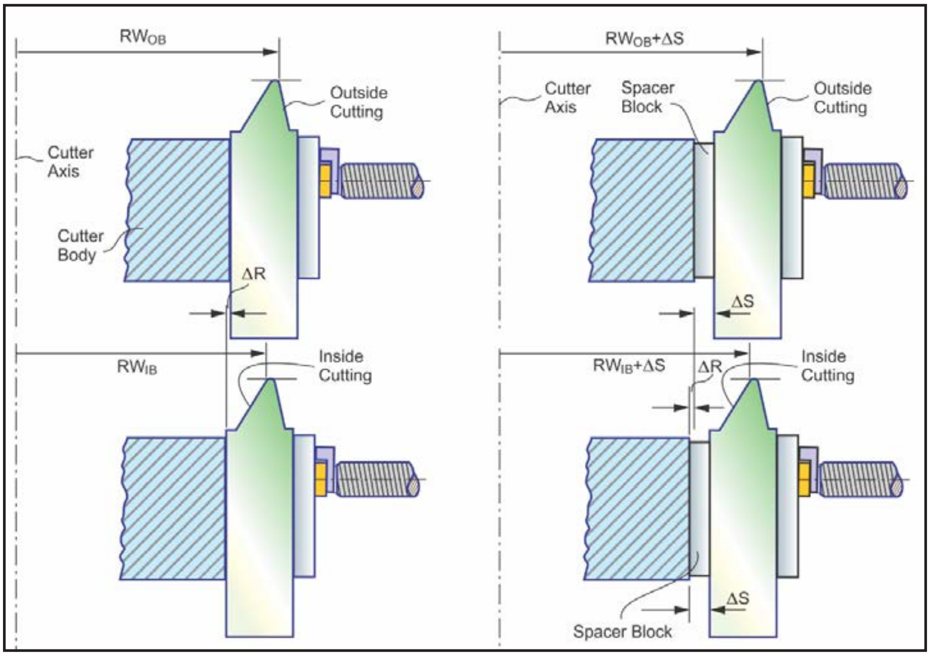

Figure 10 Blades in a PentacMono cutter head; left: without spacers, right: with spacers.

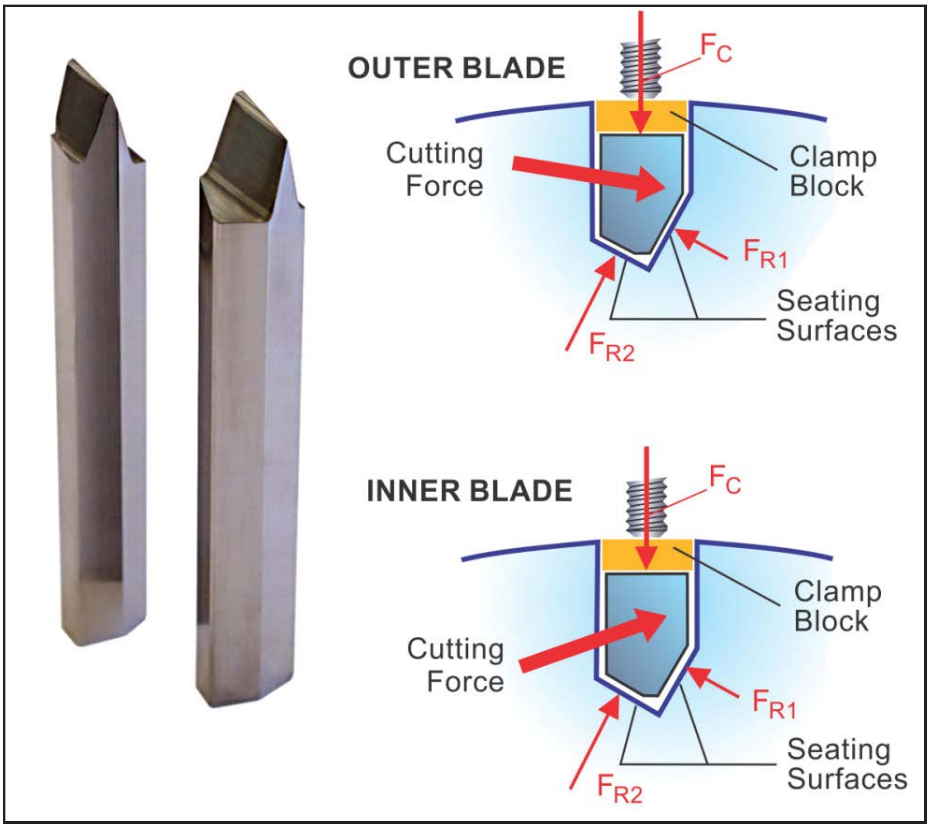

Figure 11 Pentac block blades as preferred stick blade shape for Mono blades (Ref. 2).

Some important performance criteria of the PentacMono blade system are:

- The separation of the inside and outside cutting to two different blades that have the identical specification reduces the variety of different blade geometries to be administrated, handled and refurbished.
- Chip formation is more optimal and the cutting process is smoother.
- The cutting forces are lower than the cutting forces of the full profile blade that also lowers the process temperature.
- Part quality produced with PentacMono blade and cutter system is higher than part quality of the full profile blade system.

In order to realize the PentacMono blade arrangement in a cutter head, the outside blade must be positioned in a cutter head slot with a slot bottom radius which is an amount ΔR larger than the slot bottom radius of the inside blade (Fig. 10). The slot bottom radius is the radius from the cutter head axis to the blade seating surface. The different slot bottom radii in conventional cutter heads with inside and outside blades are commonly stepped. Stepping means that the inside blades have a smaller slot bottom radius than the outside blades. The difference amount between the slot bottom radii of outside and inside blades is 5-to-20 times larger than the amount ΔR required for the PentacMono blade positioning. The mentioned difference in slot bottom radii allows conventional cutter heads to cover a wide spectrum of different bevel gear designs, and also allows cutting gears of a certain module range.

In order to enable the PentacMono cutter system to also cover a wide range of different bevel gear designs and modules, the blade seating surfaces can be modified and plan-parallel spacer blocks can be connected to them. A PentacMono cutter head can be utilized with or without the spacer blocks (left versus right sequence, Fig. 10). Different sizes of the spacer blocks can be prepared in order to achieve large radius span $RW_{OB}+\Delta S$ and $RW_{IB}+\Delta S$ by making a variety of spacer blocks with different thicknesses available. In the actual PentacMono cutter head design, the difference ΔR is worked into the thickness of the spacer blocks. This not only allows the manufacture of cutter heads with equal slot bottom radii; it also makes the PentacMono system more flexible; e. g. — for different amounts of ΔR — depending on the individual gear design. This is advantageous if a wide module range has to be covered. Different spacer block thicknesses also allow a consolidation of a variety of different gear designs for the usage of the same blade geometry (in case of identical pressure angles but different gear slot widths).

The Mono-blade cutter head system has been realized in cutter heads with pentagon-shaped slot cross-section and stick blades (Fig. 11). The spacer blocks will in this case have the form of a prism, like the two examples shown (Fig. 12). The thickness of the spacer block can be manufactured in order to exactly duplicate the thickness of the rectangular spacer blocks (Fig. 10). The spacer block (Fig. 12, right) is an optimized design resulting from numerous cutting trials. The connection to the bottom of the cutter head slots is realized with only one recessed screw. In order to achieve maximum seating stiffness between the spacer block and the cutter head, surfaces labeled with "seating 1 through 3" are in contact with precision-ground surfaces in the cutter head slot. Three seating surfaces present an over-constrained system, which is why the compliance check was implemented to assure a tight fit between the spacer block and the cutter head body.

The PentacMono cutter head system is designed with radial adjustability. Figure 13 shows the blade seating surfaces that are unmodified in the upper section and have a modification on the lower section. In addition to the clamp screws in the upper location, adjustment screws have been implemented in a lower location of the outer cutter head ring. A clockwise rotation of the adjustment screw will move the tip of the blade and increase the point radius R; a counterclockwise rotation of adjustment screw will reduce the point radius R.

Rather than modifying the cutter head seating surfaces with the relief for radial truability, in the production version of PentacMono-RT cutter heads the relief modification is machined onto the seating surfaces of the spacer blocks (Fig. 12, right).

The mono blade and cutter system, as it was described for the single indexing face milling process, can also be utilized in the continuous indexing face hobbing process. In order to achieve identical inside and outside blades the blade timing cannot be controlled with individual front face distances between outside and inside blades. The blade timing — the angular distance between the reference point of the inside blade cutting edge and the reference point of the outside blade cutting edge — influences the slot width and therewith the tooth thickness. If the front face distance and all other parameters of the blade that is placed in an outside slot are equal to the parameters of the inside blade, then the correct tooth thickness in a completing cut can only be established with a change of the radial location of the cutting edges. In order to keep both blades identical, a slot width discrepancy, e.g. — $+\Delta s$ — can be corrected by increasing the radius of the inside cutting edge by $\Delta s/2$ and a reduction of the outside cutting edge radius by $\Delta s/2$. In this case the correct tooth slot width (and tooth thickness) will be achieved by using identical blades in the cutter head slots for the outside cutting, as well as in the cutter head slots for the inside cutting.

The slot radii of outside and inside cutting slots have to be located in order to achieve, for an average gear cutting, the same radius of the reference point on both the outside and the inside cutting

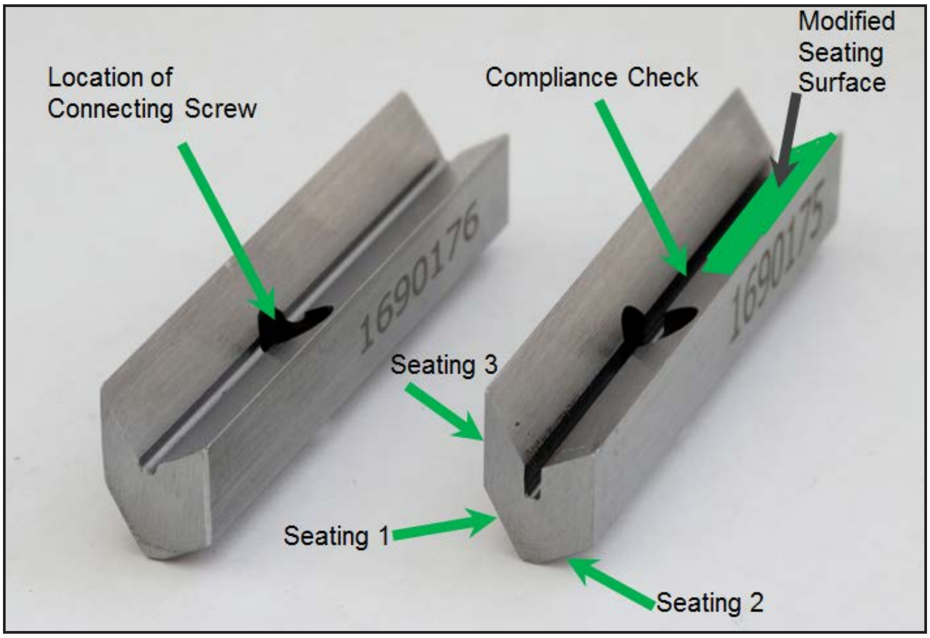

Figure 12 Blade spacer parallels adjusted to Pentac prism seating form.

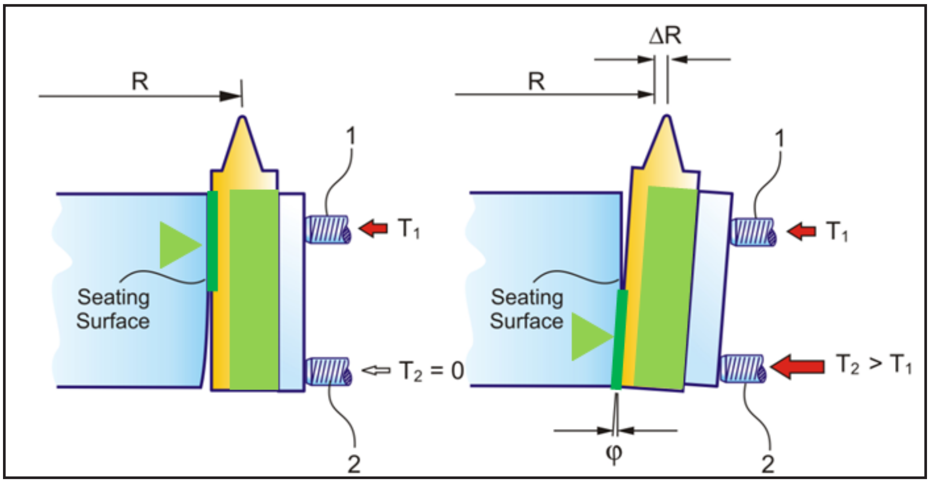

Figure 13 Modified seating surfaces for radial truability.

edge. In order to cover a wider range of gear designs in face hobbing, spacer blocks must be utilized.

PentacMono-RT — the Best of Both Worlds

The newly developed line of PentacMono cutter heads are today available for the face milling process, and in the future will also be available for face hobbing. The side rake angle (Fig. 14) must be zero degrees to fulfill the objective of having identical blades for outside and inside cutting. In order to achieve an optimal chip removing process, a high top rake angle of 4° is proposed that will offset the effect of the neutral side rake angle. A high top rake angle helps to start the forward-moving shear crack that lowers the forces for cold forming and plasticization. All PentacMono-RT cutter heads are designed with a 12° blade slot inclination, like PentacPlus cutters. This allows a variety of freedoms required in order to realize the mandatory zero degree side rake angle as well as the desirable high top rake angle.

The edge treatment of PentacMono blades after blade grinding is identical to the treatment of three-face inside/outside blades. Recommended is edge honing or vapor blasting that removes loose carbide particles along the cutting edges and only leaves a trace of edge rounding; the desirable edge rounding radius is less than 2 micrometers.

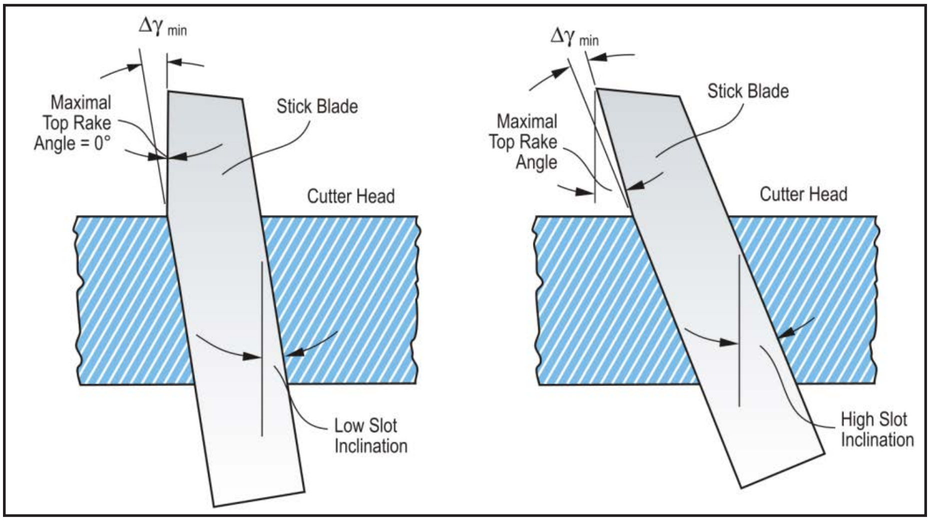

Figure 14 Higher blade slot inclination in PentacMono-RT cutter heads.

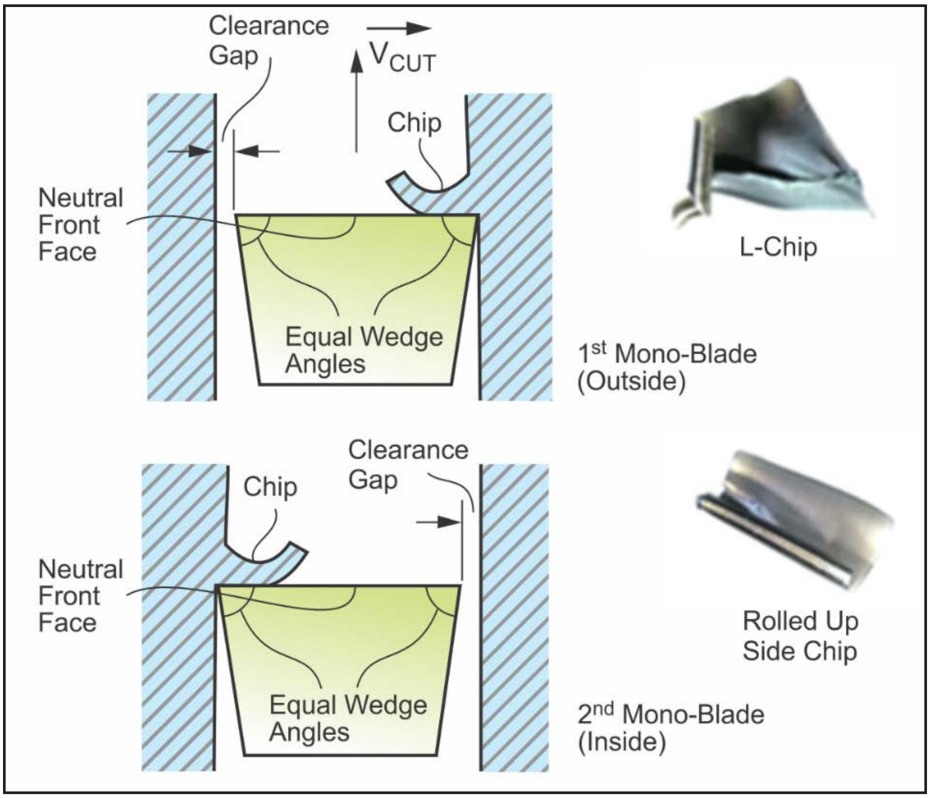

Figure 15 Simplified display of interaction between two preceding Mono blades.

A simplified principle graphic for the chip removal process of the two identical Mono blades in one blade group that have a radial offset ΔR is shown (Fig. 15). The two preceding blades (Fig. 15) act like a true outside and a true inside blade that forms rolled-up side chips (bottom) and L-shaped chips. The chip flow is identical to the chip flow of regular inside and outside blades. The side rake angle of zero degrees has to be compared to three-face ground inside/outside blades that typically have a side rake angle of 4.5°.

As mentioned above, the effect of the lower side rake angle is partially offset by the top rake angle of 4° versus 1 to 3° in regular inside/outside blades. As a result, the average part temperature of a freshly cut ring gear, for example, is at the same level as the graph for the three-face inside/outside blade cutting system (Fig. 6). Also, the temperature distribution around the circumference immediately after a face milled ring gear is finish-cut behaves very similarly to the schematic display shown in Figure 7 — especially in that the critical temperature step between the first and last cut slot is of a similar magnitude as ring gears manufactured with the traditional inside and outside blade cutter system.

Precisely radially trued blades cause less vibration during cutting action and assure that blades have a nearly equal chip load and, as a result, forms smooth cutting flats on the flank surfaces of the generated member. The result of a parameter study is shown (Fig. 16). The roll rate (degree/min) changes in the direction of the ordinate. Surface finish improvement by smoother generating marks, which are closer together, is shown in the direction of the abscissa. The diagram includes the surface roughness marks of 0.05mm that are caused by the blade cutting edges. The roughness marks are independent of the roll rate and show in each of the photos the same value; between the lower and the upper photos the roll rate doubles. For the un-trued cutter this translates into generating marks that nearly double. The radially trued cutter left generating marks are closer together and become nearly invisible with slow roll rates. PentacMono-RT cutter heads benefit from the radial truing feature and show surface characteristics consistent with the right-hand sequence in Figure 16.

PentacMono blades can be used for a second tool life if the blades in the inside slots of the cutter head are exchanged with the blades in the outside slots after the end of the first tool life. Cutting edges and edge radii on the non-cutting side do not wear during the first tool life run, which offers the possibility of a second use of the same blades — without the requirement of re-grinding and re-coating.

Summary

PentacMono-RT cutter heads have to be compared to full profile blade cutters with rectangular blade cross-section. Both systems use only one kind of blade that reduces the number of blade summaries and, therefore, reduces the number of different blades a manufacturer has in storage in half. In spite of the full profile cutter system, the PentacMono-RT blades take side chips. Depending on the slot in which a Mono blade is placed, it becomes an inside blade or an outside blade that makes for a free flow of small-sized L-chips and side chips (Fig. 15); the tendency for chip packing is reduced. If chip packing like that shown in Figure 5 still occurs, then the Pentac specific chip packing elimination by back face grinding can also be applied to the PentacMono-RT system.

Process heat generated by Mono blades is lower than the heat generated by full profile blades. The temperature step between the first cut and the last cut slot is greatly reduced due to good chip flow and the lower chip deformation work, compared to the energy required forming a bulky full profile chip. A temperature step between the first and last cut slot will, after the part has cooled down to room temperature, transform in a large indexing error between the teeth adjacent to those two slots. Even if parts are ground after heat treatment, the indexing error will require slower grinding and, in most practical applications, even calls for

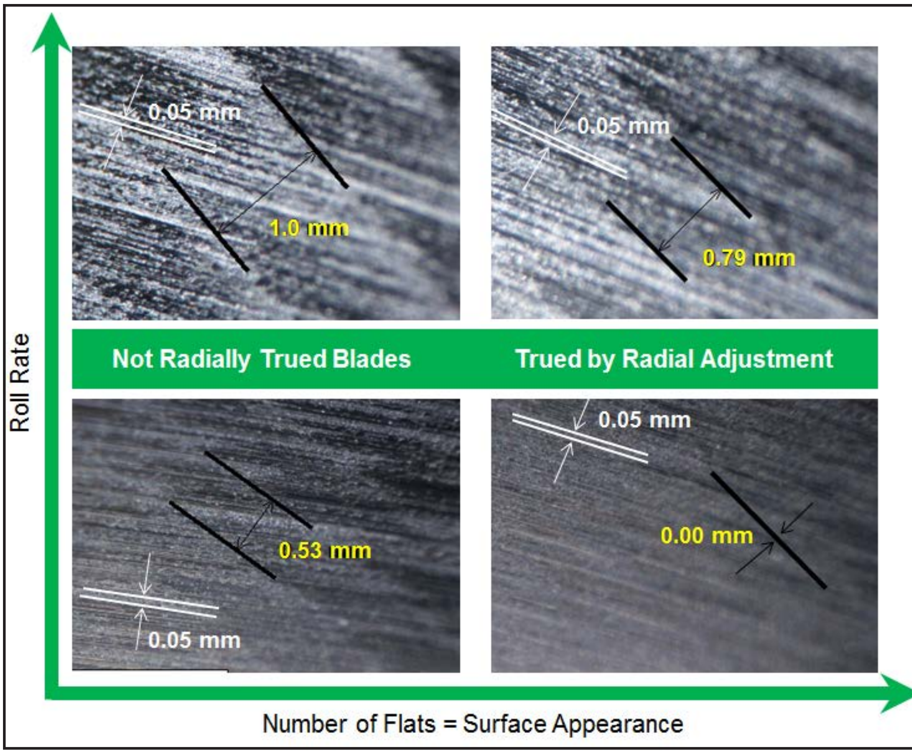

Figure 16 Surface finish improvement by radially trued side cutting blades.

- Good chip formation and chip flow
- Chip packing eliminated or reduced
- Low process generated heat
- Ground prismatic slots with stiff blade Seating
- Defined truing with RT relief
- High productivity
- Grinding in single rotation due to low indexing errors
- Low tooth to tooth error qualify for UMC and MicroPulse application
- Interchange of inside and outside blade after tool life
- Delivers a second tool life

Figure 17 Advantages of PentacMono-RT cutter head.

a dual rotation in which the first rotation is used as a rough grinding cycle and the second rotation is set up as a finish grinding cycle.

The blade seating uses the prism-formed slot bottom geometry, which establishes a positive form seating between the two prism surfaces and the clamp block surface (Fig. 11).

The prism seating is asymmetric, with the intention to utilize the steeper seating surface to support the blade against the cutting forces. Slightly higher cutting forces of the zero degree side raked blades at the moment of first cutting contact benefit from the stiff connection between blade and cutter head body.

Pentac Mono-RT cutter heads use spacer blocks with the shape of a prism (Fig. 17). The spacers have their own bottom seating in the cutter head slots with their bottom surfaces, which are formed congruent to the prismatic seat of each cutter slot. In order to increase the seating stiffness between spacers and cutter head slot bottoms, an additional surface (seating 3, Fig. 12) is precision-ground and provides in connection with a compliance slot a slight interference fit between spacer block and cutter slot. The truability of each PentacMono-RT cutter head is achieved by implementation of a relief surface on each spacer block (Fig. 12). Radial inaccuracies in a full profile blade cutter head cannot be eliminated by either axial blade shifting or by radial blade movements (Fig. 8). In practice, this makes some full profile blades work harder and others only rub on the surface. Both too large chip thickness and excessive surface rubbing will wear the cutting edges and can cause microchipping. Having defined blades for inside and outside cutting with a defined clearance gap on the adjacent blade edge allows the blades after cutter building to be trued to a precise radial position. Cutting performance, part quality, and tool life benefit greatly from equal distribution of the cutting load between all blades. In this case, the motto "less is more" applies. Less active cutting edges that all perform equal amounts of work will result in a higher productivity than more cutting edges that have a random pattern of cutting load distribution. After the end of a tool life, the Mono blades in the inside slots can be exchanged with the mono blades in the outside slots, which allows a second tool life without any blade re-grinding and coating.

Surface modifications — like, for example, *Universal Motions* (*UMC*) with three-section and ring gear end relief, as well as surface modulations like *MicroPulse* — are formed and induced in the grinding operation. However, soft cutting with a once-per-revolution index error pattern, or flank form deviations as a result of high process heat with a steep gradient around the circumference of a pinion or ring gear, will interfere with a robust grinding process and with the repeatable reproduction of the modification effects.

References

1. Stickles, L. Guidelines for Stick-Blades and Cutters Peppers, F. Gleason Specification Sheet, October 2011.
2. Stadtfeld, H.J. *Gleason Bevel Gear Technology, The Science of Gear Engineering and Modern Manufacturing Methods for Angular Transmissions*, Company Publication, The Gleason Works, Rochester, New York, March 2014.

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Full Contact Analysis vs. Standard Load Capacity Calculation for Cylindrical Gears

M. Otto, U. Weinberger and K. Stahl

Introduction

Modern gear design is driven by full tooth contact analysis (TCA) to determine adequate gear microgeometry. Engineers strive to optimize load distribution and make use of the full load carrying capacity of the gearset. Local stress levels in the tooth contact and the tooth root are important calculation results, but reliable values for the limits of the load carrying capacity are available for standard methods, e.g. — ISO 6336. Therefore, the relevant power ratio and safety factors are still determined by standard methods that use traditional approaches; combining both provides a possibility for further optimizations.

Tooth root breakage and flank damage by pitting and scuffing have been covered in international standards for some time. Recently, ISO standards have been created that cover additional gear failure modes (micropitting, tooth flank fracture). Again, for these the question of how to combine tooth contact analysis methods with standard calculations must be answered.

In this paper local tooth contact analysis and standard calculation are used to determine the load capacity for the failure modes pitting, tooth root breakage, micropitting, and tooth flank fracture; analogies and differences between both approaches are shown. An example gearset is introduced to show the optimization potential that arises from using a combination of both methods. Difficulties in combining local approaches with standard methods are indicated. The example calculation demonstrates a valid possibility to optimize the gear design by using local tooth contact analysis while satisfying the requirement of documenting the load carrying capacity by standard calculations.

Figure 1 Example for a gearbox design with closely interdependent machine elements (Representation in FVA-workbench 4.0).

The designer of a competitive gearbox has to pursue the aims of high load carrying capacity, low NVH behavior, and high overall efficiency. In many applications complex geartrains — with multiple meshes per gear and often with planetary stages — are required to reach a compact arrangement of the gears in the gearbox. An obvious conclusion seems to be that a system analysis approach is necessary to consider the mutual influence of the machine elements.

On the other hand, valid standard methods to evaluate the load carrying capacity of gear stages have only limited possibilities to introduce system influences from the whole geartrain.

This inevitably leads to two questions: 1) how valid are the results of proven standard calculations for a progressive gearbox design; 2) and how reliable are results from a non-standard full contact analysis?

This paper is a pledge to keep it simple and use high-fidelity calculation models for only the necessary aspects. Standard methods may be useful in design and documentation, and complex models for optimization in detail. Don't get lost in the complexity already in the design stage!

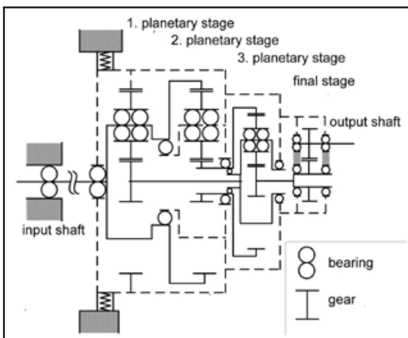

Figure 2a Sketch of gearbox structure; double circles represent bearings, horizontal double lines represent gear meshes (example structure for a gearbox design [15]).

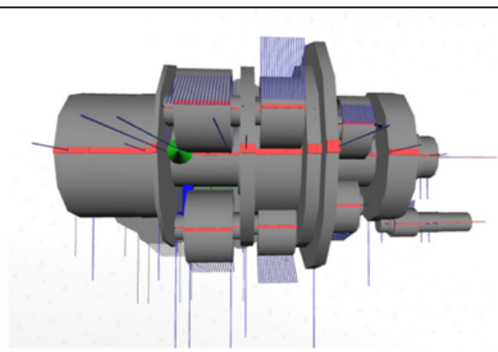

Figure 2b 3-D schematic of example gearbox (ring gears not shown); blue parallel lines represent planes of meshing action; red horizontal lines represent shaft orientation; vertical lines are mostly part of local coordinate systems.

Figure 2 Structure of example gearbox with closely interdependent machine elements.

Full Contact Analysis

A full contact analysis means a calculation model for load and deformation analysis of a geartrain — including gearbox housing and interactions between all elements. Usually, a static deformation analysis of housing, bearings, shafts, gears, teeth, and further elements (planet carrier, differential housing, etc.) is included. Full interaction between all elements and the possibility of a combination with FEM analysis results for structural parts (carrier, housing) characterizes the performance of the method. The overall analysis yields the deformations and positions of the shafts, and thereby influences the TCA. Results of the analysis include load distribution over tooth flanks, transmission error of the gear meshes, and load-dependent friction losses (Ref. 7). Therefore a full contact analysis is a tool to design flank microgeometry and balance the load distribution, according to the importance of the main design goals.

The necessity to include all system influences is obvious if a gearbox as shown in Figures 1–3 is considered (Refs. 15–16). The geartrain is built up from three coupled planetary stages according to the design sketch in Figure 2a. All elements positions and deformations under load are mutually dependent. A full contact analysis is the way of choice to determine the deformation state (Fig. 3).

Several slightly different approaches to the task of a full contact analysis are available, mostly in software packages.

Vriesen et al. (Ref. 8) document a contact analysis for a wind turbine gearbox with FVA-workbench and optimize the load distribution of the gear meshes by designing an adequate microgeometry.

Bonori et al. (Ref. 4) use a contact analysis for a spur gear mesh with a numerical optimization algorithm to optimize the profile modification; the approach does not cover the interaction of elements of whole gearboxes.

Bihr et al. (Ref. 3) use a contact analysis approach for noise prediction of a gear stage in an automotive gearbox. They show that manufacturing deviations may lead to differences between design behavior and measurement results. The contact analysis reliably covers the measurement results if manufacturing deviations are introduced in the model.

Langlois (Ref. 6) shows how to improve NVH behavior of a gearbox by using *MASTA* software. He considers load capacity aspects, but the interaction between standards calculation and contact analysis is not the main focus of the approach.

Wirth et al. (Ref. 5) use the FVA-workbench to design and optimize an automatic automotive transmission; designing modifications of gear meshes in the complex system are documented.

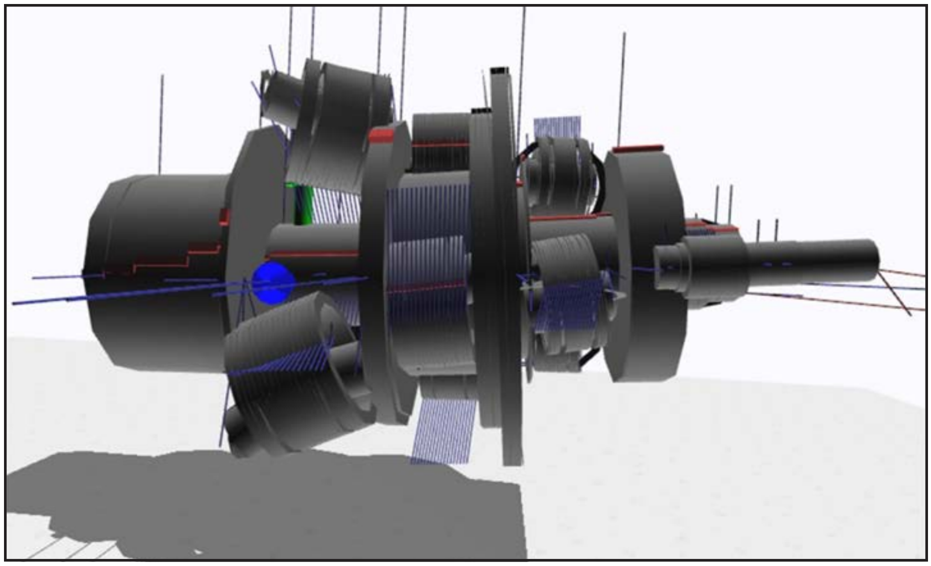

Figure 3 Scaled deformation of example gearbox under load.

The results of standard carrying capacity and the designed load distribution are interdependent via a derived load distribution factor.

Although many other articles addressing full contact analysis approaches are available, a combination with proven but traditional standard methods is normally not discussed.

A major deficiency of full contact analysis methods may be the difficulty of determining reliable values for the gear capacity. Material values that exist in standards like ANSI/AGMA 2001 (Ref. 2) or ISO 6336 (Ref. 9) have been derived from experiments using standard equations to evaluate the experimental results, so most full contact analysis methods do not yield fully transparent safety factors or power ratings. Application of a full contact analysis on load carrying capacity for gear design is closely connected to the engineer's own experience.

Standard Load Capacity Calculation

Standards for gear rating include capacity values for a number of materials that are mostly derived from experiments performed on standard gears. Usually, the testing apparatus provides an even load distribution over tooth width.

System influences are regarded as "external" and covered in factors that have to be specified up front (e.g. — "overload" factors K_A, $K_{H\beta}$, $K_{F\beta}$). Especially the $K_{H\beta}$ value includes flank deviations that result from the surrounding elements (shafts, bearings, housing, etc.). No interaction between all elements is covered in the standard approach, as these factors are constant input values, therefore they must be determined for every load case up front. One possibility is documented in AGMA 927 (Ref. 1) or in the ISO 6336 (Ref. 9) Appendix, which is mainly based on the AGMA approach.

Definition of the load distribution factor (Eq. 1) is important; it covers a deviation over tooth width and, by this approach, includes all influences from the shaft dislocations under load. It is not derived from a detailed load distribution analysis, since the load distribution in the gear mesh is part of the system of equations used in the standard approaches to determine the representative stress levels.

$$K_{H\beta} = \frac{\left(\frac{F}{b}\right)\mathrm{max}}{(F_m/b)} \tag{1}$$

$\left(\frac{F}{b}\right)\mathrm{max}$ maximum of acting load per tooth width

F_m/b acting load per tooth width for even distribution

The standard ISO 6336 covers several gear failure modes and provides equations to analyze the load carrying capacity of the gear mesh. The basic concept deals with the transverse involute gear contour; i.e. — helical gears are covered by additional empirical factors. The main assumption is that, in general, the maximum stress value determines the gear lifetime. The calculation is usually performed only on one position (e.g. — pitch circle for helical gears) or on some positions along the profile (spur gears; all gears for scuffing or micropitting) that are deemed to be the positions of maximum occurring stress.

Pitting Resistance

Pitting resistance (ISO 6336-2) is determined by the contact stress (Eq. 2) versus the permissible contact stress.

$$\sigma_{H1,2} = Z_{B,D} \cdot \sigma_{H0} \cdot \sqrt{K_A \cdot K_v \cdot K_{H\beta} \cdot K_{H\alpha}} \tag{2}$$

$\sigma_{H1,2}$ contact stress for pinion and gear, respectively
$Z_{B,D}$ single pair tooth contact factor, pinion/gear
σ_{H0} nominal contact stress
K_A application factor
K_v dynamic factor
$K_{H\beta}$ face load factor
$K_{H\alpha}$ transverse load factor

The nominal contact stress mainly relies on the Hertzian equations, but also includes empirical values for the contact ratio and for helical gears. Values for the permissible contact stress have been evaluated by these formulas from experiments and are documented in the standard.

Tooth Root Bending

Tooth root bending safety (ISO 6336-3) is determined by the tooth root stress (Eq. 3) versus the tooth root bending strength.

$$\sigma_{F1,2} = \sigma_{F0} \cdot K_A \cdot K_v \cdot K_{F\beta} \cdot K_{F\alpha} \tag{3}$$

$\sigma_{H1,2}$ tooth root stress
σ_{F0} nominal tooth root bending stress
$K_{F\beta}$ face load factor for tooth root stress ($K_{F\beta} = f\,(K_{H\beta}, b/h)$)
$K_{F\alpha}$ transverse load factor for tooth root stress ($K_{F\alpha} = K_{H\alpha}$)

The nominal tooth root stress is derived from a beam-bending approach and is extended by empirical values, e.g. — for helical gears. Values for the tooth root bending strength have been evaluated by these formulas from experiments and are documented in the standard.

Micropitting

The safety factor against micropitting is determined according to ISO/TR 15144 (Ref. 10). The relevant value is the minimum specific lubricant film thickness in the contact area that is compared to a permissible value (Eq. 4).

$$S_\lambda = \frac{\lambda_{GF,min}}{\lambda_{GFP}} \geq S_{\lambda,min} \tag{4}$$

The minimum specific lubricant film thickness is determined according to Equation 5 by the arithmetic roughness of the flanks (Eq. 6) and the minimal film thickness in the points Y along the path of contact.

$$\lambda_{GF,Y} = \frac{h_Y}{R_a} \tag{5}$$

$$R_a = \frac{R_{a1} + R_{a2}}{2} \tag{6}$$

The permissible specific lubricant film thickness must be determined in a standard micropitting test that is evaluated according to the equations of ISO/TR 15144. The standard method does not suggest a minimum value for the safety factor $S_{\lambda,min}$, although (Ref. 13) suggests a minimum value of 2 for a local approach that provides the basis for the content of ISO/TR 15144.

Tooth Flank Fracture

A standard method to evaluate the risk of tooth flank fracture is discussed, to be issued as ISO DTS 19042.

Extended Method for Load Capacity Calculation

When full contact analysis became more readily available to gear designers, effort was put into developing load carrying capacity methods that rely on the precise results of a contact analysis, but are compatible with the available strength values documented in ISO; a collection of methods is cited below. These are then used to derive some of the results shown in the example section further below. Pitting resistance on a local basis may be calculated according to an approach by Stahl (Ref. 11) (Eq.7).

$$\sigma'_{H1/2} = \sigma'_{H01/2} \cdot \sqrt{K_A \cdot K_v \cdot K'_{H\alpha\beta1/2}} \tag{7}$$

Factors K_A and K_v are defined as in ISO 6336. The local peak contact pressure factor $K'_{H\alpha\beta1/2}$ transfers the resulting pressure distribution across the tooth flank into the equation. The (in respect to ISO 6336) modified nominal contact stress covers further influences. Tooth root bending is covered according to Schinagl (Ref. 12) on a local basis.

$$\sigma'_{F1/2} = \sigma'_{F01/2} \cdot K'_{H\alpha\beta1/2} \cdot K_A \cdot K_v \tag{8}$$

Local tooth root stress is introduced by the factor $K'_{F\alpha\beta1/2}$ and the modified nominal tooth root stress into the approach.

Micropitting safety is considered based on local lubrication film thickness according to Schrade (Ref. 13) (Eq. 9).

$$\lambda_{GF} = \frac{h_{min,iso} \cdot S^{0,22}}{R_{a,mittel}} \tag{9}$$

Tooth flank fracture is covered by the method according to Witzig (Ref. 14); the main parameter is comprised from the stress levels in Equation 10.

$$(A_{FB}(y)) = \frac{\tau_{eff,Last}(y) = \Delta\tau_{eff,Last,ES,stat}(y) - \tau_{eff,ES}(y)}{\tau_{zul}(y)} \tag{10}$$

Advantages of Combining the Approaches

The full contact analysis is needed to determine adequate microgeometry and to secure even load distribution for design load; standard methods are then employed to determine the load capacity.

In general, a two-stage solution seems feasible: first, conduct a gearbox system full contact analysis to determine the relative position of the gears in respect to each other; then perform the separate detailed TCA of each mesh — considering the results of the first step.

A basic contact model for gear meshes in the first step to evaluate system behavior (not dependent on meshing position) may be used, and a detailed gear model in the second step to analyze each mesh. Considering system influences from the first step as fixed boundary conditions (e.g., introducing a constant shaft deviation in the mesh analysis) would be a possibility.

This leads to two different approaches that may be taken:

1. Performing system analysis and deriving the load factors for standard calculation.
2. Using allowable stress numbers for a load capacity calculation in a contact analysis. This makes deriving capacity limits for the gears by evaluating existing experimental results necessary with the new calculation methods; it is then possible to better evaluate the impact of modifications on capacity.

Typically, standard and local methods should both be used by the designer. Standard methods are useful to assess gear load carrying capacity already in the design stage and to allow valid documentation and reporting for the customer. Gear microgeometry doesn't have to be documented with all details for a valid standard load carrying capacity calculation; this is an advantage in documentation, since the know-how of the designer is maintained. On the other hand, standard calculations are not the tool of choice to design and optimize gear microgeometry; here, the local methods apply. They allow a much deeper insight into the connection between microgeometry and load capacity than the standards, giving the designer elaborate tools to reach optimization goals.

Example Calculation

The following gearset is used as an example:

Table 1 Gear main geometry

			pinion	gear
Number of teeth	z	-	24	89
Normal module	m_n	mm	3.5	
Normal pressure angle	α_n	°	20	
Helix angle	β	°	–12.5	12.5
Profile shift coefficient	x	-	0.2	–0.215
Center distance	a	mm	202.5	
Transverse contact ratio	ε_α	-	1.528	
Overlap ratio	ε_β	-	1.083	
Torque moment	T	Nm	1225	

The contact analysis yields the following results, which are documented in Figures 4 to 11. All figures are valid for fully modified gear microgeometry. When the results were compared to non-modified gears, the difference were clearly recognizable.

The safety factors according to the ISO calculation (load distribution factor from the contact analysis is considered), and according to the contact analysis (permissible stress levels are considered), are shown below for the gears with fully modified microgeometry.

For an even load distribution, results from a standard calculation and full contact analysis are in reasonable agreement. The only difference occurs in the micropitting analysis, as the local load distribution accounts for modifications over tooth width in more detail.

It should be noted that the design of adequate flank modifications has been made with the contact analysis. The modifications are not disclosed by the standard results, since only the effect of the modifications on the load distribution is introduced in the standard calculation; these modifications must be documented separately by the manufacturer.

As a next step, a variation of the flank line deviation resulting from higher or lower loads can be performed. Only then can the higher detail of a full contact analysis be used. Because the impact of local overloads on the flank on the results

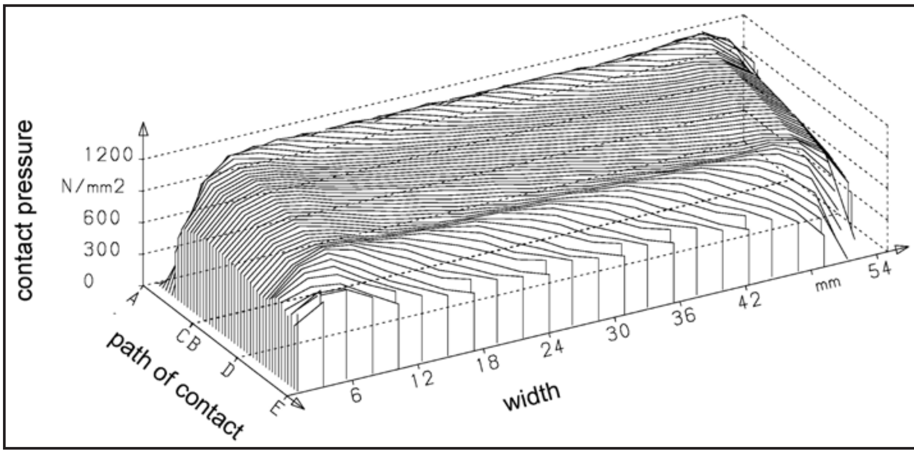

Figure 4 Pressure distribution of gear mesh. Every line represents a line of contact on the tooth flank and shows the acting contact pressure. The local pressure values are used as input for local pitting load capacity calculation (Eq. 2).

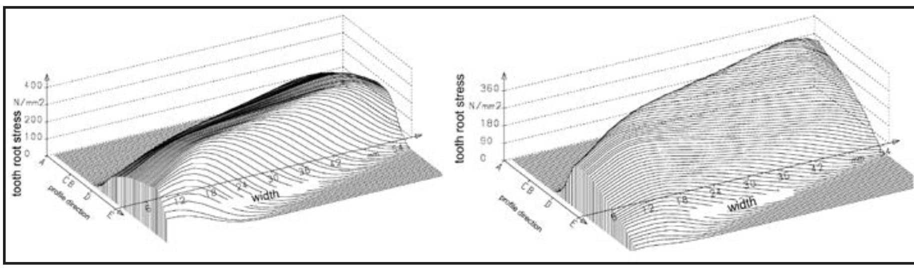

Figure 5 Tooth root stress distributions along the tooth width for pinion and gear. Each line represents the tooth root stress distribution along the tooth width at the 30° tangent in the root fillet for the load acting on one line of contact.

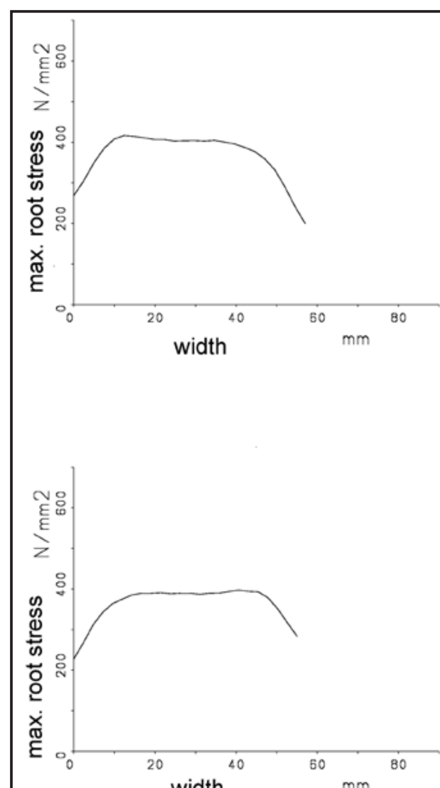

Figure 6 Maximum tooth root stress distributions along the tooth width for pinion and gear. These are the maximum tooth root stress values along the tooth width at the 30° tangent in the root (Fig. 5). The values are used as input values for the local tooth root capacity calculation (Eq. 8).

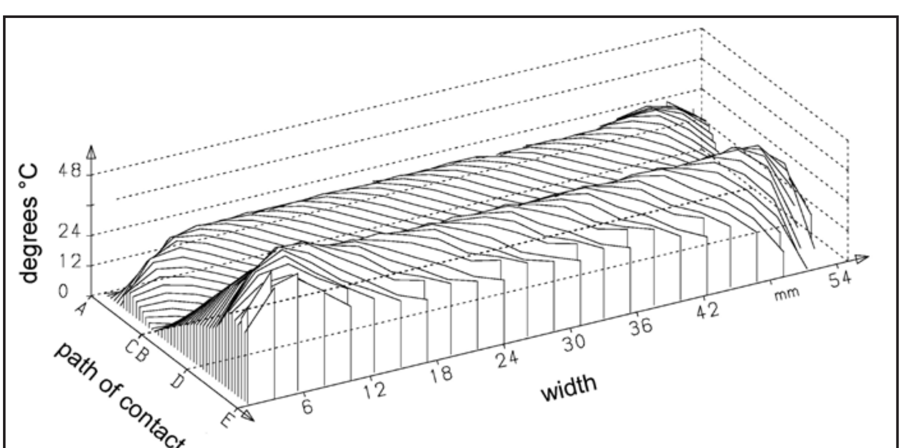

Figure 7 Contact temperature distribution over the tooth flanks; every line represents a line of contact on the tooth flank and shows the resulting local temperature increase due to local load and friction.

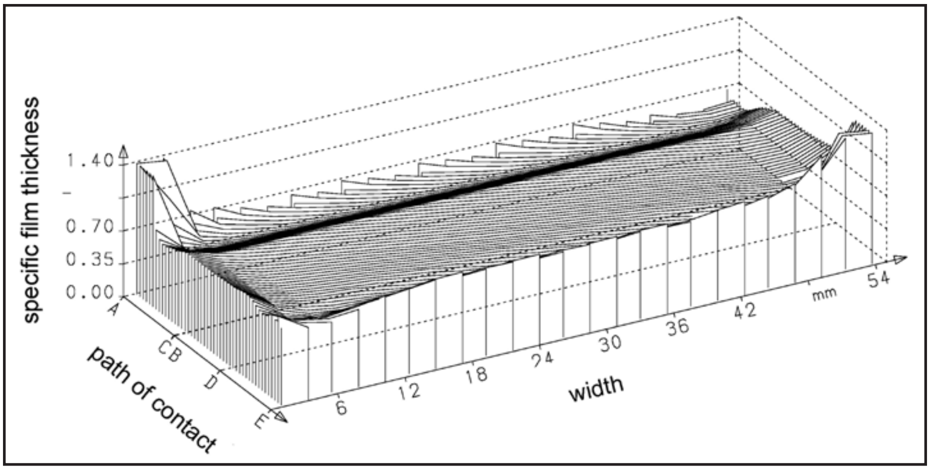

Figure 8 Specific lubrication film thickness over the contact area. Every line represents a line of contact on the tooth flank and shows the resulting local specific lubrication film thickness (Eq. 9).

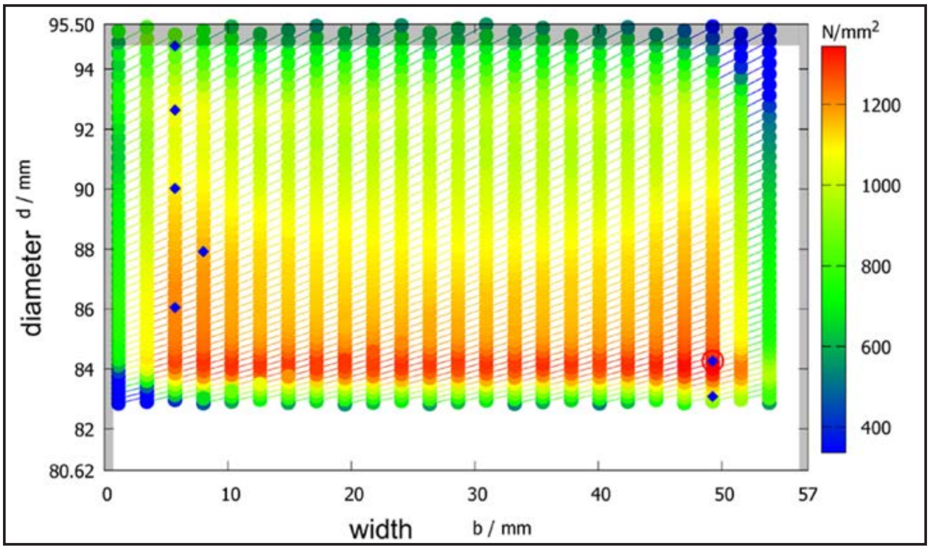

Figure 9 Color-coded pressure distribution over area of tooth contact (same data as in Fig. 4). The local contact pressure is shown over the tooth flank; lines of contact are not indicated in this figure. Point A on the path of contact is located in the root area of the tooth flank; that range shows the highest pressure values.

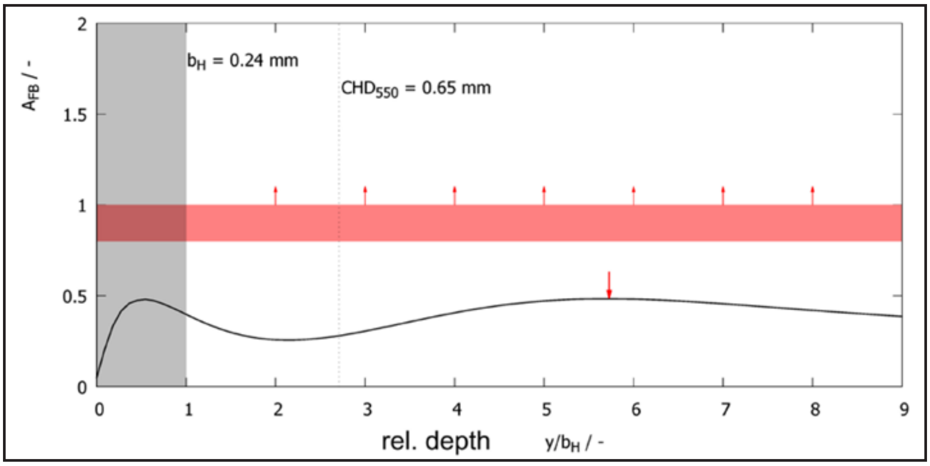

Figure 10 Relative stress under tooth flank at evaluated point at about 88 mm pinion diameter (Eq. 10) (see Fig. 9 for indication of the point by a blue square). The black line represents the risk of tooth flank fracture. The red area between values of 0.8 and 1.0 on the left axis specifies the critical range.

is considered in detail by the contact analysis, the standard methods achieve only the general influence by load distribution factors.

Conclusion

A short overview of a full contact analysis — as a mechanical approach to determine the local flank loads — has been given. The method considers mutual influences between the machine elements in a gearbox and allows one to determine adequate flank modifications. Safety factors or power ratings are not easily derived from a contact analysis, since allowable stress limits are to be agreed upon.

Standard methods documented in ISO 6336 yield safety factors, since allowable stress limits are documented. The influence of gearbox deformation must be introduced by load factors that are input values. A detailed design of flank modifications is not the focus of the standard method.

An example calculation shows the following conclusions:

- Standard method allows for accepted documentation of capacity
- Contact analysis provides necessary flank deviations and covers system interaction
- Load capacity is well-determined by the standard (ISO 6336) and is in good agreement with extended methods that are based on a contact analysis for fully modified gears

More than ever, a full numerical analysis and a full standard analysis provide combined data that allow for high-tech gear design and accepted documentation, while keeping essential know-how of the design in the company. Furthermore, the contact analysis allows a "shift" of properties between goals and to detect possible deficiencies by considering flank deviations in a detailed way.

Today's high-tech gear design is driven by experience in using the standard and combining it with a customized local contact analysis.

Calculation methods and the software *RIKOR* in the FVA-workbench were developed with support by the German Drivetrain Association (FVA e.V).

References

1. AGMA 927-A01. Load Distribution Factors – Analytical Methods for Cylindrical Gears, AGMA Standard, Alexandria VA, 2000.
2. AGMA 2001-D04. Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth, AGMA Standard, Alexandria VA, 2004.
3. Bihr, J., M. Heider, M, Otto, K. Stahl, T. Kume and M. Kato. "Gear Noise Prediction in Automotive Transmissions," *International Gear conference Lyon*, Lyon, 2014.
4. Bonori, G., M. Barbieri and F. Pellicano. "Optimum Profile Modification of Spur Gears by Means of Genetic Algorithms," *Journal of Sound and Vibration* 313, 2008, 603–616.
5. Höhn, B.-R., C. Wirth and N. Haefke. "Design and optimization of automotive transmissions with the FVA-Workbench," *VDI International Conference on Gears*, 2011.
6. Langlois, P. "The importance of Integrated Software Solutions in Troubleshooting Gear Whine," ***Gear Technology***, 2015.
7. Otto, M., M. Zimmer and K. Stahl. "Striving for High Load Capacity and Low Noise Excitation in Gear Design," *AGMA 2013 Fall Technical Meeting*, Indianapolis, 2013.
8. Vriesen, J. W., D. Lütfrenk and K. Dünck-Kerst. "Topological Gearing Modifications Optimization of Complex Systems Capable of Oscillations," ***Gear Technology***, May 2014/*VDI Conference on Gears* 2013, Garching.
9. ISO 6336-2006. Calculation of Load Capacity of Spur and Helical Gears, ISO, Genf. 2006.
10. ISO/TR 15144. Calculation of Micropitting Load Capacity of Cylindrical Spur and Helical Gears, ISO, Genf, 2010.
11. Stahl, K. "Pitting Load Capacity of Case Carburized Cylindrical Gears Regarding Pressure Distribution," (German, org.:"Grübchentragfähigkeit einsatzgehärteter Gerad- und Schrägverzahnungen unter besonderer Berücksichtigung der Pressungsverteilung"), Diss. TU München, 2001.
12. Schinagl, S. "Tooth Root Capacity of Helical Gears Regarding Load Distribution," (German, org.:"Zahnfußtragfähigkeit schrägverzahnter Stirnräder unter Berücksichtigung der Lastverteilung"), Diss. TU München, 2002.
13. Schrade, U. "Influence of Gear Geometry and Operating Conditions on the Micropitting Capacity of Gearboxes," (German, org.: "Einfluß von Verzahnungsgeometrie und Betriebsbedingungen auf die Graufleckentragfähigkeit von Zahnradgetrieben"), Diss. TU München, 2000.
14. Witzig, J. "Tooth Flank Fracture — a Limit of Load Capacity in the Material Depth," (German, org.: "Flankenbruch – Eine Grenze der Zahnradtragfähigkeit in der Werkstofftiefe"), Diss. TU München, 2012.
15. Otto, M. and K. Stahl. "Rating of Gear Load Capacity in Systems Simulation," (German, org.:"Beurteilung der Verzahnungstragfähigkeit in der Systemeimulation"), Simulation in der Antriebstechnik, 2015, Frankfurt am Main.
16. Otto, M., M. Zimmer and K. Stahl. "Striving for High Load Capacity and Low Noise Excitation in Gear Design," AGMA FTM Indianapolis, 2013.
17. Dr.-Ing. M. Otto,
18. U. Weinberger, M.Sc.,
19. Prof. Dr.-Ing. K. Stahl, FZG, Technical University Munich

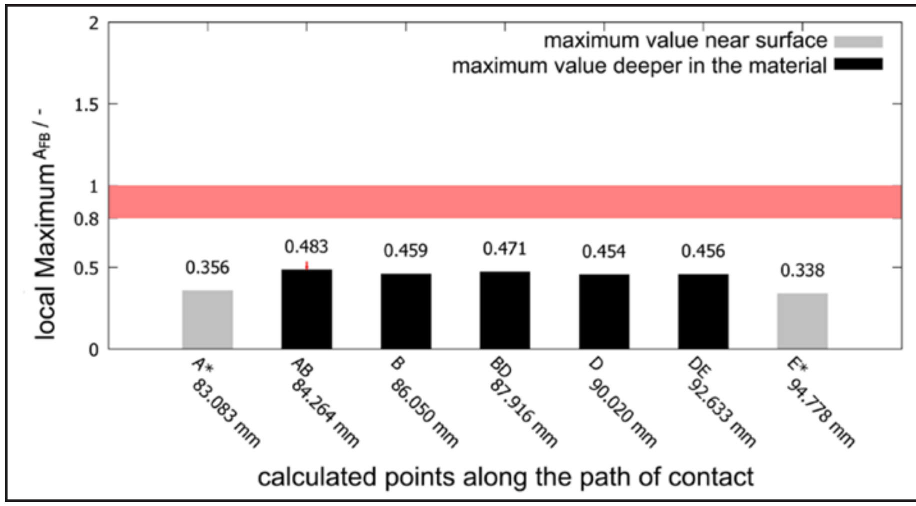

Figure 11 Relative stress under tooth flank at evaluated points on tooth flank (see Fig. 9 for indication of the point by a blue square).

Table 2 Comparison of safety factors according to ISO and to local contact analysis

			ISO 6336		Contact analysis	
			Pinion	**Gear**	**Pinion**	**Gear**
Pitting safety	S_H	-	1.205	1.254	1.14	1.19
Tooth root breakage	S_F	-	1.669	1.893	1.820	1.958
Microptting	S_λ	-	2.667		1.87	
Tooth flank fracture	-	-			1.65	

Dr. Michael Otto joined FZG in 2000 as a research assistant and gained his position as head of department in 2006. He holds a PhD in mechanical engineering; the topic of his research activities were load distribution and tooth root carrying capacity. Current research activities include gear geometry, tooth contact analysis and gearbox-related NVH. Another main focus is deformation and stress analysis of supporting shafts and bearings in the gearbox. He drives the development of various scientific programs that are available for companies that are members of FVA (German Research Association for Gears and Transmissions). He is also head of department — Calculation and Verification of Transmission Systems — at the Gear Research Center (FZG), chaired by Prof. K. Stahl, TU München.

Prof. Dr. Karsten Stahl is Chair, Machine Elements, Mechanical Engineering, at TUM. He leads and conducts research in the area of mechanical drive systems, with particular interest in investigating the load capacity, efficiency and dynamics of all gears types. His other areas of interest include applications in automotive engineering such as synchronization systems and multi-disc clutches. Stahl has developed methods for analysis that have been incorporated into international standards, together with the component strength values derived by means of these methods. He studied mechanical engineering at TUM and performed his doctoral studies from 1994 to 2000 in the Machine Elements Department. In 2001, he joined BMW, first as a gear development engineer, then as the manager of gear development in Dingolfing. In 2006 he transferred to the MINI plant in Oxford where he was initially quality manager for transmissions, then quality manager for powertrains and suspensions. In 2009 he took over responsibility for the initial development and innovation management of powertrain and vehicle dynamics systems at BMW in Munich. Stahl has been a full professor in the Machine Elements Department since 2011.

Uwe Weinberger is a student at TUM, pursuing a master's degree in mechanical engineering. He has served since 2014 as a research associate at FZG, and since 2017 has also been a team leader there for transmission systems verification, working with co-author Dr. Michael Otto. Weinberger's research focus is experimental and simulative analysis of planetary gear stages (load sharing and excitation behavior).

For more information.

Questions or comments regarding this paper? Please contact Dr. Michael Otto; *otto@fzg.mw.tum.de*.

Kapp Technologies, Penta Gear and Koepfer America

ANNOUNCE TECHNICAL SALES COLLABORATION

Kapp Technologies L.P. (KTLP), Penta Gear Metrology LLC (PGM) and Koepfer America LLC (KA) have entered into an agreement for technical sales representation and collaboration in North America.

The companies will share technical sales and engineering resources to support the growing demand for gear hobbing, shaping, chamfering, grinding, and measurement equipment and tools.

Customers seeking efficient access to gear manufacturing solutions will see that all three companies have actively expanded their product offerings to meet customer requirements. This collaboration ensures all gear manufacturers have swift access to the latest technologies available. KA, newly named Helios Gear Products LLC and based in South Elgin, IL, has earned a reputation for excellence in serving its customer base for over 30 years with premium hobbing, shaping, hob sharpening, chamfering, and analytical measurement technology. KTLP, based in Boulder, CO, provides precision gear and rotor tooth grinding and measuring equipment to all market sectors. PGM, based in Dayton, OH is an innovator in analytical measuring machine control, software, and functional gaging solutions and became a subsidiary of KTLP in 2015.

"KTLP, PGM and KA philosophies and specific capabilities are an excellent fit" says Bill Miller of KTLP. He points out that the three companies traditionally had unique niche customer bases which is changing. Leveraging the established sales relationships will benefit collectively all customers.

(*www.heliosgearproducts.com*)

Gleason

PUBLISHES COMPREHENSIVE TRAINING PROGRAM CATALOG

Companies involved in the field of gear design and manufacturing have a common requirement: well-trained employees, both in terms of understanding the basics of gearing and power transmission systems as well as understanding the latest developments in gear design, manufacturing and inspection technology.

With its "Gleason Academy", Gleason leverages more than 150 years of expertise in producing gear manufacturing equipment to provide customers with seminars, webinars and classes in Gleason Academy locations, customers' premises and at industry events and symposiums. Gleason's training classes are available throughout the year on certain pre-determined dates or on request based on customer requirements.

Now, all courses available through the Gleason Academy can be found in one comprehensive catalog. The Gleason Academy offers courses in gear theory as well as hands-on gear design and manufacturing training; in total with 115 courses in 12 training centers around the globe: 4 in Europe, 4 in Asia and 4 in the Americas. While each location specializes in different gear technology topics, specific classes have been revised to be conducted in several locations to provide customers with a consistent and state-of-the-art training experience.

(*www.gleason.com/training*)

Marposs

EXPANDS SOFTWARE CAPABILITY WITH BLULINK ACQUISITION

Marposs has announced the acquisition of Blulink (Reggio Emilia, Italy), a company specializing in quality control and process management software development.

With a team of 40 engineers and professionals, the acquisition of Blulink expands and strengthens Marposs' capability in developing software products. This will help Marposs support its customers and move them more quickly to realizing Industry 4.0 initiatives.

Established in 1990, Blulink has focused its work on the development of software solutions for the integrated management of quality and safety in the working environment with a goal of helping companies to grow, be more efficient and reduce costs. Its most advanced research resulted in the Quarta3 platform, released in 2012 and adopted by over 1,000 companies in Italy as well as in many countries in the world. (*www.marposs.com*)

Seco Tools

ANNOUNCES NEW MANAGER OF ENGINEERING SERVICES

Seco Tools has named **Tyler Martin** as its new manager of engineering services. Formerly the manager of technical services, Martin previously oversaw the Technical Center at Seco's headquarters in Troy, Michigan. In addition to the Technical Center, Martin will now also manage Seco's Engineered Solutions team, working closely with customers to assist in the development of fully optimized manufacturing processes.

"I'm very excited by the opportunity to make a greater contribution to Seco," said Martin. "Our engineering services give our customers access to our worldwide network of experts, and I'm looking forward to working with the global team to further improve our capabilities, expand our services and develop new partnerships, all to bring even greater benefit to our customers."

Martin initially joined Seco as a technical specialist, focusing on outside sales, before earning promotion to Seco Technical Education Program (STEP) technician in March 2011. For more than six years, Martin ran benchmark tests, evaluated new products and demonstrated techniques to students in STEP courses. At the same time, he began to pursue further education at Eastern Michigan University, where he is currently completing the coursework for his master's degree in engineering management.

Prior to joining Seco, Martin served as a manufacturing engineer for an Illinois-based manufacturing company, overseeing the business' CNC tooling and supply management. He also garnered experience in education as a part-time faculty member at Illinois Valley Community College, where he taught courses on CNC machining and industrial technology. Martin got his start in manufacturing as a research and development engineer following his graduation from Illinois State University with a Bachelor of Science in integrated manufacturing systems technology. (*www.secotools.com*)

Hexagon

KEYNOTE SPEAKER KICKS OFF 2018 ASQ INSPECTION DIVISION CONFERENCE

Zachary Cobb, director of engineering and R&D in North America, Hexagon Manufacturing Intelligence, was the keynote speaker at the 2018 ASQ Inspection Division Conference. Cobb presented "*Shaping the Future of Manufacturing*," a frontline view on how emerging technologies, processes and production methods are transforming the world of manufacturing.

Cobb discussed concepts of connectivity and the importance of linking systems and information together. He addressed the role model-based engineering plays in the tools, connectivity, data analysis and quality in the organization. The presentation also covered the changing workforce and its impact on the enterprise. Attendees looking to leverage the benefits of Smart Factory practices found Cobb's outlook on the future both helpful and exciting.

Cobb is part of a global team responsible for the design, development and support for Hexagon stationary and portable coordinate measurement machines and accessory products. He previously served in engineering management roles at Loud Technologies in Massachusetts and Mackie Designs in Reggio Emilia, Italy, where he led teams in the development of professional sound reinforcement products. Gaining expertise in engineering management at an international level, he learned the value of cross cultural awareness and its importance to engineers working in a global organization. Cobb holds a bachelor of science degree in electrical engineering (BSEE) from Worcester Polytechnic Institute. (*hexagonMI.com*)

Schuler

SELLS 100TH HOT STAMPING LINE

In 1993, Schuler delivered the first three hot stamping lines to automobile manufacturer Ford in the USA. What was a brand-new method at the time has since established itself on the market as a global forming technology for automotive lightweight construction — and the trend continues unabated: Schuler has now sold what is the 100th hot stamping line to a Chinese automotive supplier.

"Compared with forming aluminum, carbon fiber-reinforced plastics and dual phase steels, this technology is an inexpensive alternative for lightweight automobile construction," as Daniel Huber explained, the head of Division Hydraulic at Schuler. Oemer Akyazici, the CEO of Schuler China, added: "Chinese automobile manufacturers and automotive suppliers, such as Shanghai Superior Die Technology Co., Ltd. (SSDT) or Baowei are increasingly turning to hot stamping."

The method, which involves heating sheet steel blanks to 930 degrees and cooling them during forming, was first introduced in the early 1990s — initially to improve passenger safety in vehicles — for example, to reinforce the doors in the Saab 9000, thus helping it to pass the stricter crash tests in the USA.

The technology was first introduced to large series production of the Ford Sierra in Europe and the Ford Mercury in the USA. The side impact beams and bumpers were created on Schuler systems at the time. After the turn of the millennium, the industry increasingly saw this method's potential for reducing vehicle weight while keeping pace with increasing safety requirements. Because press hardened components have a greater tensile strength that cold-formed high-strength steels, the use of material can be reduced, thus making the components lighter.

In 2006, the body of the Volkswagen Passat was the first to use twelve press hardened components. To allow this to happen, Schuler had built six hot stamping lines within the shortest possible time, and installed these at the Kassel plant. "This laid the foundation for growth that is still continuing," said Daniel Huber, general manager of the Schuler site in Waghäusel, Germany.

Currently, some 500 million hot stamped parts are produced annually on more than 400 systems worldwide. And, according to Huber, experts anticipate further growth: "Schuler identified this development at an early stage, and set up a Competence Center for press hardening at our Waghäusel site in the year 2006." This was followed in 2016 by the Hot Stamping TechCenter in Göppingen, a research and demonstration facility at the company's headquarters. (*schulergroup.com*)

December 3–6—CTI Symposium Germany 2018

Berlin, Germany. CTI Symposium Germany provides 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 including digital manufacturing, IoT, zero-emissions, electric vehicles, hybrid transmissions and more. Speakers include representatives from Audi, ZF, VDA, Valeo, Jaguar, LG Chem, Magna Powertrain and more. For more information, visit *drivetrain-symposium.world/*.

December 4–6—Power-Gen International 2018

Orlando, Florida. Power-Gen International provides comprehensive coverage of the trends, technologies and issues facing the generation sector. Displaying a wide variety of products and services, Power-Gen International represents a horizontal look at the industry with key emphasis on new solutions and innovations for the future. Topics include plant performance, cyber security, energy storage, flexible generation and more. To celebrate the 30th anniversary, the show is awarding 30 scholarships to new attendees. Learn more at *www.power-gen.com*.

December 5–7—AGMA Steels for Gear Applications

Clearwater Beach, Florida. This new AGMA class allows attendees to make use of steel properties in a system solution and understand the potential that different steel options can offer for their various applications. Those in attendance will explore performance of the material and how the steel produced effects the component and system. Objectives include material properties, selecting materials, verifying and specifying steel properties, and applying methods. Gear engineers, gear designers, material specialists or metallurgists at OEMs, Tier 1s, Tier 2s etc, production engineers, technicians and managers should consider attendance. Instructors include Lily Kamjou, Patrik Olund and Fredrik Lindberg. For more information, visit *www.agma.org*.

January 7–11—SciTech 2019

From its creation in 1963, the American Institute of Aeronautics and Astronautics (AIAA) has organized conferences to serve the aerospace profession as part of its core mission. Spanning over 70 technical discipline areas, AIAA's conferences provide scientists, engineers, and technologists the opportunity to present and disseminate their work in structured technical paper and poster sessions, learn about new technologies and advances from other presenters, further their professional development, and expand their professional networks that furthers their work. Five focus areas include science and technology, aviation, space, propulsion and energy/defense. For more information, visit *scitech.aiaa.org*.

January 14–16—A3 Business Forum 2019

Orlando, Florida. The Association for Advancing Automation (A3) Business Forum is the world's leading annual networking event for robotics, vision & imaging, motion control, and motor professionals. Over 600 global automation leaders attended the 2018 show. A broad range of companies participate including Amazon, Ametek, GM, Fanuc, ATI, Gudel and more. The event includes keynote and breakout sessions on the human exploration of Mars, a global economic outlook, automation market update, trends in robotics, responsible artificial intelligence and others to be announced. Networking opportunities include a golf scramble, a wellness walk, and a first timer's reception. For more information, visit *www.a3automate.org/a3-business-forum/*.

January 22–25—World of Concrete 2019

Las Vegas, Nevada. Original equipment manufacturers from around the world and exclusive U.S. distributors of equipment, tools, products and services for the commercial construction, concrete and masonry industries attend World of Concrete. The show attracts approximately 1,500 exhibitors and occupies more than 700,000 net square feet of indoor and outdoor exhibit space. World of Concrete is the premier event for the commercial construction trades. Education tracks include engineering, safety and risk management, general business, business and project management and concrete 101. Interactive workshops include trainer training, construction boot camp, sales and more. For more information, visit *www.worldofconcrete.com*.

February 12–14—IPPE 2019

Atlanta, Georgia. The International Production & Processing Expo is the world's largest annual poultry, meat and feed industry event of its kind. A wide range of international decision-makers attend this annual event to network and become informed on the latest technological developments and issues facing the industry. The 2019 show will expand to all three halls of the Georgia World Congress Center. It will bring more than 1,200 exhibitors and 30,000 attendees to Atlanta to discuss innovations in production and processing. Note that the date has been moved to accommodate the Super Bowl coming to Atlanta in 2019. For more information, visit *www.ippexpo.org*.

February 26–28—Houstex 2019

George R. Brown Convention Center, Houston, Texas. Houstex 2019 examines everything from additive manufacturing to robotics, machining centers to welding, and dozens of technologies in between. With more than 58,000 square feet of exhibit space, Houstex 2019 will showcase products of all types, Lunch & Learns to Brew & Views, Keynotes to Knowledge Bars, attendees will hear about hot topics and best practices they can put to use immediately. Explore aisle after aisle of the latest manufacturing products, software and services. This event is brought to you by SME and AMT. Industries represented include aerospace, automotive, industrial, medical, oil and gas, plastics and more. For more information, visit *houstexonline.com/*.

March 2–9—IEEE Aerospace Conference 2019

Big Sky, Montana. The international IEEE Aerospace Conference, with AIAA and PHM Society as technical cosponsors, is organized to promote interdisciplinary understanding of aerospace systems, their underlying science and technology, and their application to government and commercial endeavors. The annual, week-long conference, set in a stimulating and thought-provoking environment, is designed for aerospace experts, academics, military personnel, and industry leaders. The 2019 conference is the 40th in the conference series. Conference topics include aerospace systems, military, civilian or commercial aerospace endeavors, government policies and aerospace engineering and management. For more information, visit *www.aeroconf.org*.

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Matthew Jaster, Senior Editor

Regular readers of Gear Talk, our bi-weekly gear blog courtesy of Charles Schultz, know that he is extremely passionate about building an educational library and keeping detailed records in order to best transfer a company's gear knowledge from one generation to the next.

While we adhere to this in the pages of *Gear Technology*, it's worth noting that technical journals, magazines and 1,800 page bevel gear textbooks are not the only way to learn a little something about this great industry of ours.

Technology today allows a person in Michigan (already freezing in November) to take a tour of a forging plant halfway across the globe. It allows that same person to put on a VR headset and see what is happening in a German cutting tool factory in real-time.

Books and magazines are great (and necessary to document manufacturing and engineering technology as it evolves), but don't forget that little Chrome, Safari, Edge, Firefox or Internet Explorer shortcut on your computer. The Internet has a world of good — sometimes bad — information available to those with a simple curiosity about how and why things work. Some examples:

Extreme Forging

Forging is a definite showstopper in manufacturing. If you can set up a tour of a forging factory, the Addendum team strongly suggests making it happen. However, a forging factory is very loud, very hot and the walls and floors tend to vigorously shake. An easier more comfortable solution to see how things work at a forging plant is to visit the following link:

www.youtube.com/watch?v=daZXEM-j_YA

Big Gears

Is there anything more fascinating than a gigantic gear wheel? How is it built? How is it cut? How do they move that thing across state lines and put it to work? YouTube has a treasure trove of big gear videos including one where FLSmidth produces gear units and drive solutions for the cement and minerals industries (*www.youtube.com/watch?v=SH1znWhb-a4)* and one where HMC in Indiana gives insight into the manufacture of a girth gear (*www.youtube.com/watch?v=OILZgEQHutw)*

Wind Turbine Gearbox Inspection

My bucket list includes climbing up a wind turbine one day to watch professionals inspect the gearbox. This is probably not going to happen due to OSHA regulations. The next best thing is watching it play out over YouTube with some catchy music in the background. No fear of heights, no papers to sign, just some good ole fashioned gearbox inspection footage and a sick drumbeat! *www.youtube.com/watch?v=z4vKzrGPnE8*

Testing the Factory of the Future at Purdue

Professor Karthik Ramani of Purdue University is joining forces with manufacturers to build virtual factories using augmented reality — so they can test new labor-saving technologies in the virtual world, before installing them in the real world.

Is an autonomous robot going to make a factory more productive? With augmented reality, they can physically simulate how workers will interact with a robot, or any other new technology. They can virtually experiment with rearranging their shop floor to maximize productivity. And if new technologies are successful, they can use augmented reality to train new workers — in essence, they can become pre-skilled to work efficiently, before they ever set foot on the factory floor. This is just one example of technology driving innovation in manufacturing.

There is plenty of information online to satisfy the most curious person. There are countless books, magazines, websites, and videos dedicated to teaching us how to manufacture a spur gear in our basement, what the inside of a girth gear looks like or how to 3D-print a gear and put it to good use inside an aircraft.

It's equally as important to get out into the real world and see as much of this firsthand as you can, but never forget the power of a good web search. Thanks to the Internet, you've got a potential classroom in front of you every morning you sit down at your desk with a cup of coffee.