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BUYERS GUIDE 2017

GEAR MATERIALS

- FORGINGS
- CLEANER GEAR STEELS
- INFLUENCE OF DEFECT SIZE ON LOAD CARRYING CAPACITY

PTG-1L

GS 400

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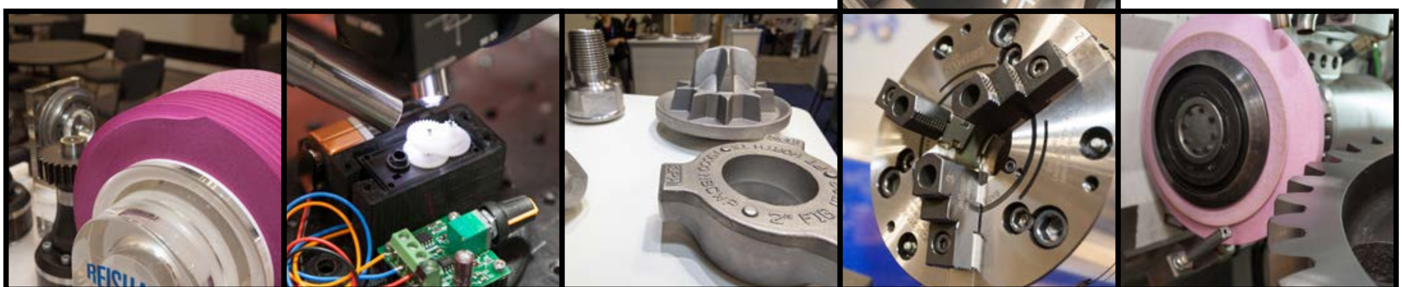

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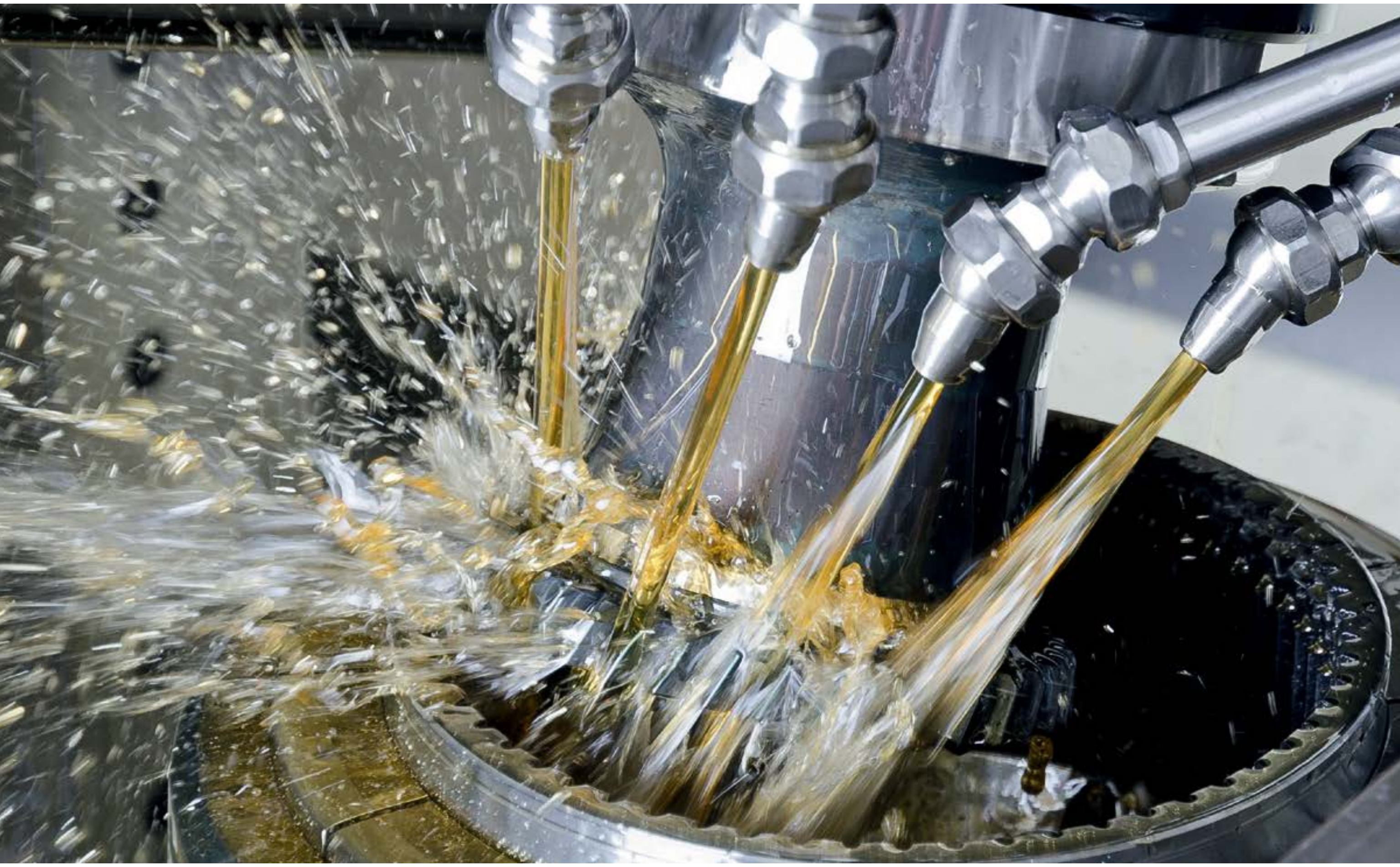

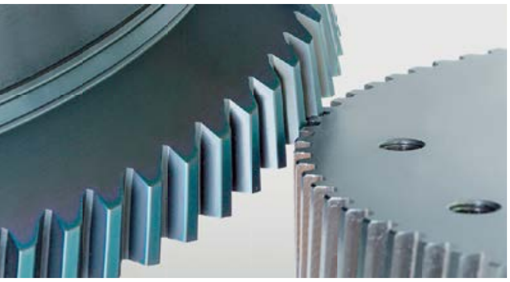

THE GEAR INDUSTRY'S INFORMATION SOURCE

www.geartechnology.com

gear TECHNOLOGY TV

Ask the Expert LIVE!

Watch all the "Ask the Expert Live" sessions recorded at Gear Expo 2017, along with one-on-one interviews with exhibitors. Watch and learn: *www.geartechnology.com/tv/*

Kapp Niles KN5Ci

Gearing and function surfaces such as drillings and plane faces can be primarily machined by grinding in one clamping fixture with the KN5Ci. Even extreme shape and positional tolerances required for precision gearing in robot and aerospace applications can reportedly be realized.

www.geartechnology.com/videos/Kapp-Niles-KN5Ci/

Gleason Automation Systems

Gleason Machine Tool Loading systems are designed for integration with multiple types of CNC machines from most manufacturers. (*www.geartechnology.com/videos/Gleason-Automation-Systems-/*)

Gear Talk

Check out (*www.geartechnology.com/blog/*) for our resident gear blogger Charles Schultz, who writes a bi-weekly column on his thoughts, musings and observations of the gear industry including information from Gear Expo in Columbus.

Gear Expo Live:

Check back to the GT website and E-Newsletters for our video series from Gear Expo including out Ask the Expert Live series and individual interviews about the latest technology in gear manufacturing.

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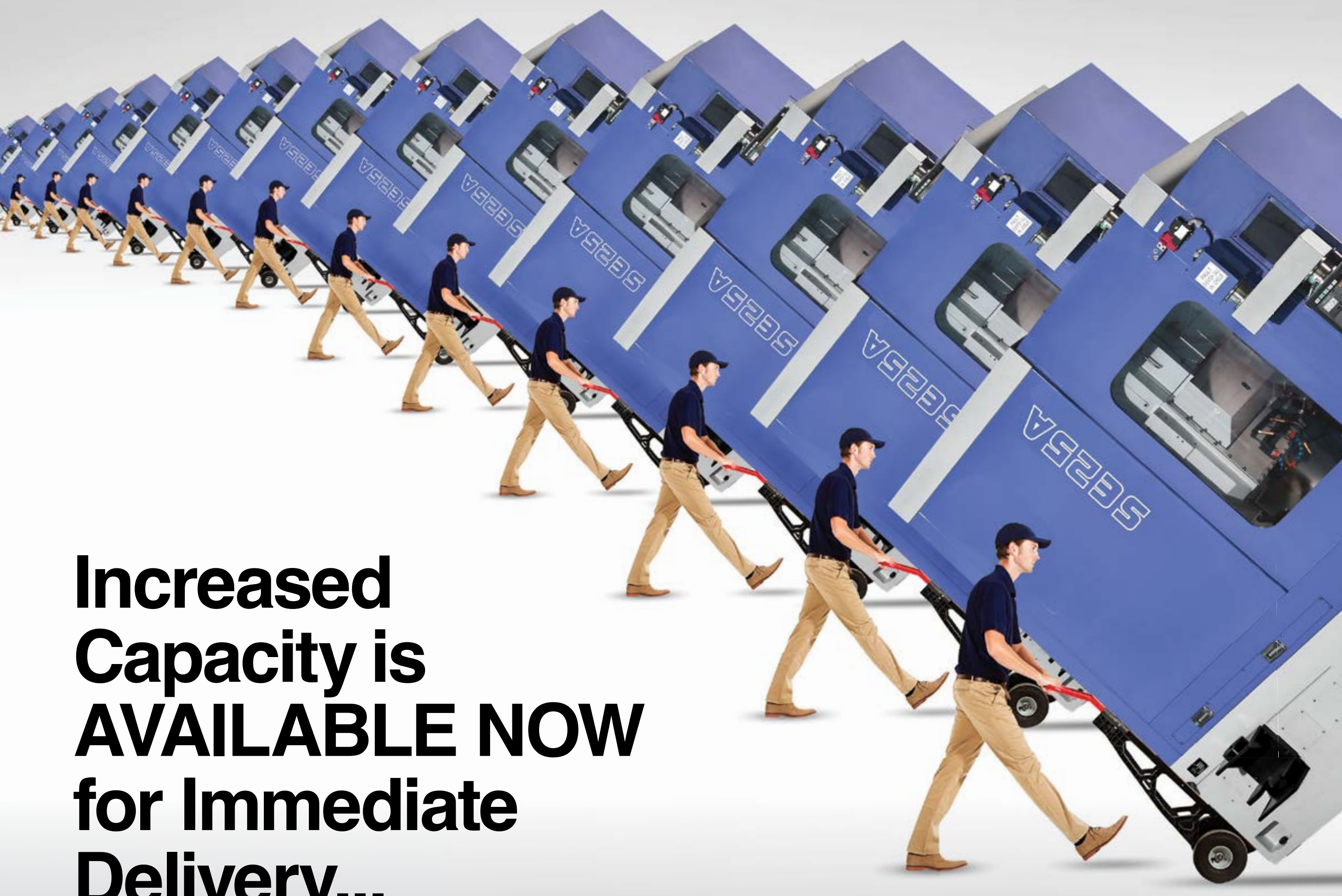

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Binge Watching for Gearheads

Publisher & Editor-in-Chief
Michael Goldstein

We've decided to install a man-cave at our office here at Randall Publications. Comfy chairs, surround sound, flat screen, the works. We're going all out, because we have some important watching to do. But before you get the wrong idea, we're not goofing off and binge-watching *Stranger Things*. No, we're watching *Gear Technology TV*.

We've recently added this new feature to our website, and we're quickly populating it with the highly educational, gear-related videos that we've produced. At Gear Expo this year, we recorded four new sessions of "Ask the Expert Live," which proved to be even more popular this time around than it was in 2015. At times we attracted as many as 50 people to our booth — sitting in the audience and standing in the aisles. They saw and participated in our sessions on "Cylindrical Gear Cutting," "Gear Design," "Gear Inspection" and "Ask Anything."

This year's panelists included Michael Hein, Team Leader, FZG; Dr. Ulrich Kissling, President, KISSsoft; Octave Labath, independent consultant and *Gear Technology* Technical Editor; Mariano Marks, Product Specialist – Gear Metrology, Wenzel America; Bill Miller, VP Sales & Service, Kapp-Niles USA; Dr. Hartmuth Müller, Head of Technology Development, Klingelnberg; Charles Schultz, *Gear Technology* Technical Editor, Blogger and Principal, Beyta Gear Service; Dr. Hermann J. Stadtfeld, VP Bevel Gear Technology and R&D, Gleason; Dr.-Ing. Karsten Stahl, Head of the Gear Research Centre, FZG; Frank Uherek, *Gear Technology* Technical Editor and Principal Engineer – Gear Engineering Software Development, Rexnord; Tom Ware, Product Manager – Gear Tools, Star SU; and Dr. Oliver Winkel, Head of Application Technology, Liebherr.

But "Ask the Expert Live" is just the start. We also recorded 18 sit-down interviews with many Gear Expo exhibitors. We asked about the latest technology on display at the show, and we learned about what you're going to see in the future from these technology leaders. It was our way of bringing Gear Expo to those of you who weren't able to make it to Columbus last month. There is a lot to learn by watching *Gear Technology TV*.

You'll find the link for *Gear Technology TV* on the main menu bar near the top of every page. Try watching a few videos and you'll quickly get hooked. Maybe you'll want to show them in the company lunchroom. You provide the pizza and we'll provide the knowledge. Maybe you'll even want to build your own man-cave.

While you're visiting *www.geartechnology.com*, don't forget to peruse the "GT LIBRARY" (you'll find it in the main menu bar near the top of the page). The GT LIBRARY includes more than 2,200 technical articles we've published in our 33+ years, searchable by subject, titles and/or keywords, including our very popular "Basics" series, which ran in our first five years. We get over 11,000 unique visitors to just this one feature of our website every month because of the essential content it provides.

If you find any of these features worthwhile, I have a small favor to ask. Our mailing list is audited each year for accuracy. That way our advertisers know that you readers actually exist, that you want to receive our magazine and that you value the information we provide. In order to prove you're out there, we need you to request a FREE subscription at least once every two years. We spend a lot of time and money on this facet of our business and we would prefer spending that time, money and energy to bring you more knowledge, including great features like "Ask the Expert Live." Please, please, go today, RIGHT NOW, to *www.geartechnology.com/subscribe.htm*. All you need to do is put in your e-mail address. If you're in our system already, we'll pre-populate the data for you. The whole process might take as little as 30 seconds, and then you're done – good for another two years.If you're like me and put it off, it won't get done, so do it now, while thinking about it, PLEASE!

And for those of you who design, use, maintain, repair or buy mechanical power transmission products (including gears), don't forget to subscribe or renew your free subscription to *Power Transmission Engineering*, too. Just go to *www.powertransmission.com/subscribe.htm*. Same routine — put in your e-mail address, and Poof! You're done in 30 seconds.

We truly appreciate you as subscribers, and as long as you keep requesting the magazine, we'll continue working hard to develop new educational and technical content. Thank you for your support.

Now, can someone dim the lights? And please pass the popcorn…

The following product items are highlights from Gear Expo 2017 in Columbus, Ohio. Please check back to *www.geartechnology.com* for additional information on the new technologies discussed during the event.

Klingelnberg

EXHIBITS SPEED VIPER 300 AND GEARENGINE ARCHITECTURE SOFTWARE

Students from Ohio State University tour the Klingelnberg booth at Gear Expo 2017.

On display front and center at Klingelnberg's booth was the Speed Viper 300, a machine designed for generating grinding small parts. The machine is catered specifically towards the automotive industry, a first attempt to break into the field for Klingelnberg. Originally introduced at EMO in September, Gear Expo was the Speed Viper 300's U.S. debut.

The Viper series of grinders has a number of different features under its belt. The platform is designed to be flexible, with tool diameters ranging from 210 mm to 320 mm and travel paths that allow for machining a broad range of components, and is built to be easily maintained. It features a cutting speed of up to 100 m/s, vibration-damping cast polymer and a compact frame. The 300 specifically is a single spindle machine, but Klingelnberg has plans for a double-spindle model by mid next year.

The Speed Viper is designed to integrate Industry 4.0 (Industrial Internet of Things) technology, and it's in this field that Klingelnberg is shining. They have developed a new software they've dubbed the *GearEngine Architecture* which is designed for a closed loop machining process and features a digital twin that follows a workpiece through every step of the entire value chain, from bar metal to end of line tests, across every machine it's used on.

The software tracks the machines themselves, as well. It keeps an eye on the tooling used in the machine, looking at how long it's been used for, as well as its performance over time, to analyze wear on the tool and when it's time to swap out for a new one.

Another main feature is that the software's evaluation parameters, which Klingelnberg has designed to one-up established paper parameters such as fH α and ß and cut out some of the guesswork involved in the process.

"You get it printed out on a sheet, and then you have to type in the deviations of these evaluation parameters," Dr. Hartmuth Müller, head of technology and innovation at Klingelnberg, said. "The big 'but' is this is not directly related to the chart. And what we have is we can now numerically, precisely describe the manufacturing imperfection and then we can create a software package that automatically minimizes these manufacturing errors without going into this abstract world of evaluation parameters like fH α, fH ß and so forth."

Müller describes the new *GearEngine Architecture* as "a data lake," a vast pool of information compiled by the software constantly monitoring every step of the manufacturing process. And from that lake of data comes many of the possibilities you're used to hearing about from Industrial Internet technology: preventative maintenance solutions such as the one described with machine tools, opportunities to iterate on product design or streamline the manufacturing process based on the data seen and more.

For more information:

Klingelnberg America Inc.
Phone: (734) 470-6278
www.klingelnberg.com

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Gleason GRSL Gear Rolling System

SETS STANDARD FOR THROUGHPUT FOR HIGH-SPEED, HIGH-VOLUME TESTING

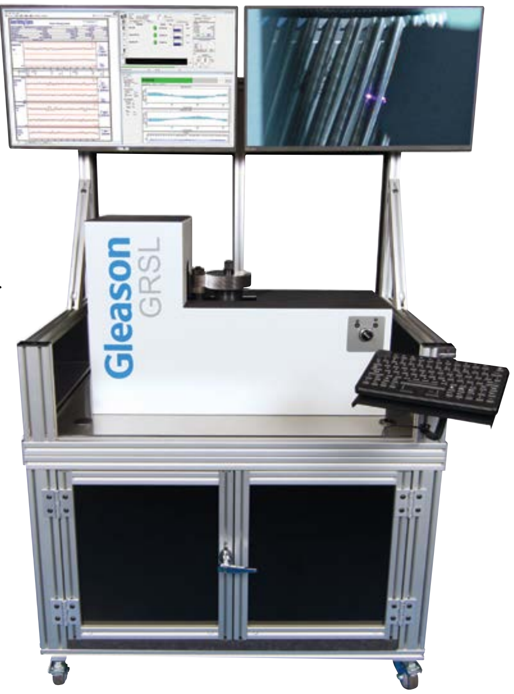
The GRSL Gear Rolling System with Laser provides both double flank roll testing as well as analytical index and involute measurement on all teeth during the same inspection cycle in a matter of seconds. It made its debut during Gear Expo in Columbus.

This new technology is available in a manual, semi-automatic or fully automatic configuration depending on the needs of the customer. The index and involute measurements are analyzed using Gleason Metrology's *GAMATM* gear analysis software which allows the operator to see common charting between the GMS analytical inspection machine and the GRSL gear rolling system. With *GAMA*, over fifty analysis packages are available for our customers with all major industry standards such as AGMA, DIN, ISO, etc., along with customer specific analysis requirements developed for industry in the *GAMA* platform.

This patent pending design measures external, cylindrical gears up to 250 mm in diameter and in a range of 0.4 to 7.2 module. The double monitor option provides a simple view of ongoing trends in the high speed inspection environment where one monitor can display results of several hundred parts inspected over time while the other can show real time results of the gear being inspected.

Additional highlights include: Composite testing and index and profile inspection are performed in the same test cycle. Inspection of all 31 teeth on a typical helical gear can be performed in under 10 seconds compared to 160 seconds on a conventional analytical machine. The workstation comes standard with a single 22" monitor with dual monitors and touchscreen also available.

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



Liebherr

INTRODUCES NEW MACHINES IN MULTIPLE FIELDS

Over the course of the last few years, Liebherr has released four new machines, many of which were revealed at EMO 2017. Each machine is an advancement for Liebherr in a separate field of gear manufacturing.

Liebherr's new offerings include the LK 300 and 500 skiving machines featuring an all-new skiving head and plug-in coolant nozzles. The machines' new skiving head is designed to be vibration free, which alongside a number of other features such as a rigid machine design and a table with a direct drive make for steady, consistent machining processes. And the LK series machines allow for enough nozzles to be plugged in for every workpiece to get its own. The result is Liebherr's flagship wet internal skiving machine line.

Another advance this year, the LD 180 C, is a chamfering and deburring machine that was released this year. A primary selling point for the machine is that it can be inserted into an already existing production line. Liebherr also designed the machine with precision, flexibility and consistency in mind. The LD 300 C is also available for those needing a bigger machine, with a third option, the 280, on its way soon.

There are also the LC 180 α/280 α modular hobbing machines. Much like with Liebherr's new skiving machines, the LC series comes with a brand new hob head designed for increased flexibility and productivity. Other improvements include better chip removal, optional equipment such as cranes and conveyors and a 50 percent faster spindle speed. The LC series is capable of machining workpieces to a module of five millimeters.

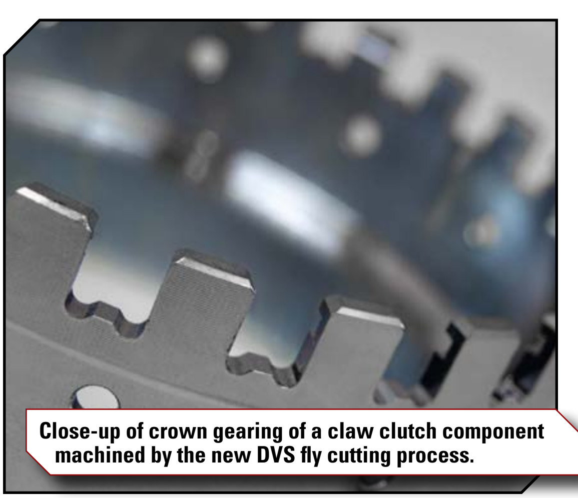
And finally, the LS 180 E gear shaping machine, is a resizing of last year's LS 180 F. The LS 180 E is half the size of the 180 F, making it more ideal for small job shops without losing any of the performance ability of its predecessor and making it easier and faster to set up manufacturing runs. The series as a whole is considered by Liebherr to be ideal for helical gearing.

Going along with the LS 180 series is the brand new SKE70 shaping head that was revealed at EMO. The new gear shaping tool is the smallest of Liebherr's shaping heads, measuring only 70 mm.

For more information:
Liebherr Gear Technology, Inc.
Phone: (734) 429-7225
www.liebherr.com

DVS Technology America

CREATES CUSTOM FLY-CUTTING SOLUTION FOR AUTO SUPPLIER



Close-up of crown gearing of a claw clutch component machined by the new DVS fly cutting process.

DVS Technology America received an inquiry from a Tier 1 supplier from the U.S. automotive industry. The inquiry concerned the complex challenge of realizing a highly productive as well as precise production cell for manufacturing castle teeth components with crown gearing on the face side, which are used in a 9-speed automatic transmission by the American end customer. According to the supplier, the manufacturing requirements for this component could not be met using any of the solutions currently available on the market.

The user required the working of a special tooth flank shape on both sides of the workpiece, in an extremely tight tolerance range of only a few micrometers. In addition, it was necessary to make the tooth base flat, with a very strict tolerance. Together with the DVS gearing specialist Präwema Antriebstechnik, DVS Technology America achieved a solution which involves two fly cutting twin spindle milling machines of the type Präwema

WPSLV 2-2 custom-designed for the application of the U.S. supplier.

An innovative axis system with synchronized CNC axes was implemented to comply with the special requirements of the customer application. Accompanying this, the production of the required flank modification of the crown gearing in combination with the special machine kinematics was simulated and analyzed in detail first using a CAD system in 3-D view. Constant achievement of the strict manufacturing tolerances was confirmed ultimately during the actual machining operation of the two Präwema machines.

In addition to maximum thermal and dynamic machine stability, one of the keys to the process was the tool concept, which was on display at Gear Expo in Columbus. The tool had been developed on the basis of precise tool geometry and application parameter design, in the form of a multi-blade fly cutter equipped with shaped indexable inserts. This stands out both on account of its

The multi-blade fly cutter with shaped indexable inserts, recently shown at Gear Expo 2017 in Columbus, OH.

extremely smooth running and the consistently high service life of the inserts used. The Präwema fly cutting method with only one direction of cutting from the inner to the outer diameter performed by rotating the cutter effectively prevents the formation of burrs in the groove of the inner diameter, which can otherwise only be removed later in a costly and labor-intensive process. The burr produced at the outer diameter is removed during the milling process in the Präwema machine using integrated deburring operations which have no effect on the cycle time. The use-optimized synchronization of tool and workpiece in a constant speed and angle ratio permits the U.S. supplier to achieve extremely short cycle times and thus maximum productivity.

The production cell comprising the two Präwema machines was implemented in the existing infrastructure of infeed and outfeed conveyors – also with the support of local experts from DVS Technology America – and put into operation there. The raw parts are picked up from the customer-side automation by a shuttle system integrated in each machine and then transferred to the two spindles from behind through the respective machine. Following machining, the finished parts are collected automatically by the shuttle system and returned to the customer's automation system. The machines are also equipped with an engraving device which labels the machined castle teeth components with their respective drawing number, machining date, time and spindle, thus permitting permanent traceability of the finished workpieces for customer and end user.

For more information:
DVS Technology America
Phone: (734) 656-2080
sales.america@dvs-technology.com
www.dvs-technology.com

Kennametal

OFFERS TWO NEW SOLUTIONS FOR ROUGHING AND FINE FINISHING

Iron's everywhere. The turbines in those big windmills popping up all over the place. Engine blocks, transmission cases, and turbocharger housings. The pumps that bring water to our faucets and the hydraulic manifolds that put the "move" into earthmoving machinery. Without iron, none of these would be possible. This is why Kennametal has put so much effort into producing cutting tools that make iron machining both cost-effective, efficient, and ensures easy handling.

One significant step in this direction came a little over one year ago, when Kennametal announced its Mill 16 face mill, the next generation in roughing tools designed specifically for removing large amounts of cast iron quickly, offering the highest productivity and lowest cost per edge in roughing and semi-finishing applications.

Making a change

Kennametal is pleased to announce that it is building on that success by expanding the Mill 16 platform by introducing new cutter body styles, new insert geometries and grades, and a split case design for large diameter bodies that reduces spindle bearing loads.

With these new additions the portfolio will fit any cast iron face milling applications. From fine pitch wedge style cutters for highest productivity and very powerful machines to medium and coarse pitches screw-on cutters where horsepower is limited (the machining of small components to very large components).

The Mill 16's new split case design meets truly massive machining needs, with wedge-style cutter bodies ranging from 300 to 500 mm (12 to 20 in.) in diameter. And for those worried about hanging such humungous cutters off their machine spindles, there's good news: the largest split case Mill 16 cutter body weighs only 20.4 kg (48.45 lb.), roughly one-third that of competing designs, but still able to rotate at up to 2,800 rpm.

And there is even more good news. All cutters use the same innovative, multi edged design insert. An insert with 16 cutting edges that provides lowest cost per cutting edge.

Finishing Up Consistently with KCFM

To an engine manufacturer, flatness and finish is everything. Without it, leaks are sure to occur, leading to expensive warranty claims and unhappy customers. The same can be said for those making transmissions, hydraulic manifolds, pump bodies, and anywhere a smooth sealing surface is needed. Unfortunately, the material used to make many of these components—cast iron—can be challenging to machine.

There are many options available on the market for fine finishing of cast iron these days. And most of them can achieve the required surface finish.

The deterioration of the finishing occurs as soon as the inserts show slight wear. That causes an increase in cutter pressure, resulting in vibration, and feeding marks are observed. The result is downtime due to frequent insert exchange.

The super positive KCFM — Kennametal Cast Iron Finishing Milling — with the new KBK50 full top PCBN (polycrystalline cubic boron nitride) grade was developed to address these issues.

Now customers can produce much more parts per edge in a reliable and consistent manner, so the cost per component will decrease.

And keep in mind machining time reduces drastically since PCBN can be applied with 3 times higher cutting speeds compared to carbide inserts.

Additional Options

Combining the semi finishing KY3500 silicon nitrate ceramic with KBK50 finishing wiper inserts is also a very productive, and cost effective solution for customers that don't want to have a full load PCBN inserts in the cutter.

PCBN and ceramic grades are perfect for mass production and stable conditions.

But in many cases there is also the need for fine finishing on rather unstable conditions, such as weak workpiece clamping, limited spindle speed, long overhang, or when tooling cost is the primary consideration.

The answer to that the carbide grade KC514M. A TiAlN PVD coating that is both tough and wear resistant. Designed for light to medium machining, KC514M can be applied with or without cutting fluids.

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

Koepfer America

TM200 R3 GEAR DEBURRING MACHINE OFFERS AUTOMATIC LOADING

As automation continues to transform the manufacturing industry, gear deburring often remains an operation performed by hand. This burdens gear manufacturers in several ways. First, quality control remains a challenge because each technician's skill impacts the final product. Second, as other processes become automated, deburring labor continues to grow as a portion of a finished part's overall cost. Finally, deburring time is highly variable because of breaks, distractions, tardiness, sickness, and other human effects. Consequently, manufacturers both large and small are looking to automated deburring solutions to remain competitive in today's market. The TM 200 R3 machine tool is such a solution.

Koepfer America now offers the TecnoMacchine ("TM") model 200 R3 gear deburring machine, which benefits gear manufacturing job shops and other gear manufacturing departments with a wide variety of part types and sizes. Adam Gimpert, business manager of Koepfer America, said "The versatility of these deburring machines helps job shops and gear manufacturers keep a competitive edge into the future."

The TM 200 series of gear deburring machines features 5 workstations that can be equipped with milling tools, cutoff wheels, and brushes to achieve the exact edge break, deburring, and/or chamfering operation required on multiple edges. These tools are easily adjusted for position, orientation, pressure, and speeds up to 24,000 rpm. The machine also includes radial CNC tool wear compensation. Lastly, work holding is flexible to accommodate most part types and sizes. Together, these features allow straightforward, versatile gear deburring with changeovers in under 30 minutes.

The TM 200 R3 features a rotary-magazine-type ("carousel") CNC loading and unloading system. This solution accommodates stackable work pieces up to 7.874" diameter (alternative TM models can deburr larger work pieces). The dual rotary magazines each comprise 8 easily adjustable towers. Each tower can hold parts up to 17.7" high. For example, 283 pieces can be loaded assuming a 0.5" face width gear. This allows the machine to

deburr unattended for hours.

During operation, the machine's SPC (statistical process control) station allows an operator to check quality mid-process. Additionally, for small lot sizes, the machine can also be used in manual-mode. In this case, the SPC station allows easy loading and unloading of a single work piece.

The TM 200 R3 produces finished work pieces in as little as 20 seconds for 3" diameter parts or 55 seconds for 7.8" diameter parts. This productivity combined with the machine's flexible automatic loading and unloading system offers gear manufacturers a long-term competitive deburring solution. The TM 200 R3 provides an optimum balance between productivity and flexibility, which is perfect for job shops as well as gear manufacturing departments with a complex variety of parts.

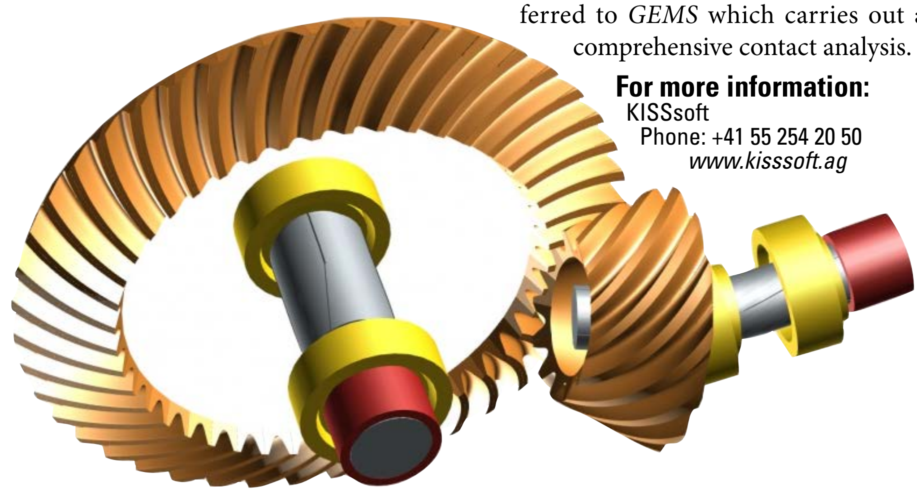
For more information:
Koepfer America
Phone: (847) 931-4121
www.koepferamerica.com

KISSsoft

TWO SOFTWARE SOLUTIONS, ONE SYSTEM DESIGN INTERFACE

KISSsys is KISSsoft's system add-on that enables you to model complete gear units and drive trains. KISSsoft calculates the service life and strength of the different machine elements, and transfers the results to *KISSsys*, where they are displayed in clear overviews. To achieve this, *KISSsys* brings together kinematic analysis, service life calculation, 3D graphics, and user-defined tables and dialogs.
With *GEMS* Gleason has introduced the next-generation design and manufacturing system for bevel gears. It is a powerful new software platform that provides highly desirable gear design and analysis capabilities, seamlessly connects with all your existing Gleason design software. *GEMS* helps optimize the complete bevel gear manufacturing process - from the idea to the finished, tested gear.
GEMS and *KISSsys* programs are now linked by a direct interface to exchange gear tooth and system design data between the two software packages. *GEMS* supplies the values for the geometry data of the bevel gear pair, which is imported into *KISSsys*. KISSsoft determines the EPG misalignments for the specified load points, taking shaft bending values into account. Results are transferred to *GEMS* which carries out a comprehensive contact analysis.

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



Jenoptik

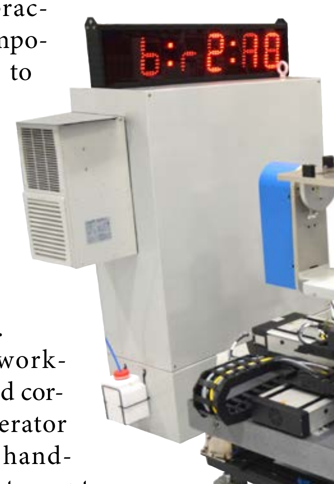
OFFERS FULLY AUTOMATED MEASURING SYSTEM FOR ROUGHNESS, CONTOUR

The Jenoptik Industrial Metrology division offers a fully automated measuring station which can be operated directly by staff on the production line. The HOMMEL-ETAMIC wavemove combines high-precision roughness and contour measurement technology with innovative CNC technology and eight fully automatic CNC axes to measure both roughness and contours in a single measuring run, recording as many data points as necessary. The system is well-suited to automotive production.

wavemove is integrated directly into the production process as an SPC measuring station. The workpiece can be clamped into the measuring system at any stage of production — wavemove recognizes the workpiece and automatically suggests the predefined measuring points via the operating program.

The wavemove allows manufacturers to perform twist measurements on sealing surfaces. On camshafts, roughness is typically measured at bearing points, in grooves and on the cam itself. The machine is also capable of performing highly complex measurement tasks on and in cylinder blocks. In this application, roughness measurements are performed in cylinder bores, on sealing surfaces and in the crankshaft bearing channel. In practice, these components have up to 70 defined measuring points, which are processed sequentially in a single measuring run.

Once the workpiece is clamped correctly, the operator uses a DMC hand-held scanner to capture



the data matrix code. Depending on the stage of production and the workpiece type, the operator selects the appropriate measuring program and starts the measuring run.

The measurement process itself is fully automatic — the measuring probes independently travel to the predefined measuring points on the workpiece, and the movable axes allow the measuring column to be moved upwards and downwards, crossways and lengthways. In addition, the pick-up element for the workpiece is mounted on a 360° turntable and can also be moved in different directions. Similarly, the traverse unit and measuring probe can be tilted, swiveled and rotated. This freedom of movement allows the sleeve to move the roughness probe to any measurement position, even those that are difficult to access.

If required, the contour probe can be operated in parallel with the roughness probe, which provides convenient top and bottom measurement via two probe heads. The high degree of flexibility in axis positioning means that the probes can access almost any point on the workpiece.

The software is designed to react flexibly to changes, and the presentation of measurement results can be customized, with printed reports including a high level of detail based on the customer's specific requirements. Any characteristics falling outside tolerance limits are flagged visually, and immediate reactive measures can be initiated by the machine operator thanks to the system's close proximity to the production line.

The measuring station itself is designed to meet the requirements of manufacturing environments. The motorized positioning unit is mounted on a granite plate and can be programmed to move the measuring column on an air slide. The control panel for the WAVECONTROL provides a simple interface that can be used to program the CNC programs. The operator uses a joystick to navigate to the relevant positions and then stores these values in the measuring program, ensuring that preparations for the fully automated measurement process can be quickly completed.

For more information:
Jenoptik
Phone: (248) 537-1471
www.jenoptik.com/metrology

About This Directory

The 2017 *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.

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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 2017 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 subcategories: *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

300 Below, Inc.
www.300below.com

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

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

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
SEE OUR AD P16

Broaching Machine Specialties
www.broachingmachine.com

Canada Broach
www.canadabroach.com

Capital Tool Industries
7-A, INDUSTRIAL ESTATE
PATIALA PUNJAB 147004
INDIA
Phone: +(91) 175-2351089
Fax: +(91) 175-2217102
capitaltool@usa.net
www.capital-tool.com
SEE OUR AD P61

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 P24

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
www.faessler-usa.com

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
4630 FREEDOM DRIVE
ANN ARBOR MI 48108
Phone: (734) 973-7800
Fax: (734) 973-3053
info@gmtamerica.com
www.gmtamerica.com
SEE OUR AD P28,29

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 P56–57,105

Gleason Cutting Tools Corporation
1351 WINDSOR ROAD
LOVES PARK IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com
SEE OUR AD P56–57,105

Gleason Works (India) Private Ltd.
PLOT NO. 37
DODDENAKUNDI INDUSTRIAL AREA
WHITEFIELD ROAD, MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com
SEE OUR AD P56–57,105

Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
SEE OUR AD P56–57,105

Goldstein Gear Machinery LLC
1840 JARVIS AVE.
ELK GROVE VILLAGE IL 60007
Phone: (847) 437-6605
Fax: (847) 437-6618
michael@goldsteingearmachinery.com
www.goldsteingearmachinery.com
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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
201 E. OGDEN AVE., SUITE 34
HINSDALE IL 60521
Phone: (847) 364-4800
Fax: (847) 364-4840
info@hanikcorp.com
www.hanikcorp.com
SEE OUR AD P4

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
SEE OUR AD P51

HobSource Inc.
834 E. RAND ROAD , SUITE 2
MOUNT PROSPECT IL 60056
Phone: (847) 398-8320
Fax: (847) 398-8326
sales@hobsource.com
www.hobsource.com
SEE OUR AD P62

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
info@klingelnberg.com
www.klingelnberg.com
SEE OUR AD BACK COVER, P15

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, P15

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

Koepfer America
koepferamerica.com

LMT USA
www.lmt-fette.com

Lalson Tools Corporation
www.lalsoncuttingtools.com

Leistritz Corporation
www.leistritzcorp.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, 27

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 Chicago
lurenusa.com

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
SEE OUR AD P8

Mitsubishi Materials USA
11250 SLATER AVENUE
FOUNTAIN VALLEY CA 92708
Phone: (714) 352-6100
Fax: (714) 668-1321
crivas@mmus.com
www.mmus.com
SEE OUR AD P41

Modern Gearing
www.moderngearing.com

Moncktons Machine Tools, LLC
www.mmtproductivity.com/

Mutschler Edge Technologies
mutschleredgetech.com

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

Norton | Saint-Gobain
www.nortonindustrial.com

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

QC American
www.qcamerican.com

R.A. Heller
www.raheller.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.
STAR SU LLC
5200 PRAIRIE STONE PARKWAY
HOFFMAN ESTATES IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.samputensili.com
SEE OUR AD INSIDE FRONT COVER–1, P60

Sandvik Coromant
www.sandvik.coromant.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
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Seco Tools Inc.
www.secotools.com/us

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

Shape-Master Tool Company
www.shapemastertool.com

Slater Tools Inc.
www.slatertools.com

Slone Gear International, Inc.
www.slonegear.com

Star Cutter Co.
23461 INDUSTRIAL PARK DRIVE
FARMINGTON HILLS MI 48335
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@starcutter.com
www.starcutter.com
SEE OUR AD INSIDE FRONT COVER–1, P60

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 INSIDE FRONT COVER, P60

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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com*.

300 Below, Inc.
www.300below.com

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

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

ATO Inc
www.ato.com

Accurate Specialties Inc.
www.accuratespecialties.com

Aksan Steel Forging
www.aksanforging.com

All Metals & Forge Group, LLC
75 LANE RD
FAIRFIELD NEW JERSEY 07004
Phone: (973) 276-5000
Fax: (973) 276-5050
info@steelforge.com
www.steelforge.com

SEE OUR AD P25, 43

American Friction Welding
www.teamafw.com

American Industrial Repair
www.americanindustrialrepair.com

Anihas Castings
www.anihas.com

ArcVac ForgeCast Ltd.
www.arcvacsteel.com

BGH Specialty Steel Inc.
www.bgh.de

Bhandari Precision Forgings Pvt. Ltd.
www.bhandariforgings.com

Bharat Forge Ltd.
www.bharatforge.com

Bohler High Performance Metals Pvt. Ltd.
www.bohlerindia.com

Bohler-Uddeholm Corporation
www.bucorp.com

Boltex Manufacturing
www.boltex.com

Brooker Bros. Forging Co.
www.brookerbrosforgings.com

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
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

Hunan Standard Steel Co. Ltd.
www.hu-steel.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

Lafert North America
www.lafertna.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

CATEGORY LISTINGS

McInnes Rolled Rings
1533 EAST 12TH STREET
ERIE PA 16511
Phone: (800) 569-1420 or (814) 459-4495
Fax: (814) 459-8443
sales@mcrings.com
mcinnesrolledrings.com
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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 & Metals, Inc.
www.nbmmetals.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
3665 E. 78TH STREET
CLEVELAND OH 44105
Phone: (216) 441-5990
Fax: (216) 441-2644
www.presrite.com
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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

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

Sensor Products Inc.
www.sensorprod.com

Shree Krishna Auto Indsutries
www.shreekrishnaauto.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

Walker Forge
www.walkerforge.com

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

Welland Forge
www.wellandforge.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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com*.

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

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

American Industrial Repair
www.americanindustrialrepair.com

American Swiss Products
www.americanswiss.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.
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

Breton USA
www.bretonusa.com

Broaching Machine Specialties
www.broachingmachine.com

C & B Machinery
www.cbmachinery.com

CNC Center
www.cnccenter.com

Capital Tool Industries
7-A, INDUSTRIAL ESTATE
PATIALA PUNJAB 147004
INDIA
Phone: +(91) 175-2351089
Fax: +(91) 175-2217102
capitaltool@usa.net
www.capital-tool.com
SEE OUR AD P61

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

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

Dreamtec Consulting LLC
www.dreamtec.us

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
5200 PRAIRIE STONE PKWY
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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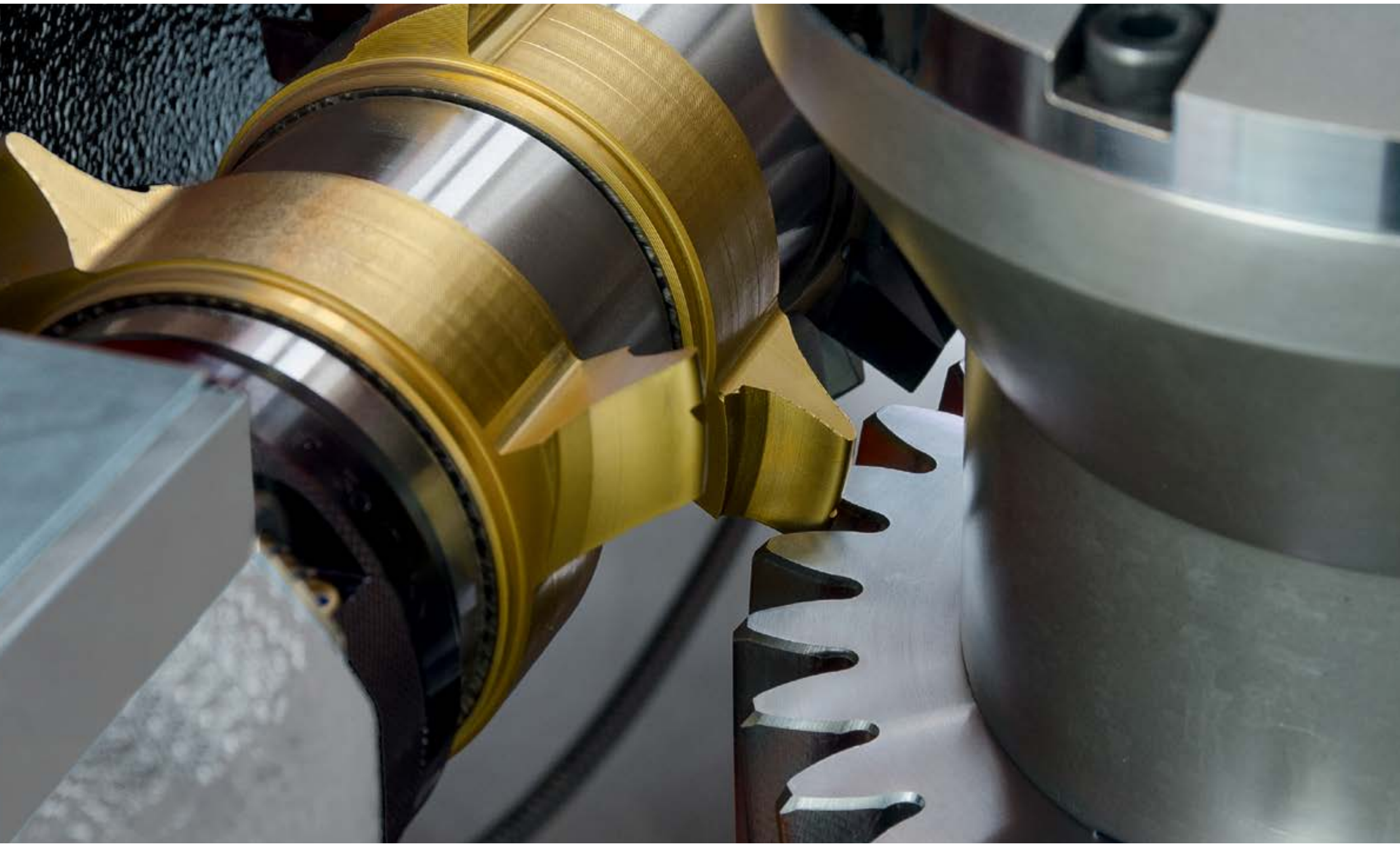
Fassler by Daetwyler Industries
www.faessler-usa.com

Federal Broach & Machine
www.federalbroach.com

Fellows Machine Tools
www.bourn-koch.com

Liebherr Performance.



Gear hobbing machine LC 180 DC

Gear hobbing machine LC 300 DC

Chamfering machines LD 180 C and LD 300 C

Chamfering in the work area

Simultaneous chamfering with ChamferCut – The best and most economical solution

- Established process in gear production
- Very precise chamfer geometry
- Premium chamfer quality and reproducibility
- No bulging or material deformation
- Standard tooth-root chamfering
- Very long tool life
- Lower tool costs compared to alternative processes

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

LIEBHERR

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
4630 FREEDOM DRIVE
ANN ARBOR MI 48108
Phone: (734) 973-7800
Fax: (734) 973-3053
info@gmtamerica.com
www.gmtamerica.com
SEE OUR AD P28,29

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 P56–57,105

Gleason Works (India) Private Ltd.
PLOT NO. 37
DODDENAKUNDI INDUSTRIAL AREA
WHITEFIELD ROAD, MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com
SEE OUR AD P56–57,105

Gleason Works Rochester
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 256-6776
www.gleason.com
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Goldstein Gear Machinery LLC
1840 JARVIS AVE.
ELK GROVE VILLAGE IL 60007
Phone: (847) 437-6605
Fax: (847) 437-6618
michael@goldsteingearmachinery.com
www.goldsteingearmachinery.com
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Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greg Allen Company
www.gallenco.com

HÖFLER - A Brand of KLINGELNBERG
www.hofler.com

Haas Multigrind LLC
www.multigrind.com

Hamai Co. Ltd.
www.hamai.com

Hanik Corporation
201 E. OGDEN AVE., SUITE 34
HINSDALE IL 60521
Phone: (847) 364-4800
Fax: (847) 364-4840
info@hanikcorp.com
www.hanikcorp.com
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Hans-Juergen Geiger Maschinen-Vertrieb GmbH
JAMES-WATT-STRASSE 12
D-72555 METZINGEN
GERMANY
Phone: +(49) 7123-18040
Fax: +(49) 7123-18384
geiger@geiger-germany.com
www.geiger-germany.com
SEE OUR AD P60

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
www.itwheartland.com

Index Corporation
www.indextraub.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 Niles
CALLENBERGER STRASSE 52
D-96450 COBURG
GERMANY
Phone: + 49 9561-866-0
Fax: +49 9561-866-1003
info@kapp-niles.com
www.kapp-niles.com
SEE OUR AD P37, 61

Kapp Technologies
2870 WILDERNESS PLACE
BOULDER CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
sales-USA@kapp-niles.com
www.kapp-usa.com
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Khemka Broach & Spline Gauge
www.khemkabroach.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

Koepfer America
koepferamerica.com

Lambda Technologies
www.lambdatechs.com

Leistritz Corporation
www.leistritzcorp.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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Luren Precision Chicago
lurenusa.com

MPT Manufacturing Process Technologies
www.mptinc.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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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
MACHINE TOOL DIVISION
46992 LIBERTY DRIVE
WIXOM MI 48393
Phone: (248) 669-6136
Fax: (248) 669-0614
brenda_motzell@mhiahq.com
www.mitsubishigearcenter.com
SEE OUR AD P8

Mutschler Edge Technologies
mutschleredgetech.com

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

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

Pegard Productics Division HARO
harotechnologies.com

Penta Gear Metrology LLC
6161 WEBSTER STREET
DAYTON OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com
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Phoenix Inc.
www.phoenix-inc.com

Pioneer Broach Co.
www.pioneerbroach.com

PlasmaRoute CNC
www.cncplasmacutterinc.com

Power Inverter Inc.
www.powerinverter.org

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
www.reishauer.com

Reishauer Corporation
www.reishauer.com

Roberts Sinto Corp.
3001 W. MAIN STREET
P.O. BOX 40760
LANSING MI 48901
Phone: (517) 371-2460
Fax: (517) 371-4930
www.robertssinto.com
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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.
STAR SU LLC
5200 PRAIRIE STONE PARKWAY
HOFFMAN ESTATES IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.samputensili.com
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Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

SerWeMa GmbH & Co. KG
www.serwema.de

Star Cutter Co.
23461 INDUSTRIAL PARK DRIVE
FARMINGTON HILLS MI 48335
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@starcutter.com
www.starcutter.com
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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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Steelmans Broaches Pvt. Ltd.
www.steelmans.com

Stenhoj Broaching Machines
www.stenhoj.dk

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

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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com*.

2L Inc.
www.2Linc.com

3M Abrasives
www.3m.com/Abrasives

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

ATO Inc
www.ato.com

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
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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
5200 PRAIRIE STONE PKWY
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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Fassler by Daetwyler Industries
www.faessler-usa.com

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 P56–57,105

Gleason Cutting Tools Corporation
1351 WINDSOR ROAD
LOVES PARK IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com
SEE OUR AD P56–57,105

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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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 Niles
CALLENBERGER STRASSE 52
D-96450 COBURG
GERMANY
Phone: + 49 9561-866-0
Fax: +49 9561-866-1003
info@kapp-niles.com
www.kapp-niles.com
SEE OUR AD P37, 61

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

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, 27

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 Chicago
lurenusa.com

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

Norton | Saint-Gobain
www.nortonindustrial.com

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
www.reishauer.com

Reishauer Corporation
www.reishauer.com

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

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

Samputensili S.p.A.
STAR SU LLC
5200 PRAIRIE STONE PARKWAY
HOFFMAN ESTATES IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.samputensili.com
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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
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Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

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

Star Cutter Co.
23461 INDUSTRIAL PARK DRIVE
FARMINGTON HILLS MI 48335
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@starcutter.com
www.starcutter.com
SEE OUR AD INSIDE FRONT COVER–1, P60

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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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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com*.

300 Below, Inc.
www.300below.com

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

AFC-Holcroft
www.afc-holcroft.com

ATO Inc
www.ato.com

Abbott Furnace Company
www.abbottfurnace.com

Advanced Nitriding Solutions
www.ans-ion.net

Aichelin Heat Treatment Systems, Inc.
www.aichelinusa.com

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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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 GmbH
www.stopoffpaints.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
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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 & Engineering
www.flametreating.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
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Gleason Works Rochester
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 256-6776
www.gleason.com
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Goldstein Gear Machinery LLC
1840 JARVIS AVE.
ELK GROVE VILLAGE IL 60007
Phone: (847) 437-6605
Fax: (847) 437-6618
michael@goldsteingearmachinery.com
www.goldsteingearmachinery.com
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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
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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
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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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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

Mindon Engineering
www.mindon-eng.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 P37

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.
3001 W. MAIN STREET
P.O. BOX 40760
LANSING MI 48901
Phone: (517) 371-2460
Fax: (517) 371-4930
www.robertssinto.com
SEE OUR AD P11

Rubig US, Inc.
www.rubig.com

SECO/Vacuum Technologies LLC
www.secovacusa.com

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

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.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 P34

Stack Metallurgical Services, Inc.
www.stackmet.com

Surface Combustion
www.surfacecombustion.com

TM Induction Heating
www.tminductionheating.com

Thermal Spray Coatings - A&A Coatings
www.thermalspray.com

Welland Forge
www.wellandforge.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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com.*

300 Below, Inc.
www.300below.com

ALD Thermal Treatment, Inc.
2656 24TH STREET
PORT HURON MI 48060
Phone: (810) 357-0685
Fax: (810) 357-0699
sales@aldtt.net
www.aldtt.net
SEE OUR AD P34

ATO Inc
www.ato.com

Accu-Temp Heat Treating
www.accutempheat.com/

Accurate Steel Treating, Inc.
www.accuratesteeltreating.com

Advanced Heat Treat Corp.
www.ahtweb.com

Advanced Nitriding Solutions
www.ans-ion.net

Aichelin Heat Treatment Systems, Inc.
www.aichelinusa.com

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 P60

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

Dayton Forging and Heat Treating
www.daytonforging.com

Detroit Steel Treating Co.
www.detroitsteeltreating.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

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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 & Engineering
www.flametreating.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
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 Works Rochester
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 256-6776
www.gleason.com

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Gozuk Co.LTD
www.vfds.org

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

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GERMANY
Phone: +(49) 2192-810
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com

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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.
715 PUSHVILLE ROAD
GREENWOOD IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

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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 Heat Treating Corporation
www.phtc.net

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

Precision Thermal Processing
www.precisionthermal.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

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

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

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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

Welland Forge
www.wellandforge.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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com*.

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

ABTech Inc.
www.abtechmfg.com

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

ATO Inc
www.ato.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 Industrial Repair
www.americanindustrialrepair.com

American Stress Technologies, Inc.
540 ALPHA DRIVE
PITTSBURGH PA 15238-2912
Phone: (412) 784-8400
Fax: (412) 784-8401
info@astresstech.com
www.astresstech.com
SEE OUR AD P91

American Swiss Products
www.americanswiss.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

Big C Dino-Lite Scopes
www.dinolite.us

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 P16

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

CNC Center
www.cnccenter.com

Capital Tool Industries
7-A, INDUSTRIAL ESTATE
PATIALA PUNJAB 147004
INDIA
Phone: +(91) 175-2351089
Fax: +(91) 175-2217102
capitaltool@usa.net
www.capital-tool.com
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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

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

Flame Treating & Engineering
www.flametreating.com

Flexbar Machine Corporation
www.flexbar.com

Foerster Instruments Incorporated
foerstergroup.com

Fredericks Company - Televac
www.fredericks.company.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
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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 ROAD, 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
1840 JARVIS AVE.
ELK GROVE VILLAGE IL 60007
Phone: (847) 437-6605
Fax: (847) 437-6618
michael@goldsteingearmachinery.com
www.goldsteingearmachinery.com
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Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Greg Allen Company
www.gallenco.com

HITEC Sensor Developments
www.hitecorp.com

Hanik Corporation
201 E. OGDEN AVE., SUITE 34
HINSDALE IL 60521
Phone: (847) 364-4800
Fax: (847) 364-4840
info@hanikcorp.com
www.hanikcorp.com
SEE OUR AD P4

Hexagon Metrology
www.hexagonmetrology.us

HobSource Inc.
834 E. RAND ROAD , SUITE 2
MOUNT PROSPECT IL 60056
Phone: (847) 398-8320
Fax: (847) 398-8326
sales@hobsource.com
www.hobsource.com
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Hydra-Lock Corporation
www.hydralock.com

ITW Heartland
www.itwheartland.com

Innovative Analytical Solutions
www.steelanalyzer.com

Interstate Tool Corp.
itctoolcorp.com

Involute Gear & Machine Company
www.involutegearmachine.com

Kapp Niles
CALLENBERGER STRASSE 52
D-96450 COBURG
GERMANY
Phone: + 49 9561-866-0
Fax: +49 9561-866-1003
info@kapp-niles.com
www.kapp-niles.com
SEE OUR AD P37, 61

Kapp Technologies
2870 WILDERNESS PLACE
BOULDER CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
sales-USA@kapp-niles.com
www.kapp-usa.com
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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
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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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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
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MPT Manufacturing Process Technologies
www.mptinc.com

Magnetic Inspection Laboratory
www.milinc.com

Maheen Enterprises
www.maheenbroaches.com

Mahr Federal 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.
715 PUSHVILLE ROAD
GREENWOOD IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com
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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
6161 WEBSTER STREET
DAYTON OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com
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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
12350 UNIVERSAL DRIVE
TAYLOR MI 48180
Phone: (313) 965-2900
Fax: (734) 946-0974
info@protoxrd.com
www.protoxrd.com
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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.
STAR SU LLC
5200 PRAIRIE STONE PARKWAY
HOFFMAN ESTATES IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.samputensili.com
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CH-2504 BIEL
SWITZERLAND
Phone: +(41)(32) 344-0406
Fax: +(41)(32) 344-0404
george.boon@schnyder.com
www.schnyder.com
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Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.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.
23461 INDUSTRIAL PARK DRIVE
FARMINGTON HILLS MI 48335
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@starcutter.com
www.starcutter.com
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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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Stone Tucker Instruments Inc.
www.stone-tucker.com

Stotz Gaging Co.
www.stotz-usa.com

Stresstech Oy
TIKKUTEHTAANTIE 1
40800 VAAJAKOSKI
FINLAND
Phone: +(358) 14-333-000
Fax: +(358) 14-333-0099
info@stresstech.com
www.stresstech.com
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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

Test Equipment Distributors
www.tedndt.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

Wenzel America
28700 BECK ROAD
WIXOM MI 48393
Phone: (248) 295-4300
Fax: (248) 773-7565
inquiries@wenzelamerica.com
www.wenzelamerica.com
SEE OUR AD P64

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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, 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
2115 PROGRESS DRIVE
SPRINGFIELD OH 45505
Phone: (800) 428-1133
Fax: (800) 634-6480
sales4@dillonmfg.com
www.dillonmfg.com
SEE OUR AD P51

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

Lafert North America
www.lafertna.com

Lubegard / International Lubricants Inc.
www.lubegard.com

Lubrication Engineers
www.lelubricants.com

Lubriplate Lubricants Co.
129 LOCKWOOD STREET
NEWARK NJ 07105
Phone: (973) 589-4432
Fax: (800) 347-5329
www.lubriplate.com
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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

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
SEE OUR AD P61

Particular Technology, Inc.
www.particulartechnology.com

PetroChoice
www.PetroChoice.com

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

RedLine Tools
www.redlinetools.com

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

SWD Inc.
www.swdinc.com

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com.*

2L Inc.
www.2Linc.com

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

ADF Systems Ltd.
www.adfsys.com

AGA Parts
www.aga-parts.com

ANCA, Inc.
www.anca.com

ATO Inc
www.ato.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

American Industrial Repair
www.americanindustrialrepair.com

American Swiss Products
www.americanswiss.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

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

Breton USA
www.bretonusa.com

Brighton Laboratories
www.brightonlabs.com

Broaching Machine Specialties
www.broachingmachine.com

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
7-A, INDUSTRIAL ESTATE
PATIALA PUNJAB 147004
INDIA
Phone: +(91) 175-2351089
Fax: +(91) 175-2217102
capitaltool@usa.net
www.capital-tool.com
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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

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

DataLink Technologies
www.datalinkgateways.com

Daubert Cromwell
www.daubertcromwell.com

Des-Case Corporation
descase.com

Desch Canada Ltd.
www.desch.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

Flame Treating & Engineering
www.flametreating.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
1840 JARVIS AVE.
ELK GROVE VILLAGE IL 60007
Phone: (847) 437-6605
Fax: (847) 437-6618
michael@goldsteingearmachinery.com
www.goldsteingearmachinery.com
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Gozuk Co.LTD
www.vfds.org

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

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

Guardair Corporation
www.guardair.com

Haas Multigrind LLC
www.multigrind.com

Hans-Juergen Geiger Maschinen-Vertrieb GmbH
JAMES-WATT-STRASSE 12
D-72555 METZINGEN
GERMANY
Phone: +(49) 7123-18040
Fax: +(49) 7123-18384
geiger@geiger-germany.com
www.geiger-germany.com
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Hardinge Inc.
ONE HARDINGE DRIVE
ELMIRA NY 14902
Phone: (800) 843-8801
Fax: (607) 734-3886
marketinginfo@hardinge.com
www.hardinge.com
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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.
834 E. RAND ROAD , SUITE 2
MOUNT PROSPECT IL 60056
Phone: (847) 398-8320
Fax: (847) 398-8326
sales@hobsource.com
www.hobsource.com
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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
www.indextraub.com

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

Industrial Hard Carbon LLC
www.CarbonRaptor.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.
4071 ALBANY STREET
MCHENRY IL 60050
Phone: (815) 363-8268
Fax: (815) 363-8089
info@kwikmark.com
www.kwikmark.com
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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 Chicago
lurenusa.com

MPT Manufacturing Process Technologies
www.mptinc.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

Material Handling Exchange
www.m-h-e.com/pallet-rack-uprights/

Mazak Corporation
www.mazakusa.com

Meccanica Nova Corporation
www.novagrinders.com

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

Melfast - Fasteners
www.melfast.com

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

Modicon PLC
www.modiconplc.com

Moncktons Machine Tools, LLC
www.mmtproductivity.com/

Mutschler Edge Technologies
mutschleredgetech.com

NTC America Corporation
www.ntcmc.com

Nachi America Inc.
715 PUSHVILLE ROAD
GREENWOOD IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com
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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

Pegard Productics Division HARO
harotechnologies.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
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Philadelphia Carbide Co.
www.philacarbide.com

Phoenix Inc.
www.phoenix-inc.com

Pinpoint Laser Systems
pinpointlaser.com

Pioneer Broach Co.
www.pioneerbroach.com

PlasmaRoute CNC
www.cncplasmacutterinc.com

Power Inverter Inc.
www.powerinverter.org

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.
3001 W. MAIN STREET
P.O. BOX 40760
LANSING MI 48901
Phone: (517) 371-2460
Fax: (517) 371-4930
www.robertssinto.com
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Russell Holbrook & Henderson
www.tru-volute.com

SETCO Precision Spindles
www.setcousa.com

SMS Elotherm North America
www.techinduction.com

SWD Inc.
www.swdinc.com

Samputensili S.p.A.
STAR SU LLC
5200 PRAIRIE STONE PARKWAY
HOFFMAN ESTATES IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.samputensili.com
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Schunk
www.schunk.com

Schutte LLC
www.schutteusa.com

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

SerWeMa GmbH & Co. KG
www.serwema.de

Slater Tools Inc.
www.slatertools.com

Slone Gear International, Inc.
www.slonegear.com

Star Cutter Co.
23461 INDUSTRIAL PARK DRIVE
FARMINGTON HILLS MI 48335
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@starcutter.com
www.starcutter.com
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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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Stenhoj Broaching Machines
www.stenhoj.dk

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

Thermal Spray Coatings - A&A Coatings
www.thermalspray.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
www.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

WardJet
www.wardjet.com

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

Weldon Solutions
www.weldonsolutions.com

West Michigan Spline, Inc.
www.westmichiganspline.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 (bevel gear cutters, broaching tools, hobs, milling cutters, shaping tools, etc.) at *www.geartechnology.com*.

AGMA - American Gear Manufacturers Association
www.agma.org

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

Arvin Global Solutions
1800 OGDEN AVE.
LISLE IL 60532
Phone: (800) 815-2303
contact@arvinglobalsolutions.com
www.arvinglobalsolutions.com
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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

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

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

EES KISSsoft GmbH
www.ees-kisssoft.ch

EnergyWatch - Energy Consulting
energywatch-inc.com/

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
DRIVETRAIN TECHNOLOGY CENTER
PENN STATE APPLIED RESEARCH LABORATORY
UNIVERSITY PARK PA 16802
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 ROAD
LOVES PARK IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com
SEE OUR AD P56–57,105

Gleason Works Rochester
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 256-6776
www.gleason.com
SEE OUR AD P56–57,105

Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
SEE OUR AD P56–57,105

Goldstein Gear Machinery LLC
1840 JARVIS AVE.
ELK GROVE VILLAGE IL 60007
Phone: (847) 437-6605
Fax: (847) 437-6618
michael@goldsteingearmachinery.com
www.goldsteingearmachinery.com
SEE OUR AD P62

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
SEE OUR AD P56–57,105

Kapp Niles
CALLENBERGER STRASSE 52
D-96450 COBURG
GERMANY
Phone: + 49 9561-866-0
Fax: +49 9561-866-1003
info@kapp-niles.com
www.kapp-niles.com
SEE OUR AD P37,61

Kapp Technologies
2870 WILDERNESS PLACE
BOULDER CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
sales-USA@kapp-niles.com
www.kapp-usa.com
SEE OUR AD P37,61

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

Randall Publications LLC
www.geartechnology.com

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

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

Suresh Mehta Associates
www.sureshmehta.com

Thors, LLC
www.thors.com

VDI
www.vdi.de

Virgo Communications & Exhibitions Pvt Ltd.
VIRGO HOUSE NO. 250, 7TH MAIN
AMARJYOTI LAYOUT, DOMLUR EXTENSION
BANGALORE 560071
INDIA
info@virgo-comm.com
www.virgo-comm.com
SEE OUR AD P107

West Michigan Spline, Inc.
www.westmichiganspline.com

SERVICES

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*.

AC Frequency Converter Co., Ltd.
www.frequencyconverter.net

ATO Inc
www.ato.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

American Industrial Repair
www.americanindustrialrepair.com

American Swiss Products
www.americanswiss.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

Arvin Global Solutions
1800 OGDEN AVE.
LISLE IL 60532
Phone: (800) 815-2303
contact@arvinglobalsolutions.com
www.arvinglobalsolutions.com
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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
SEE OUR AD P106

Bill's Machine Repair
www.billsmachinerepair.com

Birchwood Technologies
7900 FULLER ROAD
EDEN PRAIRIE MN 55344
Phone: (952) 937-7931
www.birchwoodtechnologies.com
SEE OUR AD P30

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/

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
7-A, INDUSTRIAL ESTATE
PATIALA PUNJAB 147004
INDIA
Phone: +(91) 175-2351089
Fax: +(91) 175-2217102
capitaltool@usa.net
www.capital-tool.com
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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
www.excelgear.com

FPM Heat Treating
www.fpmht.com

FVA GmbH
www.fva-service.de

Fine Wisdom(suzhou) Driving System Co.,Ltd
www.fw-gearbox.com

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
CELLER STR. 67 -69
D-38114 BRAUNSCHWEIG
GERMANY
Phone: +(49) 531-129-399-0
Fax: +(49) 531-129-399-29
info@gwj.de
www.gwj.de
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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 ROAD
LOVES PARK IL 61111
Phone: (815) 877-8900
Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com
SEE OUR AD P56–57,105

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 ROAD, MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com
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Gleason Works Rochester
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 256-6776
www.gleason.com

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

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

HobSource Inc.
834 E. RAND ROAD , SUITE 2
MOUNT PROSPECT IL 60056
Phone: (847) 398-8320
Fax: (847) 398-8326
sales@hobsource.com
www.hobsource.com
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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.
www.gallenco.com

Industrial Hard Carbon LLC
www.CarbonRaptor.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 Niles
CALLENBERGER STRASSE 52
D-96450 COBURG
GERMANY
Phone: + 49 9561-866-0
Fax: +49 9561-866-1003
info@kapp-niles.com
www.kapp-niles.com
SEE OUR AD P37, 61

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

Kingsford Broach & Tool Inc.
www.kingsfordbroach.com

Kleiss Gears, Inc.
www.kleissgears.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, P15

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
SEE OUR AD P5, 27

Longevity Coatings
www.longevitycoatings.com

Luren Precision Chicago
lurenusa.com

MATsolutions
www.matsolutions.com

MESYS AG
www.mesys.ag

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

Magnetic Inspection Laboratory
www.milinc.com

Maguire Technologies
www.maguiretech.com

Mahr Federal Inc.
www.mahr.com

Masternet Ltd.
www.masternetltd.com

Metallized Carbon Corporation
www.metcar.com

Metallurgical Processing, Inc.
www.mpimetaltreating.com

Micro Precision Calibration Inc.
microprecision.com/repair-service

Micro Surface Corp.
www.microsurfacecorp.com

MicroTek Finishing, LLC
www.microtekfinishing.com

Milburn Engineering, Inc.
www.milburnengineering.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
SEE OUR AD P8

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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Mitutoyo America Corporation
www.mitutoyo.com

The Modal Shop
www.modalshop.com

Motor & Gear Engineering, Inc.
www.motorgearengineer.com

New England Gear
www.newenglandgear.com

Noria Corporation
www.noria.com

Oerlikon Balzers - PPD Division
www.oerlikon.com

Oerlikon Balzers USA
www.oerlikon.com/balzers/us

Orbitless Drives Inc.
www.orbitless.com

Peening Technologies
www.hydro-honing.com

Perry Technology Corporation
www.perrygear.com

Phoenix Tool & Thread Grinding
phoenixthreadgrinding.com

Pinpoint Laser Systems
pinpointlaser.com

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

Precision Spindle & Accessories Inc.
www.precisionspindleinc.com

Proto Manufacturing
12350 UNIVERSAL DRIVE
TAYLOR MI 48180
Phone: (313) 965-2900
Fax: (734) 946-0974
info@protoxrd.com
www.protoxrd.com
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Quality Reducer Service, Inc
www.qualityreducer.com

REM Surface Engineering
www.remchem.com

Red Rover
www.red-rover-china.com

Rewitec GmbH
www.rewitec.com

Riverside Spline & Gear
www.splineandgear.com

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

Romax Technology
www.romaxtech.com

SMT
CHARTWELL HOUSE
67-69 HOUNDS GATE
NOTTINGHAM NOTTINGHAMSHIRE NG1 6BB
UNITED KINGDOM
Phone: +44 (0) 115 941 9839
Fax: +44 (0) 115 958 1583
info@smartmt.com
www.smartmt.com
SEE OUR AD P103

SWD Inc.
www.swdinc.com

Samputensili S.p.A.
STAR SU LLC
5200 PRAIRIE STONE PARKWAY
HOFFMAN ESTATES IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.samputensili.com
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Sandvik Coromant
www.sandvik.coromant.com

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

Sedlock Companies
www.sedlockcompanies.com

Seenpin Precision Products (Zhejiang) Co., Ltd.
www.seenpin.com

Shenzhen Gearshine Precision Machine Co. Ltd.
3F/A3 BUILDING, BLUE SKY TECHNOPART LOUGANG ROAD
SONGGANG TOWN SHENZHEN 518105
CHINA
Phone: +(86) 755-6158-3630
Fax: +(86) 755-2814-1006
marketing@gearept.com
www.gearshine.com
SEE OUR AD P49

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

Slone Gear International, Inc.
www.slonegear.com

Star Cutter Co.
23461 INDUSTRIAL PARK DRIVE
FARMINGTON HILLS MI 48335
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@starcutter.com
www.starcutter.com
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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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Stone Tucker Instruments Inc.
www.stone-tucker.com

Stresstech Oy
TIKKUTEHTAANTIE 1
40800 VAAJAKOSKI
FINLAND
Phone: +(358) 14-333-000
Fax: +(358) 14-333-0099
info@stresstech.com
www.stresstech.com
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Suresh Mehta Associates
www.sureshmehta.com

Surface Finishing Equipment Co.
www.sfecindia.net

Thermal Spray Coatings - A&A Coatings
www.thermalspray.com

Titanium Coating Services Inc.
www.pvdamerica.com

TopGun Consulting LLc
www.topgunconsulting.com

Ty Miles, Inc.
www.tymiles.com

U.S. Equipment
www.usequipment.com

USA Borescopes
www.USABorescopes.com

Ultramatic Equipment Co.
ultramatic-equipment.com

United Tool Supply
www.united-tool.com

United Tool Supply Ltd.
www.unitedtoolsupply.com

VFA Engineering Group
failure-analysis-durability.com

VaporKote, Inc.
www.vaporkote.com

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

Welter Group
www.welter-lahr.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Willrich Precision Instrument Company
willrich.com

SOFTWARE

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.*

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

AKGears, LLC
www.akgears.com

ATS - Advanced Technology Services
www.advancedtech.com

Acme Manufacturing Co.
www.acmemfg.com

Andec Mfg. Ltd.
www.andec.ca

Anthony Best Dynamics Ltd
www.abd.uk.com

Artis Division of Marposs
www.artis.de

Ash Gear & Supply
www.ashgear.com

Autodesk Configure One
www.configureone.com/capabilities/cpq/

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
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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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Camnetics, Inc.
camnetics.com

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

Community PC
www.meshingwithgears.com

DMG MORI USA
www.dmgmori-usa.com

Diametal AG
www.diametal.ch

Donner+Pfister AG
www.dpag.ch

Dontyne Systems
www.dontynesystems.com

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

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

Dynamic Systems
www.dynamic-systemsinc.com

EES KISSsoft GmbH
www.ees-kisssoft.ch

ESI ITI GmbH
www.itisim.com

Eltro Services, Inc.
www.eltroservices.com

EnergyWatch - Energy Consulting
energywatch-inc.com/

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

Estudio Piña
www.estudiopina.com

Euro-Tech Corporation
www.eurotechcorp.com

Excel Gear
www.excelgear.com

FARO Technologies, Inc.
www.faro.com

FPM Heat Treating
www.fpmht.com

FVA GmbH
www.fva-service.de

FastCAM Inc.
www.fastcam.com

Frenco GmbH
www.frenco.de

GWJ Technology GmbH
CELLER STR. 67 -69
D-38114 BRAUNSCHWEIG
GERMANY
Phone: +(49) 531-129-399-0
Fax: +(49) 531-129-399-29
info@gwj.de
www.gwj.de
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GearOffice
www.gearoffice.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 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 Rochester
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 256-6776
www.gleason.com
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Great Lakes Gear Technologies, Inc.
www.greatlakesgeartech.com

Heller Machine Tools
www.heller-machinetools.com

Hexagon Industriesoftware GmbH
www.hexagon.de

Hexagon Metrology
www.hexagonmetrology.us

HiTech e Soft
www.hitechesoft.com

Involute Simulation Softwares Inc.
www.hygears.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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KISSsoft/Gleason
2167 US HIGHWAY 45 NORTH
EAGLE RIVER WI 54521
Phone: (715) 477-0828
Fax: (866) 623-7269
info@KISSsoft.com
www.kisssoft.com
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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, P15

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

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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MESYS AG
www.mesys.ag

MSC Software Corp.
www.mscsoftware.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
SEE OUR AD P7

Marposs Corporation
www.marposs.com

Mitutoyo America Corporation
www.mitutoyo.com

Normac, Inc.
www.normac.com

Orbitless Drives Inc.
www.orbitless.com

PTG Holroyd
www.holroyd.com

Penta Gear Metrology LLC
6161 WEBSTER STREET
DAYTON OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com
SEE OUR AD P37

Pinpoint Laser Systems
pinpointlaser.com

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

Prime Technologies
www.gear-testers.com

Promess Inc.
www.promessinc.com

Romax Technology
www.romaxtech.com

SMT
CHARTWELL HOUSE
67-69 HOUNDS GATE
NOTTINGHAM NOTTINGHAMSHIRE NG1 6BB
UNITED KINGDOM
Phone: +44 (0) 115 941 9839
Fax: +44 (0) 115 958 1583
info@smartmt.com
www.smartmt.com
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SU (Shanghai) Machine & Tools Co., Ltd.
www.samputensili.com

SWG Solutions
www.swgsolutions.com

Saazor
www.saazor.de

Sandvik Coromant
www.sandvik.coromant.com

Scientific Forming Technologies Corp.
www.deform.com

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Strategies for Building Your Business

Joe Arvin

One phrase that I've come to understand as a basic truth for most manufacturing companies is this: If you're not moving forward, you're falling behind. And if you're falling behind, one day you will not only find it difficult to win new customers, but you will be losing the ones you do have.

It's very easy to get caught up in the essential day-to-day operations of your business, but it is equally important to keep your eye on the future and remain vigilant in the ongoing pursuit of finding ways to expand your share of the market. In the end, increased market share means the safety of diversity, increased revenue, and larger profits. And to accomplish this, you must be continually and systematically reinventing yourself with the primary objective of growth. The following are some points to consider as you pursue this goal.

Purchasing Your Way to Expansion

For the most part, the fastest way to grow your business is through purchasing a competitor or a company that complements your existing products. With this approach, you will have the experienced people, equipment, and systems already in place, as well as an established customer base. In addition, you are more likely to experience the benefit of a rapid return on your investment.

Another way to quickly increase your bottom line is to consider purchasing your key vendors. By looking at the list of outside services you require and the associated costs, you can easily develop a prioritized list of potential acquisitions. But as you evaluate this option, be sure to ask yourself this question: Can you effectively perform any of this work in-house by simply investing in some new equipment and training your internal resources?

Ramp Up vs. Buying

When you are looking at purchasing your way to expansion, it is common to embrace what feels like the safer option—and that is slowly ramping up. Slowly ramping up certainly seems to be less risky at the onset, but in my experience, in the end, both will require a similar level of investment. When buying your way to expansion, this can take the least amount of time, but ramping up can take a very long time before seeing a return on your investment.

So now you might be thinking, "Joe, what planet are you living on? I don't have the money to buy competitors or vendors. I'm having a hard enough time making payroll."

Ah yes, an unlimited supply of money can certainly make life easier. And if you don't have money trees growing on your property, overleveraging to prematurely create an industrial empire is not advisable. But still, there are other ways to remain dedicated to the goal of growth and expansion that are less aggressive. Consider the following as other ways to grow.

Expanding Your Product Line

As an alternative to purchasing competitors and vendors, a logical step for growth is to internally expand your current product line. For example, if you only cut gear teeth, consider moving into the make-complete arena. If you're a loose gear producer, consider expansion into complete gearboxes. After that you might consider moving into complete drive trains.

Here is another potential opportunity. If your customer takes your product and uses it in the assembly of another product, you should investigate the option of producing that final assembly yourself. The more you know about your customer's product, the better equipped you'll be to help them while providing opportunities for you.

What other products can you make which fit your engineering expertise and factory equipment? Try this: Ask your engineers. You may be surprised what you hear. Consider making component parts that do not have gear teeth. If you do shaft work, you might want to go after shafts without gear or spline teeth. How about housing turning, making tooling for others, or performing design?

Joint Ventures

Another avenue for expansion that doesn't require significant funding is a Joint Venture. By taking this approach and partnering with another company within your industry, you can gain the benefit of expanding your product utilizing the expertise of someone else, while they benefit from the expertise that you have.

Optimizing Your Marketing

As I've mentioned in previous issues of this column, marketing is essential so that your potential customers know what you have to offer. Ask yourself this key question: Are you marketing your product to a specific niche or are you just casting a broad net hoping for the best? Focusing on a niche that is ideally suited to your strengths can be of significant value. Keep in mind, however, that it's almost impossible to grow substantially solely through sales and marketing efforts of your existing services or products. This will only take you so far, but it is important to be sure your existing capabilities have optimal market exposure.

Don't overlook marketing offshore—as this can result in a significantly larger pie. And if you decide to move into exporting, don't forget the importance of having local representation in those areas. These resources can provide valuable market intelligence and assist you in making the best connections.

You might be saying, "Come on Joe. I know all about the problems competing in low-wage countries. That's impossible." Generally speaking, it's tough to win when going head to head with the low wages of off-shore competitors. But don't forget about your niche market. Don't forget about your unique expertise and capabilities. These can give you a competitive edge. I know first-hand that this can work. At Arrow Gear, we grew our exports from zero to over one-third of our business.

Sleeping With "The Enemy"

When I was at Arrow Gear, we had more customers than competitors among the members of the AGMA. We didn't think of these competitors as arch rivals or our enemies. In fact, we reached out to them to establish collaborative relationships. We did gear design for other companies. We loaned cutters and grinding wheels. In the end, these relationships led to a lot of offload work for us. We also had mutual agreements with several competitors for disaster planning. While thankfully disasters seldom happen, if one does happen to you, you can keep supplying your customers uninterrupted so they don't have to go somewhere else. And if a disaster happens to the other company, you can experience a significant inflow of work.

Open Capacity

The open capacity of idle equipment is also ideal for securing offload work from other companies — even your competitors, and this can be a substantial means of growth. Look at your open capacity in milling and drilling, as some farm out this work. Also, look for those who farm out special gear cutting. And if you have heat treat, look here for open capacity and opportunities as well.

Upgrades to Your Facility

As I mentioned in a previous article, in the past, you used to be able to wait from fifteen to twenty years before you needed to upgrade to new technology. Now, with the rapid advancement of technology, this timeline is shortened to approximately every five years. The harsh reality is this — if you're not investing in new equipment, you're not going to be able to compete. This doesn't always mean that you have to be purchasing million dollar machine tools on a routine basis. Even retrofitting older machines will result in improved performance, and there are a lot of very good used machines on the market. Keep in mind that smaller investments, in aggregate, can have a significant impact over the long run.

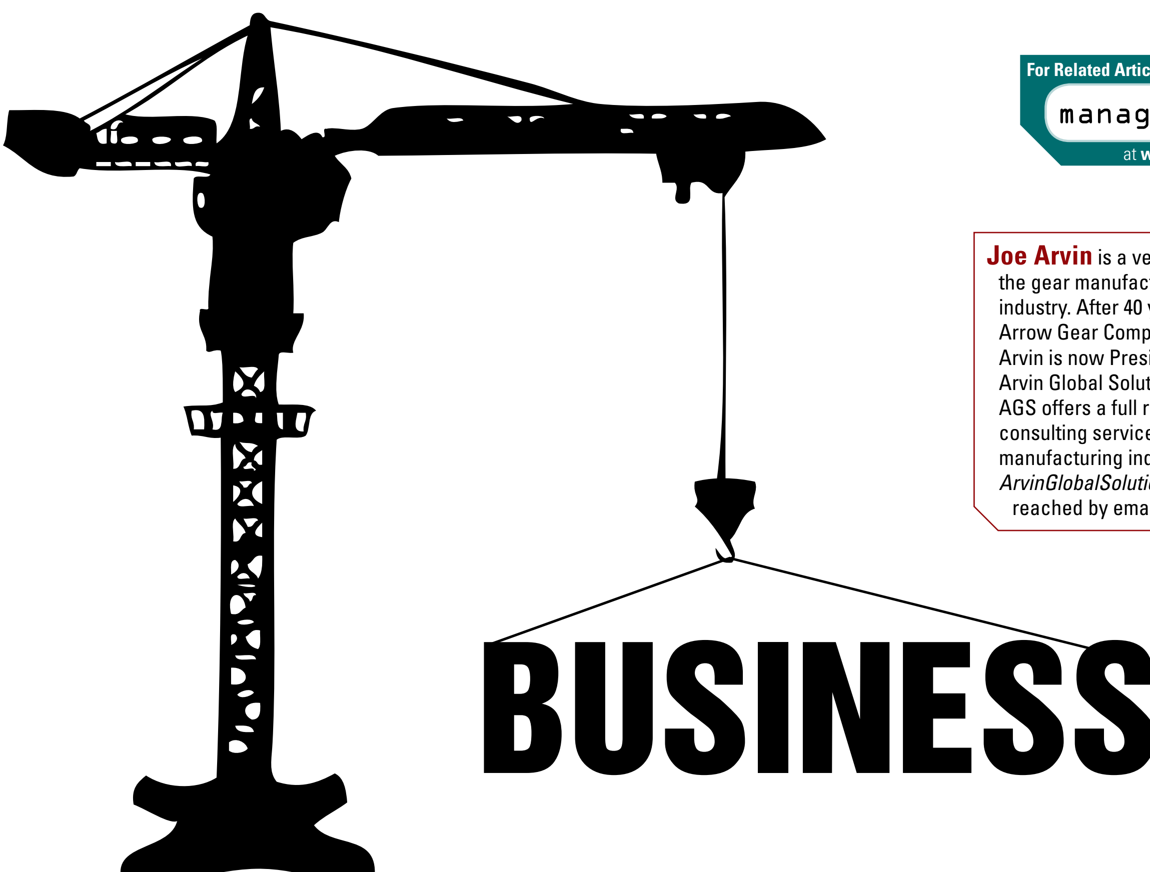
Regarding technology, it's important to remain educated in what is taking place and monitor these advancements closely. A valuable resource for accomplishing this is trade publications like *Gear Technology* magazine. I hope you and your team members attended the recent AGMA Gear Expo in Columbus. And don›t forget the International Manufacturing Technology Show (IMTS) that will be taking place next year. Finally, be sure that you're plugged in to the marketing channels of the key machine tool manufacturers and other suppliers to be sure you're aware of the latest developments.

Conclusion

It is my hope that these ideas will give you something to think about as you contemplate the future growth of your business.

A Final Word

If there is a topic you would like to have addressed in this column, please send me an email at *ArvinGlobal@Gmail.com*. Also, if you have a particular problem or question, please call me at 815-600-2633. I'm always happy to provide some free advice.



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Friction Coefficient of Differently Treated Steel Surfaces

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

QUESTION

My company designs and manufactures rotating machinery, and recently we adopted ion-nitride finish to our shafts. We have been led to believe that this process reduces the coefficient of friction used to calculate torque transmitted through a tapered hub interference fit.

Currently we use a friction coefficient of 0.15 per ANSI/AGMA 9003 for the calculation.

Do you know how much reduction, based on your knowledge of the finishing process and torque transmission?

Expert response provided by Dr. Hermann J. Stadtfeld. Ion-Nitride treatment is used to achieve an increase of surface hardness of mechanical components. Although the ion-nitride changes the color of the components from silver to a greenish gray, it is not a coating layer on top of the surface. The nitriding process creates a hard layer of only about 0.005mm at and underneath the surface. In order to investigate the reader's question, at first surface roughness measurements were conducted with parts which had a ground steel surface and parts of the same design which had been nitrided. In order to compare all results to a rather well known surface condition, the same part design had been REM super-finished. The next step was a laboratory experiment with the variety of different parts in order to gain individual friction coefficients. The goal of this work was not only to give a plain answer to the question, but to also present a simple and straightforward guideline for practical-oriented engineers for determining friction coefficients between different materials with different surface conditions. These guidelines are accurate enough for mechanical applications, as the interference fit connection between shaft and disk as described in the question.

The principle of friction determination is shown in Figure 1. In the example, the normal force is created by the weight, multiplied with the gravity constant g. At the left side in Figure 1 the friction exists between the flat block and the flat base surface. The problem with flat surfaces is that they are either not really flat, which could make the weight rock while it slides, or they are too flat, which could cause a surface bonding like that experienced with Jo blocks. In order to avoid those effects, cylinders are often used in friction investigations. The cylinders create line contact with the weight if their alignment is precise. At the right side in Figure 1, two cylinders locked in place with a stop are used to conduct the friction measurement. The following practical bench measurements have been conducted according to the right side principle in Figure 1.

The results from the surface roughness investigation, using a Zeiss surface tracer are summarized in Figure 2. The surface of the gage bar used in combination with all the different tested

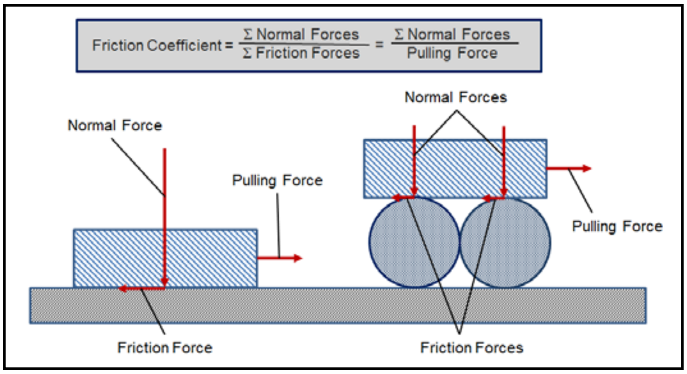

Figure 1 Theoretical principle of friction coefficient determination.

surfaces (No. 1, Fig. 2) shows very low roughness numbers, but exhibits some scratches that can be disregarded for the following friction measurements.

The surface roughness values of the ground steel specimen, the ion-nitrided specimen, and a super-finished specimen are shown respectively as the No. 2, No. 3 and No. 4 graphs in Figure 2. The ion-nitride treatment was applied to a ground steel ring, like the one represented in graph No. 2. One can observe that the ion-nitride, although it has the optical appear-

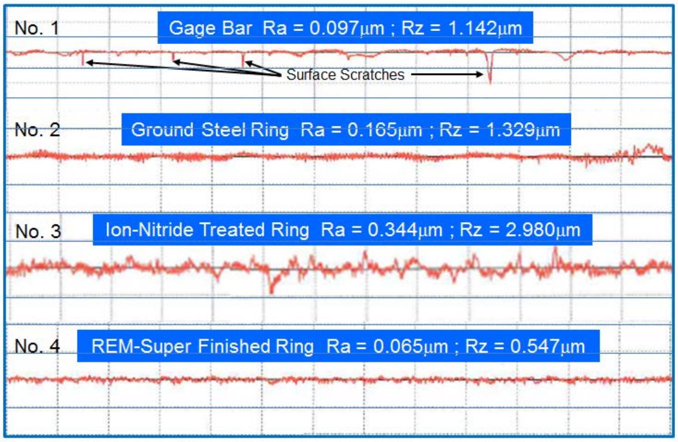

Figure 2 Surface roughness Comparison between ground steel, ion-nitrited steel and super-finished steel.

ance of a phosphate coating, does the opposite of what a phosphate coating would do to the surface roughness. The values of Ra and Rz more than doubled due to the nitriding. Another interesting surprise presents the result of the surface roughness measurement of the super-finished parts. The super-finishing generated a mirror surface finish on the treated rings, yet compared to the ground steel ring and gage bar, only a limited improvement can be seen.

The bench test setup is shown in Figure 3. Two ring gears with a ground steel surface are the artifacts. Defined surface contact was created with a precision ground steel gage bar. In order to achieve sufficient surface contact a second bar was placed on top of the first one. The photo in Figure 3 shows the arrangement with a pull scale. The scale was pulled gently until the gage bars broke loose. The drag pointer feature allowed capturing the maximal value of pulling force, which was then used to calculate the static friction factor. The surface combination was cleaned with a solvent in order to use conditions that are representative for friction between dry surfaces as present with interference fits (no lubrication present). The friction coefficient calculated from the breaking loose pulling force resulted in 0.145. It is interesting to mention that this experimentally obtained value is very close to the coefficient found in ANSI/AGMA 9003, which is 0.15.

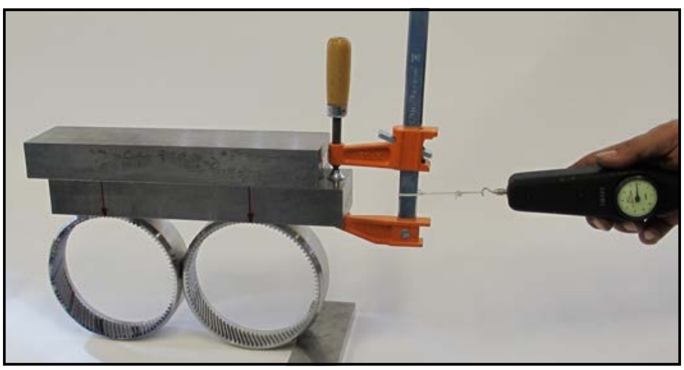

Figure 3 **Bench setup for friction determination pull test: ground steel on ground steel.**

Figure 4 shows the pull test conducted for the surface combination ground steel versus nitrided surfaces. The test conditions were the same as mentioned with the first test of Figure 3. Although the pulling force seemed to be slightly higher in some of the tests, the average friction coefficient calculated are identical to the steel versus steel combination.

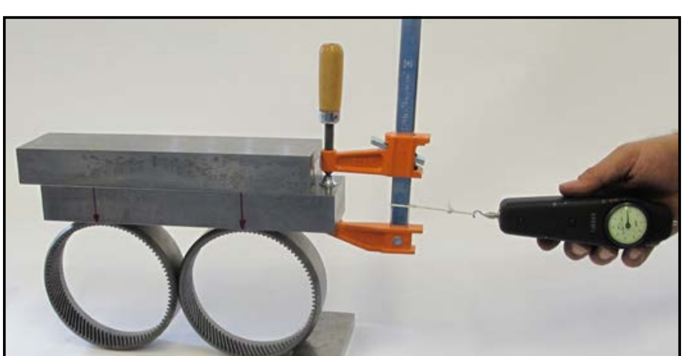

Figure 4 **Bench set-up for friction determination pull test - Ion-Nitride treated surfaces on ground steel**

Figure 5 shows the setup for the ground steel versus REM super-finished steel. Readers who expected a significant reduction of the friction coefficient will be disappointed with a resulting average value of 0.138. Although the super-finishing might enhance hydrodynamic conditions, there is only a very small friction reduction in the dry stage.

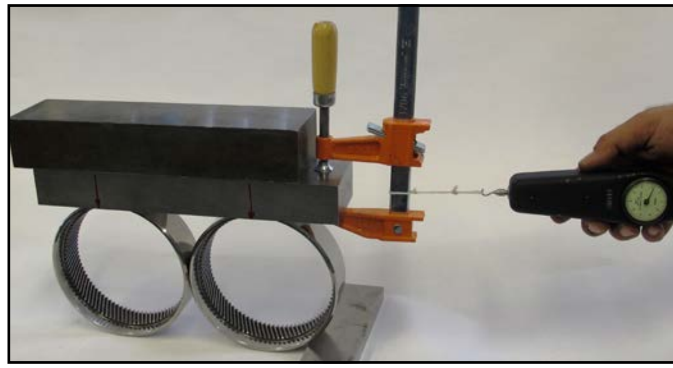

Figure 5 **Bench setup for friction determination pull test: super finished surfaces on ground steel.**

The conclusions of the experiments are summarized in the table shown in Figure 6. With the documented results, the reader's question can be answered favorably. The press fit with the combination of a ground or hard-turned tapered bore and a ground or hard-turned nitrided shaft will result in the same torque transmission capability as the previous components, which consisted of a steel versus steel combination.

Material	Steel-on-Steel	Steel-on-Nitrided Steel	Steel-on-Superfinished Nitrided Steel
Ring Roughness, Ra [µm]	0.165	0.344	0.065
Bar Roughness, Ra [µm]	0.097	0.097	0.097
Normal Force [N]	161.09	161709	164109
Average Pulling Force [N]	23.26	23.16	22.15
Mean Coefficient of Friction	0.145	0.145	0.138
Mean - 3σ	.125	0.129	0.122
Mean + 3σ	.165	0.160	0.155

Figure 6 **Friction coefficient test evaluation results.**

Test Articles/ Ra	Static Coefficient of Friction
Steel-on-steel,a=0.16S prn	0.14S
Steel-on-Nitrided Steel, Ra=0.344	0.14S
Steel-on-Superfinished Nitrided Steel, Ra= 0.065	0.138

Figure 7 **Friction coefficient result summary.**

The table in Figure 7 is a management summary for fast readers; it contains the resulting friction coefficients of the three investigated friction combinations.

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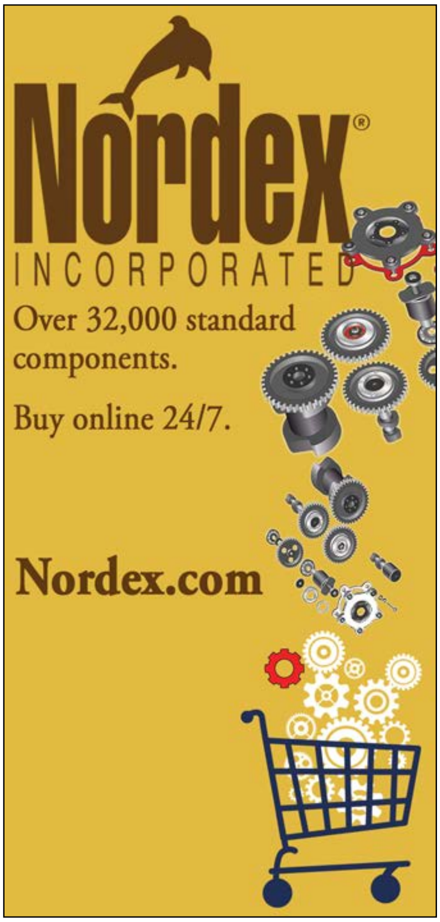

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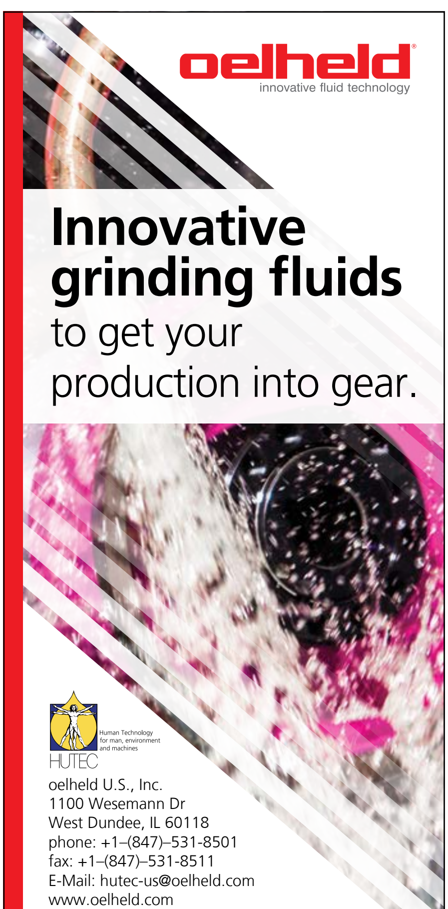

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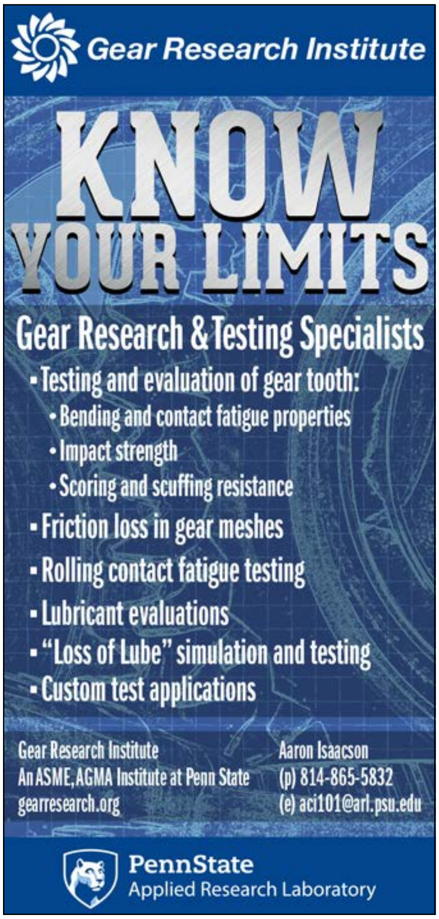
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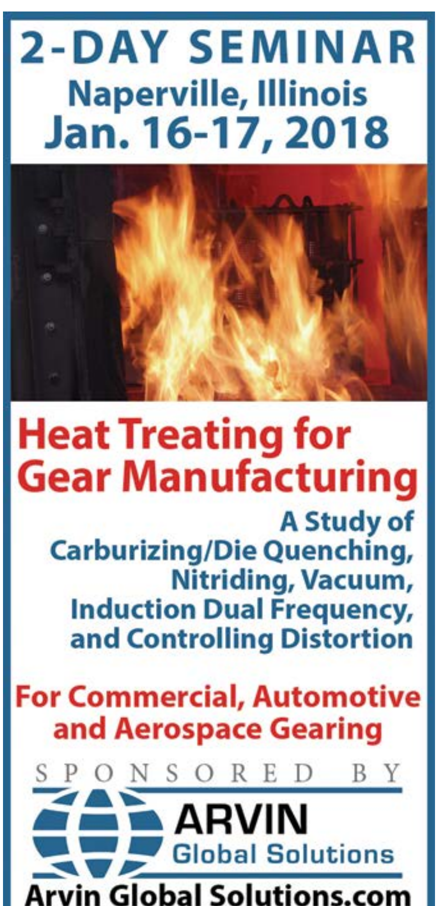
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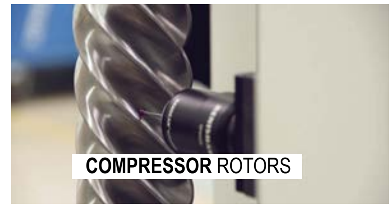
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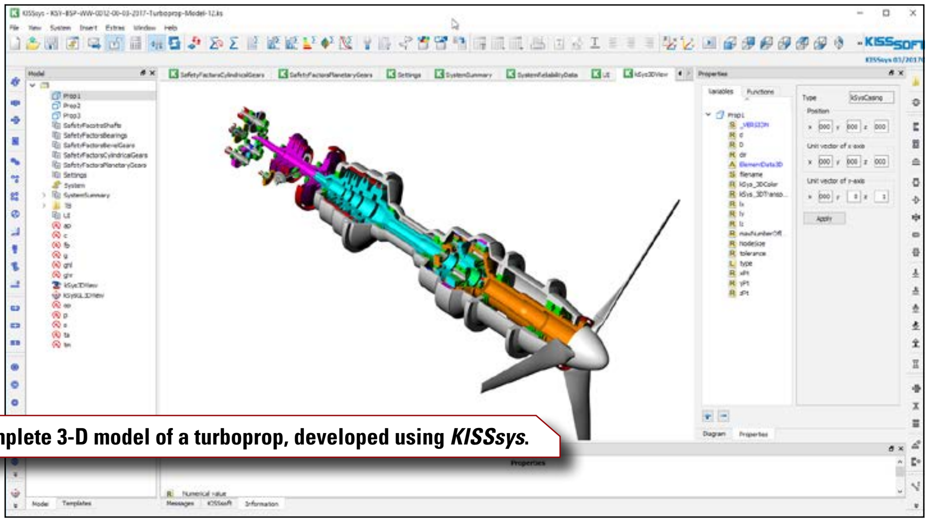
Helping Software Developers Help You

A key part of gear design software development is customer feedback. With the right feedback, you can get your software developer to work for you to provide the most relevant features possible.

Alex Cannella, News Editor



Complete 3-D model of a turboprop, developed using *KISSsys*.

Something that sets gear design software apart in an industry of physical products is its unparalleled ability to be iterated upon. While a manufacturer may go decades without replacing a gear cutting machine, gear design software is a product that is constantly being upgraded on a yearly, monthly, or sometimes even weekly basis. By its nature as a medium, one of software's greatest strengths is that it can constantly be tweaked, expanded or retooled. It's an advantage every gear design software developer takes healthy advantage of to the benefit of everyone involved.

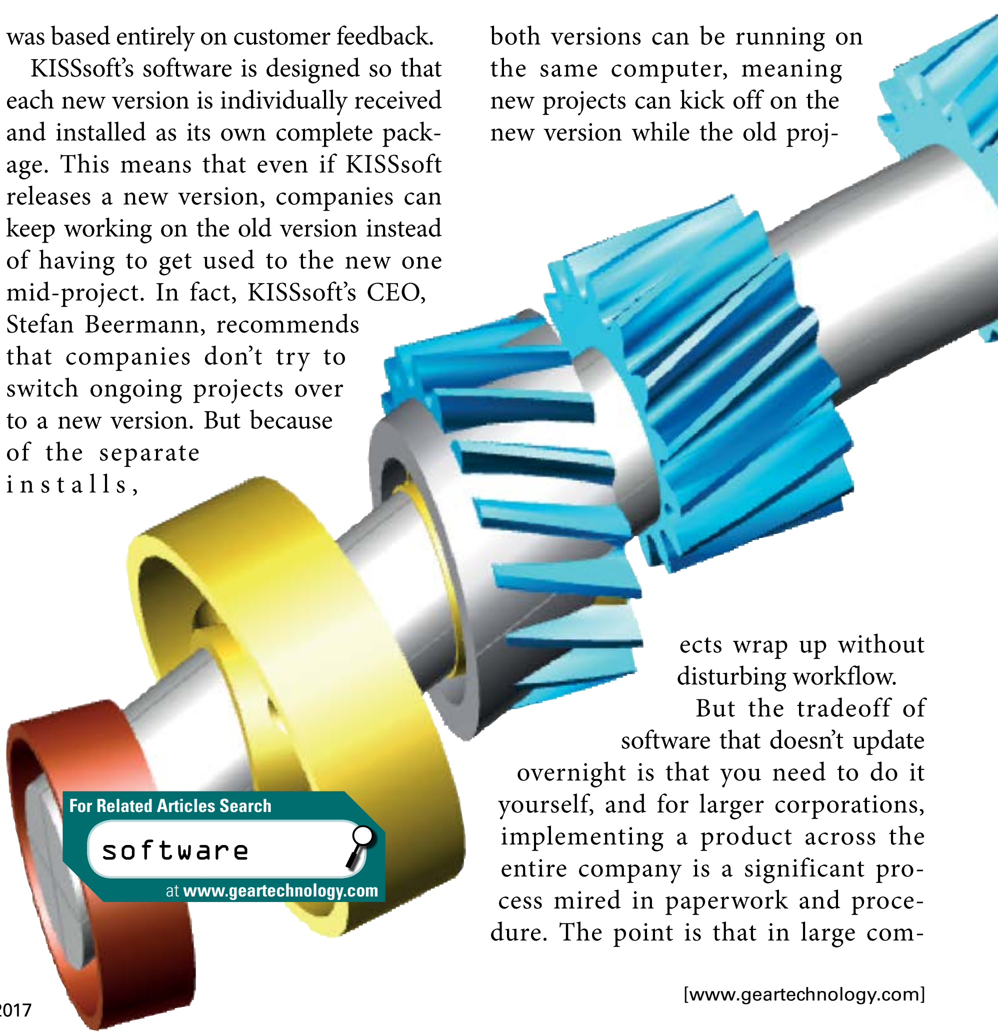
But something that sometimes goes understated is just how important the customer's feedback is in that iterative process. Software developers face a daily dilemma. No matter how many modules or expansions a developer produces, they will never be able to cover every base. No matter how long a developer's list of accomplishments, the wishlist of future features that have yet to be implemented will always be longer. So how does a software developer pick their battles?

There's no single, universal answer for any software developer. The choice is always a subjective one that can be influenced by a number of factors ranging from industry standards to market trends. But customer feedback is consistently a regular source of direction when a developer is looking to the future to decide what to make next.

This can manifest in a few different ways depending on how a software developer's business is built. KISSsoft, for example, releases a new version of their software once a year, but a decade ago, they had a new version every six months. The decision to change, when it came, was based entirely on customer feedback.

KISSsoft's software is designed so that each new version is individually received and installed as its own complete package. This means that even if KISSsoft releases a new version, companies can keep working on the old version instead of having to get used to the new one mid-project. In fact, KISSsoft's CEO, Stefan Beermann, recommends that companies don't try to switch ongoing projects over to a new version. But because of the separate installs, both versions can be running on the same computer, meaning new projects can kick off on the new version while the old projects wrap up without disturbing workflow.

But the tradeoff of software that doesn't update overnight is that you need to do it yourself, and for larger corporations, implementing a product across the entire company is a significant process mired in paperwork and procedure. The point is that in large com-



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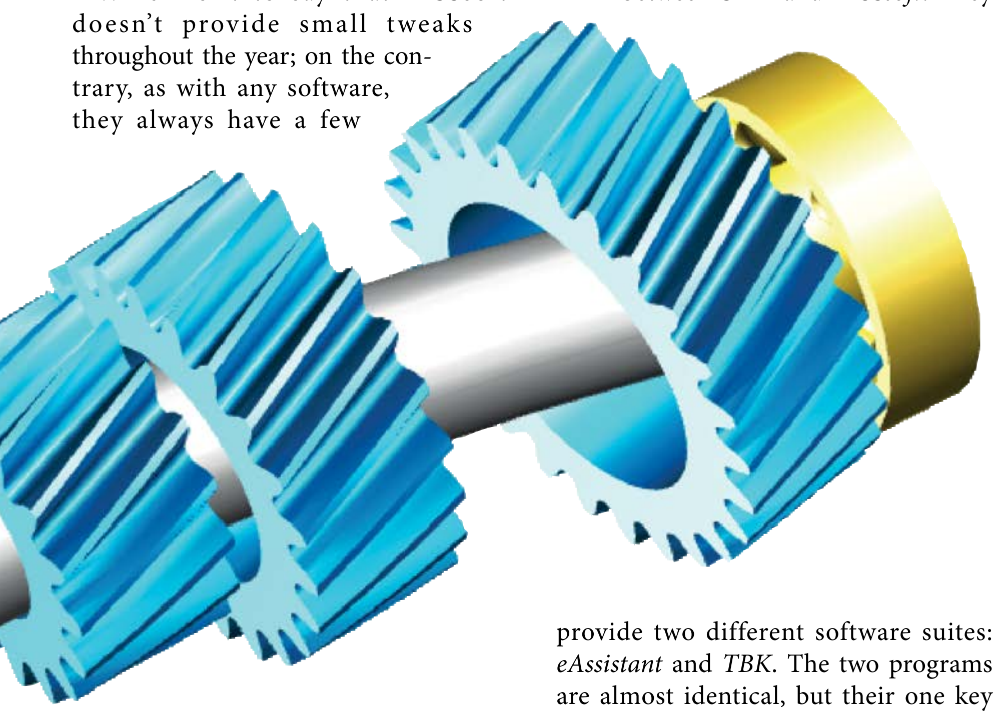
panies, software has to be released for installation, to have a well-defined status on the users' computers. For some of KISSsoft's customers, large businesses with thousands of computers, installing two updates a year across the entire company became a logistical hassle, and the difficulties these customers were having prompted KISSsoft to adjust their release schedule.

"It would be a complete mess if you had 1,000, 2,000 employees in one location and you don't know how the computers are set up," Stefan Beermann, CEO at KISSsoft, said. "This would simply break down. For small companies, this is not an issue. They just get it and install it. But for the large ones, it is."

Which isn't to say that KISSsoft doesn't provide small tweaks throughout the year; on the contrary, as with any software, they always have a few patches for working out any bugs in the program. But you will only ever see one major release that is the culmination of everything KISSsoft's been working on in the past year.



Over at SMT, on the other hand, there are no such binding restrictions, and releases are much more frequent. According to Paul Langlois, department manager of CAE products development at SMT, the company's releases are put out as frequently and early as possible. In 2016, they had 16 releases over the course of the year. Like most gear design software developers, SMT is working on multiple features at once, but without a steady release schedule, a larger item can be developed over the course of a few months while customers see several updates filled with smaller features that may only take days or weeks to implement.

"The ideal release schedule is to get out any functionality developed as soon as it can to the customer," Langlois said. "In our opinion, there's no point in holding back...just because of an official release schedule. We just like to get out our functionality as soon as possible so it can be of use to the customer as soon as possible. Some of the larger companies have procedures which do limit the ability to install frequent updates, but this should not hold back the many others which do not."

GWJ is a middle of the road option between SMT and *KISSsoft*. They provide two different software suites: *eAssistant* and *TBK*. The two programs are almost identical, but their one key difference is their distribution method. *eAssistant* is online, while *TBK* is the offline licensed version. *eAssistant* is the standard version that GWJ is always updating as new features are ready, but *TBK* still gets one or two updates a year compiling everything new in *eAssistant*. The offline version gives customers flexibility in deciding how they want to maintain their software while also providing opportunities for customers with limited internet access.

Design decisions, of course, go well beyond picking a release schedule. The meat of the decision making process isn't on when, but on what. And here, customer feedback becomes even more important. A majority of the features being developed by every gear design software company we talked to were first considered because of a specific request from a customer who either needed an entirely new function or had run into an unexpected difficulty while using an already established one.

At KISSsoft, there's still the occasional big ticket update that the company develops in response to market trends such as an upcoming feature for calculating asymmetric teeth. But *KISSsoft* has been around for so long that you can already design almost any gear you want using almost any method under the sun with their software. And with the main market trends covered, all that's left for KISSsoft to develop are features that cater to the newest, most bleeding edge manufacturing methods and smaller features, things like quality of life updates, which half the time they'd only even think to implement due to feedback from customers regularly using the software in the field. Customer feedback is the compass that often helps KISSsoft find a starting point for what to do next.

And according to Beermann, the little tweaks KISSsoft couldn't have found without feedback can often be the most important changes in each new iteration. For every new module they develop, there are a dozen smaller changes that get put into each new version, which over the course of the year, starts to really add up and means each update launches with almost 100 smaller adjustments or features, and Beermann finds those changes the most valuable because they're each meant to improve an already existing, regularly utilized piece of software.

"For the user, I think the other 90 changes are most likely more important ones," Beermann said. "Because these are the small things we improve or we extend and is used in everyday work."

One recent example is for KISSsoft's module for contact analysis in cylindrical gears. Up until now, users would see graphics with the results, where the x-axis was the rotation angle of the pinion. In another graphic, the user can animate the meshing of the two gears and thus analyze the situation. Some of KISSsoft's most recent work was to simply add the current rotational position of the teeth in the physical representation of how the gear and pinion mesh.

"This is for sure nothing which is very spectacular. We won't make a huge press release out of it," Beermann said. "But if you're using that module, it's very, very helpful, because you can now make a good mapping of what you see with what the results are. Before it was more estimating, 'yeah it could be five degrees, maybe six degrees,' so it was not very exact."

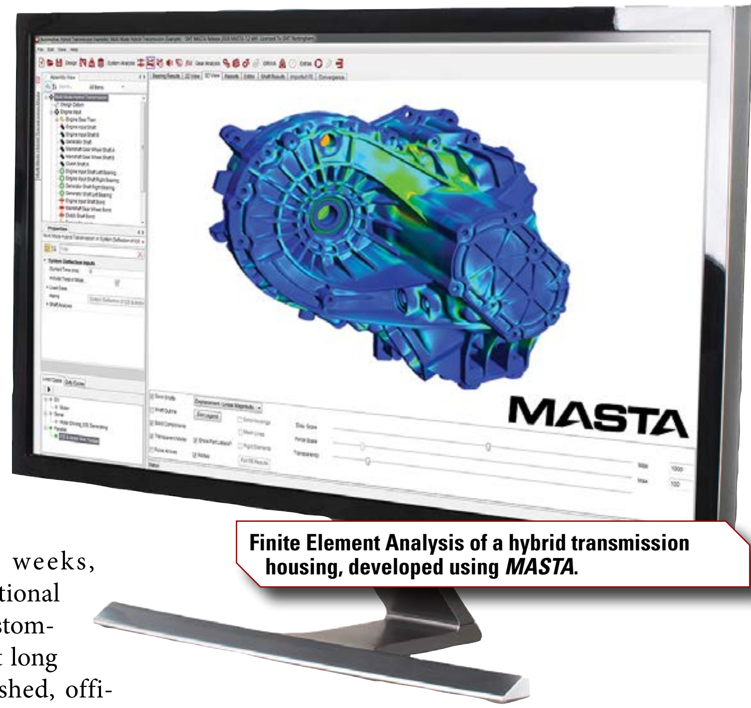
Much of KISSsoft's current work is in this vein. According to Beermann, 2017's update saw a number of large features make their debut, and 2018 is going to mostly be about "cleaning things out" and polishing what came out this year.

Customer requests and feedback are similarly at the top of SMT's list of priorities.

"We try very hard to keep our customers happy and they have a lot of input in what we do," Langlois said.

However, SMT's support also extends to prospective customers, such as it did with one of their most recent updates to their *Masta 8* software. A potential customer was shopping around comparing different software suites, and found SMT's to be favorable. However, there was one issue: *Masta 8* couldn't integrate with Klingelnberg's *KIMoS* software, which was a critical requirement for the customer.

"This link to *KIMoS* was on our radar," Langlois said. "It was in our feature request system, but it was lower down the priorities list. But when this customer stressed that it was critical to them, we had to act on that immediately."



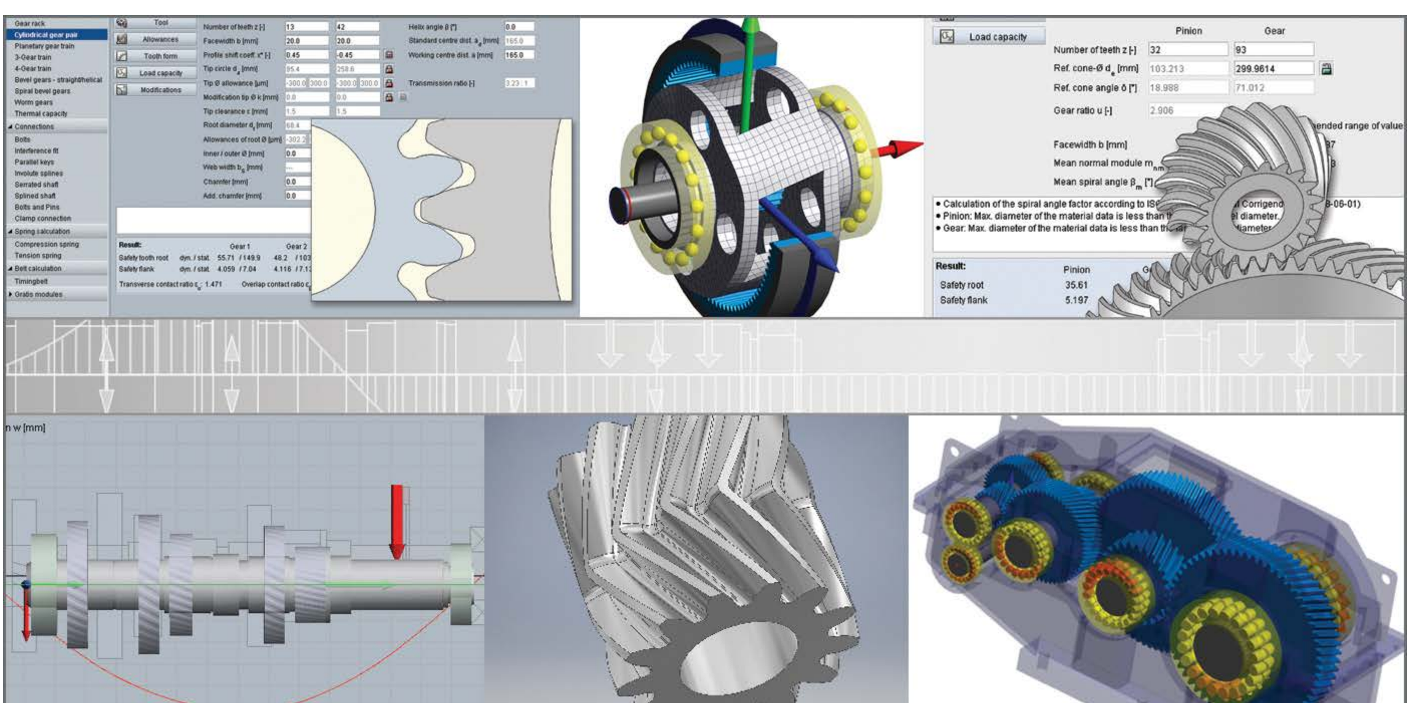
Finite Element Analysis of a hybrid transmission housing, developed using ***MASTA***.

Within two weeks, SMT had a functional demo for the customer to try, and not long after that, a finished, official version was released for all to use. It's a story that ends happily for both parties: SMT received a new customer, and the customer got the service they needed to do their business.

It's also a story that illustrates a point on how to effectively make your needs known to your software developer: At SMT, the process of developing new software is not one in which customers drop memos to have some new software feature on their desk by Friday. It's an extended, back and forth dialogue.

"It doesn't stop at [a customer] requesting a feature and then us implementing it with no conversation," Langlois said. "We very much encourage that conversation all the way through."

After an initial request for a feature is presented, SMT often provides a demo version for the company to try out, a dry



TBK **software from GWJ offers many design options for individual gears as well as shafts and complete systems.**

run before they finalize the product for commercial release. And the more feedback a customer can give them based on that demo, the better they can hone and refine it for a final version. And according to Langlois, the more details that a customer can provide about their experience, from how using the software felt to the actual results, the better they know whether the new feature needs to be tweaked or not. And then once both parties feel they've gotten it right, it's on to the final release.

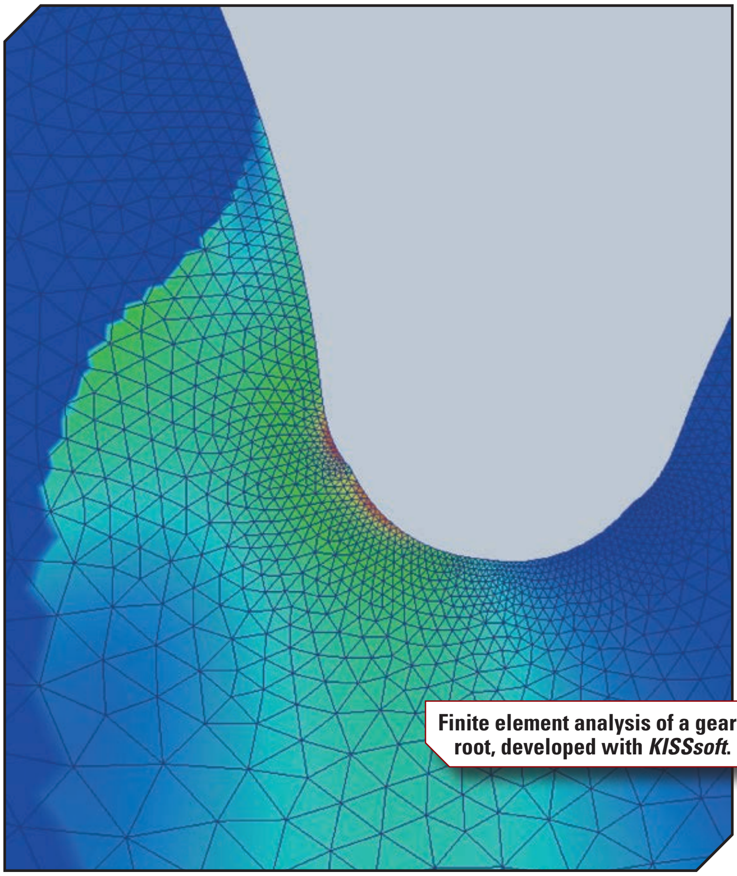
Even during the initial request, the more detail you can provide your software developer, the better they can serve your needs. Every developer we talked to has found that quality trumps quantity. The more detailed a feature request is, the more well-thought out it is. And the more well-thought out a request is, the better you'll be able to express its importance. Being able to say not just what you want, but why you want it and under what circumstances it would be implemented, is extremely helpful for a software developer. And in turn, a well-thought-out request is more likely to be implemented.

"From [active requests] we really do implement the largest percentage, simply because this is usually a well-thought-out thing where the customer already had some brain work put in," Beermann said. "So, it's much better prepared than talking things at conferences or even the problems people bring to a training."

"If you understand why the customer has this wish, it's much more effective for us because we understand the need," Gunther Weser, general manager at GWJ said. "And so we have more information to integrate this. It's very important for our guys in development. If they understand why they should integrate this, it draws really better."

Langlois stated: "We always try and tie [customers] down as much as possible to tell us what their priorities are and why... Stressing to the customer that if they can prioritize on their side, think about it significantly what would best suit them — what would save them the most money, the most time — and then communicate that to us. That makes our prioritization process much easier."

Langlois also stressed criticality as a key component that makes a specific request important. Often, companies submit a full wishlist detailing every little bit of software they'd like tweaked or added, and it can be difficult to sort out which additions are critical to a company's process and which are just wishful addons. Those wishlists provide a developer with far more features than they could implement, and so often they require more information regarding which ones are most important and should be prioritized, while figuring out how much time it would take to develop each feature. Explaining in no uncertain terms a feature's importance to how your company operates (and, obviously, making sure that feature is actually critical) is the number one way you can get your developer's attention and jump to the top of the list.



Finite element analysis of a gear tooth root, developed with ***KISSsoft***.

Patience can also be required. The process for developing new features takes time and includes a lot of testing even after the code has been laid down. For companies like SMT, that means a regular back and forth as the kinks in the programming get hammered out. For others with a consistent schedule like KISSsoft, this means that at some point, there needs to be a hard cutoff where the company focuses on testing and prepping all the already developed features for release, often months before the actual release date.

"This is something customers don't always understand is that we have to stop very early so we have time to test things," Beermann said.

But in the end, the situation is stacked in your favor: gear design software developers want your feedback. They want to build the best product they can, and they've found that the best way to do that is to cater it to their customers' needs.

"If we start somewhere and work our way through, we will never be finished," Beermann said. "If the customer has a request, we know exactly what to do next. At least one person will be happy. It really helps everyone in the process."

And when the customer is happy, everyone wins.

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Material Assets

Accuracy, Speed and Creativity Move Gear Manufacturing Forward

Matthew Jaster, Senior Editor

You get one shot to make a first impression. One opportunity to show your customers, vendors and suppliers that you provide a steady, reliable product that will generate repeat business. How do you make this happen? What tools and strategies are available to get gear materials (forgings, gear blanks, etc.) shipped faster and more efficiently in today's tech-heavy, fast-paced, manufacturing environment?

Lead-time is simply a numbers game. How many minutes, hours, days, (god forbid months) will it take to complete an order? That's pretty much all there is to it. Unfortunately, many organizations that supply gear materials struggle with these numbers. Equipment failure, lack of personnel and increased competition add to the growing list of challenges. By focusing on lead-time improvements, companies like McInnes Rolled Rings and Scot Forge have found innovative and creative ways to bring some much needed consistency to the materials market. Here's how:

"Lead-time is an opportunity to differentiate ourselves from the competition. We've established 1 to 2 week lead-times as our standard. In many cases we are shipping in a matter of days," said Shawn O'Brien, vice president sales and marketing at McInnes Rolled Rings. "Our mission is to offer industry leading cycles in every market. When our customers realize that they can consistently rely on this, it gives them an advantage over their competition and enables them to avoid carrying excess inventory."

"In the gear industry, quite a few of our customers are not just manufacturing new, original gearboxes. Instead, they are servicing the existing gear business with repair work," said Sarah Marski, senior account manager and business segment leader at Scot Forge Company. "For this, delivery reliability is extremely important because purchasing

An integrally forged shaft, made as a tooled double hub, then torch cut and finished. The part displays a number of different process including loose tooling, torch cutting, heat treating and machining (courtesy of Scot Forge).

decisions are made according to which company can service the broken gearbox the fastest. If a gearbox is down, the equipment is down. If the equipment is down, there is no way to turn out product."

Gear Specific Challenges

Due to the fact that the gear industry cannot forecast a potential breakdown in an accurate manner, speed and nimbleness are critical to service this industry, according to Marski.

"In many cases, most of manufacturing capacity is constrained by labor, not necessarily assets. With the pickup of primary markets and the influx of orders, we have to look at several options to optimize our capacity including shifting resources and utilizing our outside preferred vendors if we can't accomplish it on-time, in-house," Marski said.

The greatest challenge in manufacturing today is finding good, skilled labor. According to a study by Deloitte, over the next decade nearly 3.5 million manufacturing jobs will likely be needed and 2 million are expected to go unfilled due to the gap between the talent manufacturers need to keep growing their businesses and the talent they can actually find.

"With the long-term in mind, Scot Forge has internship programs where we partner with local technical colleges and high schools to expose students to manufacturing and trade work with the goal of adding new resources back into the field," Marski added.

McInnes Rolled Rings, like all manufacturers, relies on its people, equipment and raw material supply to meet the demands of the gear industry. "We prepare for challenges by proactively and continuously managing these areas. We maintain a full staff during recessionary conditions and take advantage of opportunities to cross train throughout the plant," O'Brien said.

A well-established preventive maintenance program keeps their equipment in top shape and a healthy inventory of critical parts minimizes any equipment interruptions. Managing the raw material supply, however, can be a bit more intricate.

"Understanding the market's appetite and matching that with our supply chain's responsiveness is critical. Our experience and well established supplier relationships are both keys to our success," O'Brien said.

Invest, Improve and Innovate

O'Brien remarked that speed has been the cornerstone of the McInnes brand for years. The company always looks for new efficiencies and its lead-times have remained steady at 1–2 weeks. So what's the recipe for success?

"There are no premiums or special programs. It's simply our normal course of business. We continued to invest in our team and equipment during the recent economic downturn and we are fully prepared for the next upswing. Our new $8M heat treat investment enables us to process significantly more tonnage. Maintaining a full staff of experienced associates in our plant, office and in the field enables us to meet any demand surges in stride," O'Brien said.

In order to combat the need for more skilled labor so they can keep production flowing through the shop (which improves delivery reliability and helps reduce lead-times), Scot Forge has introduced a formalized flex-labor program along with its existing lean manufacturing principles. This helps the company stay nimble and pull labor into areas of constraint on the shop floor so that manufacturing isn't held up. Having a cross-functionally trained staff gives the company a better understanding of what its customers need and helps keep production on-schedule.

"Additionally, having the right material grade and stocking size on-hand so material availability doesn't add to delivery time is something Scot Forge has improved over the years with the help of new technology," Marski said.

Scot Forge has implemented a *Material Resource Planning* tool that gives a better visibility of material grade usage and stock size usage, allowing the organization to better service the gear market.

'If we can understand the usage by customer and particular grades, then we can make sure we have it on the ground, ready to go. Along those lines Scot Forge stocks OEM grades which is unique to the industry. Simply having this material available can shave over five weeks off of delivery in some cases," Marski added.

Making the Most of Your Resources

The materials market struggles with an identity crisis of sorts regarding technology. You don't typically think of software upgrades, advanced machine technology or data analytics when discussing forgings and gear blanks (It's more likely that you think of pulling a flaming hot piece of metal out of an open flame). But like other areas of manufacturing, these tools are essential to improve lead-times.

As mentioned earlier, Scot Forge's *Material Resource Planning* tool helps inventory material grades and input stock. "These analytics help determine what raw materials we need to have on hand to meet our gearing customers' needs, which makes our turnaround to our customers faster. However, improved equipment also can reduce delivery time and material waste. Any time you can cut waste — whether that's speed, production or responsiveness — you're optimizing your ability to react to market needs," said Marski.

In terms of information retrieval, it pays to pay attention to what material providers have to say and the data that is being collected. Marski said that since forging is at the bottom of the supply chain for most end-use markets, they experience the peaks and troughs of industry demand much sooner than a lot of their gearing customers.

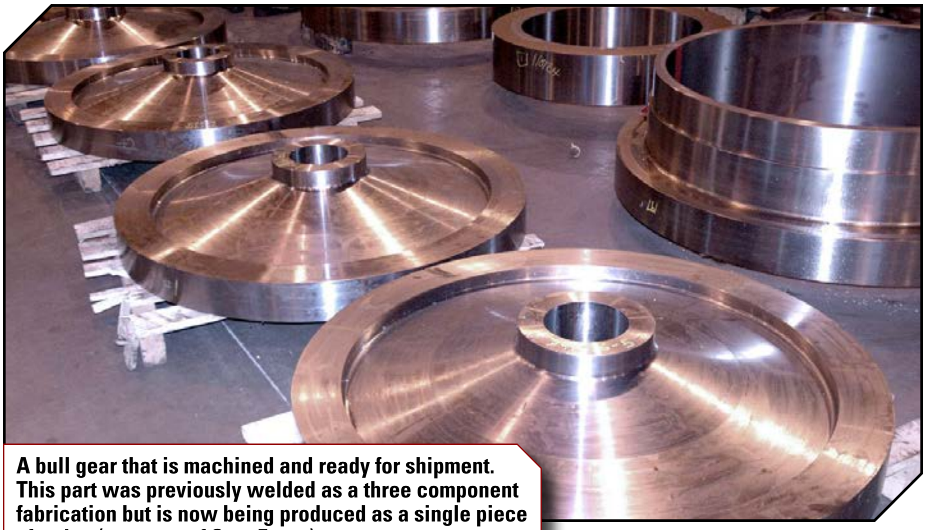
"Using this data along with the data generated from our customer's purchasing history helps us track and forecast demand for certain industries with better accuracy. We can work with our gearing customers, in turn, to help them anticipate demand and share information about the market so they can plan accordingly," Marski said.

McInnes recently upgraded its *Enterprise Resource Planning (ERP)* system. ERP is an integrated software package that tracks and collects a variety of business resources including raw materials, production capacity, etc.

"While change can be difficult, the benefits far outreach the rigors of implementation. This modernization makes data more accessible so we can examine our key performance indicators in real-time and set new goals that help us continuously improve. The costs of not investing in technology are higher than keeping up with the advances that are available," O'Brien said.

Expanding Opportunities

At this year's Gear Expo, Scot Forge highlighted the advances of "hybrid



A bull gear that is machined and ready for shipment. This part was previously welded as a three component fabrication but is now being produced as a single piece forging (courtesy of Scot Forge).

forging". Using the advantages of open die forging combined with the near-net shape capability of closed die forging, the forging process can now be tailored to optimize time and cost savings for the gearing industry.

Companies who are looking for a better competitive advantage have started seeking the help of forging facilities with the metallurgical know-how to deliver improved products, processes and—especially—costs. This is exactly what hybrid forging can offer according to Marski.

The operator's point of view from the state-of-the-art Wagner RAW 160/160 control room (courtesy of McInnes Rolled Rings).

"Instead of pushing 100 percent of the material's surface area, hybrid forgers are able to use far less tonnage in a prescribed manner to move material more efficiently. This is due to the tooling and mechanics of the process. For impression die (or closed die), a forging company must manipulate 100 percent of the workpiece at the same time. So it comes down to pounds per square inch, which is why this hybrid process makes it possible to make larger, more complex parts on an open die press. It's also a more efficient use of tooling and investment dollars; the tool design can be changed quicker and more effectively than closed die impression blocks or casting molds," Marski said.

The material handler removes a rolled ring from the Wagner RAW 160/160 mill. The mill is capable of rolling rings up to 144" OD (courtesy of McInnes Rolled Rings).

This offering is ideal for prototypes or low volume production where the die block cost for impression die does not provide economic justification. The immediate availability of this tooling can also allow for a shortened production lead time offering flexible order quantities and reduced lead time in situations where needed.

McInnes has received such positive feedback from the company's recent lead-time performance that they've made it the current centerpiece of its ad campaign.

"We have pages of our website dedicated to posting testimonials from our customers. The comments are not just about delivery speed, but our overall responsiveness. One example is our quote response time. We process an astounding number of inquiries each week and still manage to respond to 95 percent of them in less than 4 hours. As demand picks up I think the customer's main concern is having lead-times and delivery performance slip. We see this as our opportunity to earn their loyalty," O'Brien said.

Forging the Future

According to a recent global steel forging report, the market for automotive applications was valued at over 41 billion in 2016 and is expected to reach 56 billion by 2022. Forging helps to produce desired shape and size of components. It offers tensile strength, excellent uniformity of composition and structure.

The automotive industry depends significantly on steel forged metal components. Forged steel is utilized for demanding applications, such as crankshafts, transmission gears, and bearings. Forged steel is essential in handling the torque and stress placed on those components. Additionally, intense competition is driving demand for more attractive and lightweight vehicles and material considerations and lead-times will be significant factors moving forward.

What will occur in the coming years that will improve lead-times? Nobody knows a definitive answer to this question, but preparing for peaks and valleys, skilled work shortages and fluctuating manufacturing markets will be pivotal in staying ahead of the competition.

O'Brien said that the future of the gear industry, in general, is always difficult to predict. He believes that without any significant process technology advances there will be an increased value on service.

Marski agreed. "If you have a complex problem, partner with a forging supplier that is willing to work with your engineers to help solve it. When reviewing your component, it is helpful to take a step back and ask, 'What is the purpose of my design?' Don't get stuck with something that doesn't take advantage of today's technological advancements. The best results occur if you're willing to think creatively and challenge traditional methods."

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Heat treating is the final stage of the seamless rolled ring process. The new dedicated 25,000 square-foot heat treat bay offers complete annealing, normalizing, quenching and tempering treatments to meet a desired combination of hardness and strength (courtesy of McInnes Rolled Rings).

Cleaner Steels Provide Gear Design Opportunities

Randy Stott, Managing Editor

Gear designers face constant pressure to increase power density in their drivetrains. In the automotive industry, for example, typical engine torque has increased significantly over the last several decades. Meanwhile, the demands for greater fuel efficiency mean designers must accommodate these increased loads in a smaller, more lightweight package than ever before. In addition, electric and hybrid vehicles will feature fewer gears, with fewer transmission speeds, running at higher rpms, meaning the gears in those systems will have to endure life cycles far beyond what is typical with internal combustion engines.

All of this puts a lot of stress on the materials used to make the gears, and conventional gear steels will not be able to accommodate these increased demands.

Fortunately, there is a readily available solution, according to Erik Claesson, Director, Head of Industry Solutions Development for Ovako AB. That solution is cleaner gear steel, which has smaller inclusions, and which may also be produced to yield isotropic properties so that the material provides equal strength in all directions.

What Is Clean Gear Steel?

At its heart, cleaner gear steel means smaller inclusions. Inclusions are hard, nonmetallic flaws in the material that result from oxidation during the manufacturing process. They are the primary cause of fatigue failure in steels. Traditionally, reducing the inclusions in steel to low amounts and sizes required very expensive secondary operations at the mill, such as vacuum arc remelting, electroslag remelting, vacuum induction melting or some combination of those techniques, and many aerospace, medical, military and nuclear applications specify that their steels must be made using these processes. But because of those extra steps, along with the vacuum process required, those steels come with an extremely high price tag.

However, the air melting techniques, along with the secondary metallurgy, casting and reduction processes used by Ovako are all tightly controlled, says Patrik Ölund, Head of Group R&D at Ovako. This allows Ovako's BQ (bearing quality) and IQ (isotropic quality) steels to offer fatigue performance much higher than conventional steels made via air melting processes, and even offering performance comparable to some of those made with more complicated or expensive processes.

Step one is controlling the starting material, Ölund says. Ovako steel is made from recycled material, so selection of the scrap used for melting is extremely important. The scrap is carefully selected towards batches with minimized amounts of residuals.

Also, careful control of the melting process is extremely

Steel melt at the Ovako facility in Hofors, Sweden.

important, as are the secondary metallurgy processes, where de-sulphurization and de-oxidation are controlled. Ovako casts the steel into large ingots, and the tops and bottoms of those ingots are cropped off, because that's where the greatest risk of inclusions is found. Finally, a carefully controlled rolling process helps to reduce any inclusions down to smaller and less harmful features, Ölund says.

In fact, Ovako's ability to control the inclusions has made the company's BQ and IQ steels a viable, economical alternative for those wanting more performance out of their gear steels.

Unfortunately, standards such as ISO 6336-5, which covers the strength and durability of gear materials, don't include definitions for steels such as Ovako's BQ and IQ steels. So, Ovako has done extensive testing to determine the bending fatigue limits and contact/surface fatigue limits of its steels in comparison with standard grades. The tests included extensive rotating bending fatigue tests, as well as pitting failure tests using the FZG method. Also, Claesson says, the values in Figures 3–4 are "at least" values, meaning that the bending and contact fatigue values are the minimum provided by the BQ and IQ steels.

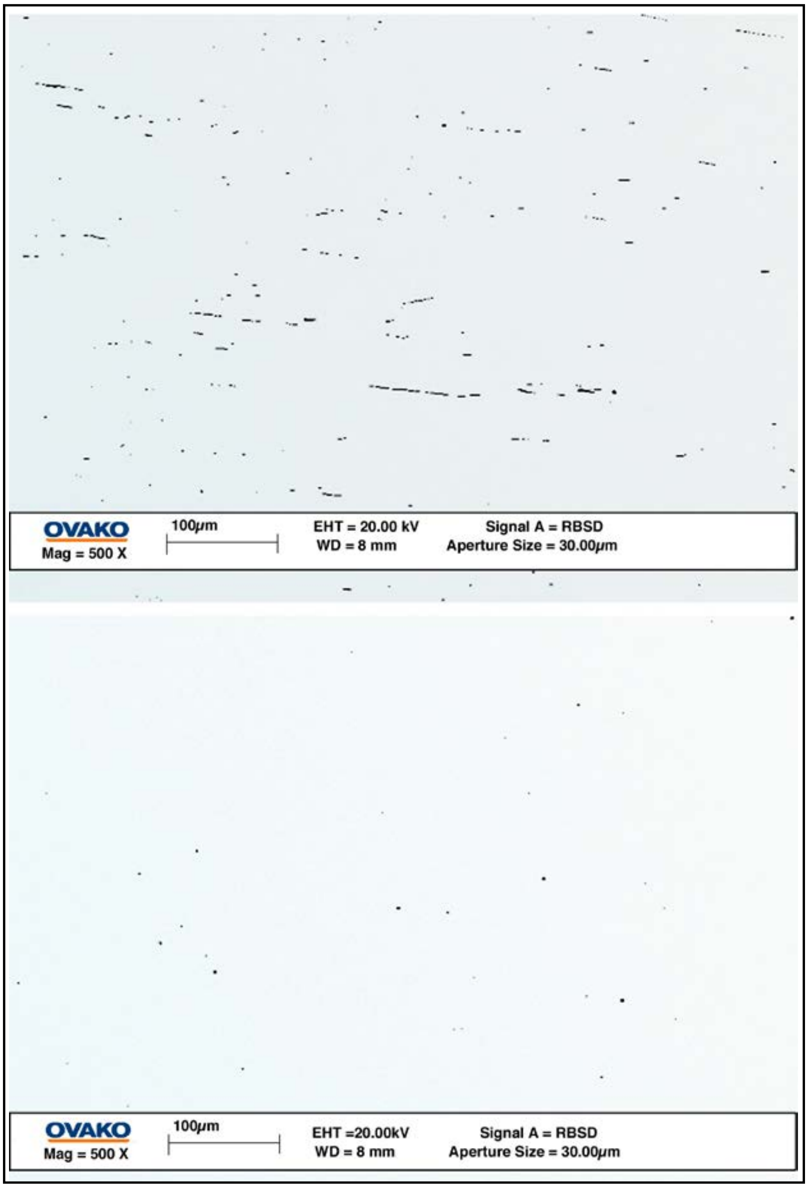

Figure 1 **Comparison of the inclusions found in standard steel (top) and Ovako's BQ steel (bottom).**

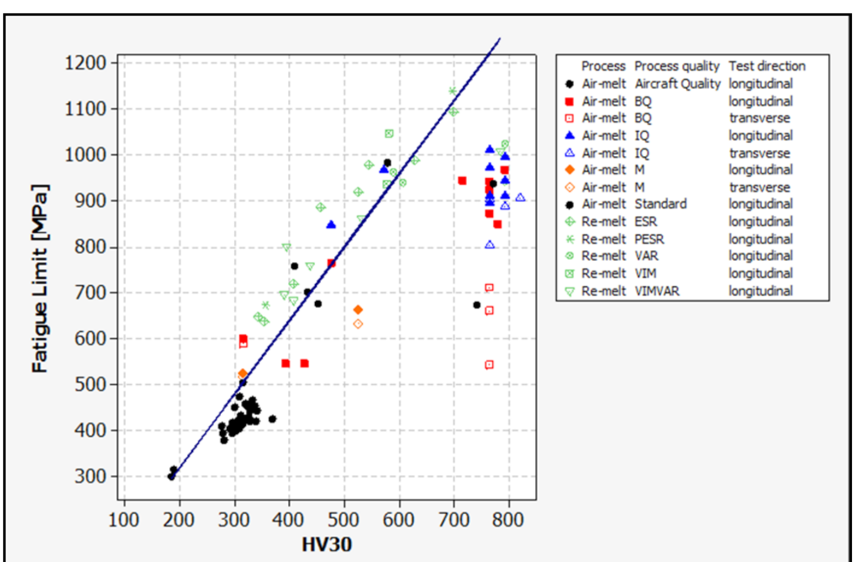

Figure 2 **Fatigue limits for Ovako's BQ and IQ steels, in comparison with steels made by other methods.**

According to Claesson, most gear designers use the MQ values. However, the much higher values of σ_{Flim} (bending fatigue limit) and σ_{Hlim} (contact fatigue limit) offered by the BQ and IQ steels give gear designers a lot more flexibility with their designs.

Increased Design Opportunities

Gear designers looking to increase power density in their designs have a number of options, Claesson says. Ovako proposes three different levels of change that cleaner steels offer. They call it their "20-50-100" concept:

20 level — upgrading the material while maintaining an existing design or making only minor design changes, such as modifying gear tooth geometry to take advantage of enhanced bending fatigue strength of the new material while reducing contact pressure on the gear flank.

50 level — combining the use of cleaner gear steel with significant internal design changes, allowing designers to reduce component size, add components or otherwise modify the system without changing the overall size.

100 level — designing the complete system from the ground up to take maximum advantage of all the benefits cleaner gear steel can offer. "Basically, you get a smaller, stronger gearbox," Claesson says.

In the most basic example, changing the material for an existing component to a cleaner steel of the same grade allows the designer to provide increased life or greater torque in the same package, without undergoing extensive modifications to the manufacturing process.

For example, a manufacturer of an automotive final drive unit might consider just upgrading the material in the pinion. This is often a very cost-effective modification, Claesson says, because it can significantly increase the performance of the transmission without the costs of redesigning the whole system or any of its components. In other words, it's an economical way to extend the lifetime of the transmission, or to expand the options available to include a higher performance model.

The need for increased fatigue resistance will definitely come into play for engineers working on transmissions for hybrid electric or straight electric vehicle drivetrains, Claesson says. The higher rpms and fewer gears mean that each individual gear will have to endure significantly higher load cycles than the gears in a transmission coupled to an internal combustion engine.

What Does it Cost?

BQ and IQ steels definitely cost more than standard quality steels, Claesson says. But it's important to consider that the increased performance they provide might allow manufacturers to eliminate some secondary machining operations such as shot peening. Shot peening is typically done to improve the fatigue resistance of gears. But if the base material has significantly better fatigue resistance because of the cleanliness of the steel, then shot peening might be reduced or even eliminated. In fact, Claesson says, some manufacturers have even seen a decrease in overall costs while still significantly improving the performance of their transmissions.

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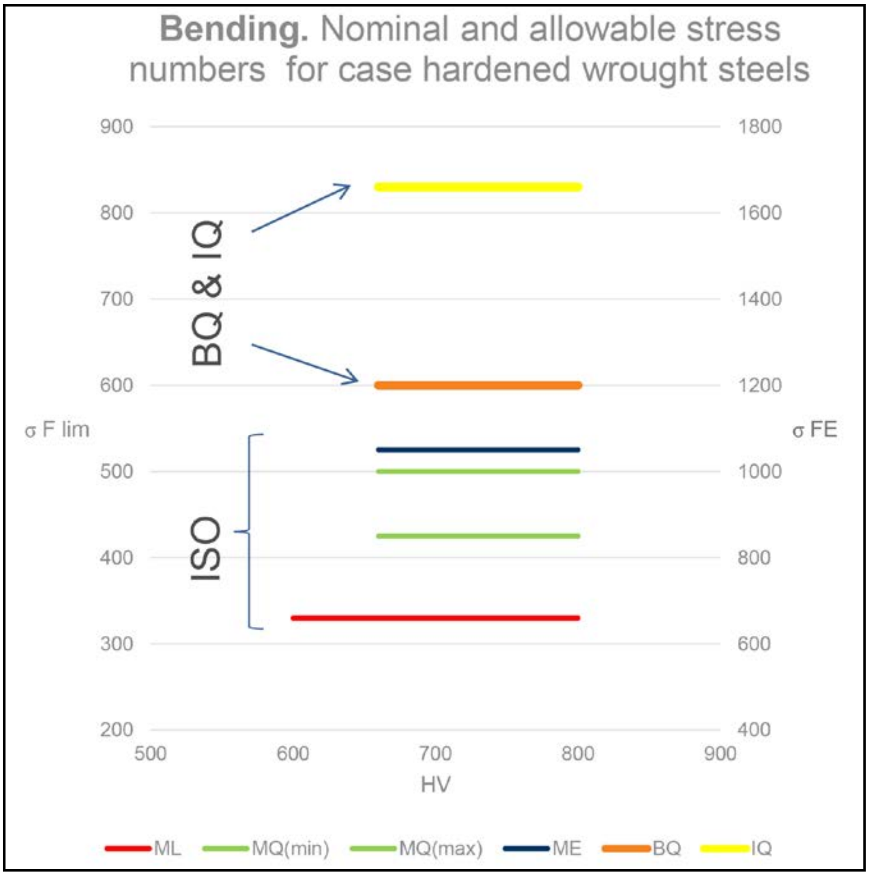

Figure 3 **Bending fatigue limits for BQ and IQ steels are not represented in standards such as ISO 6336-5.**

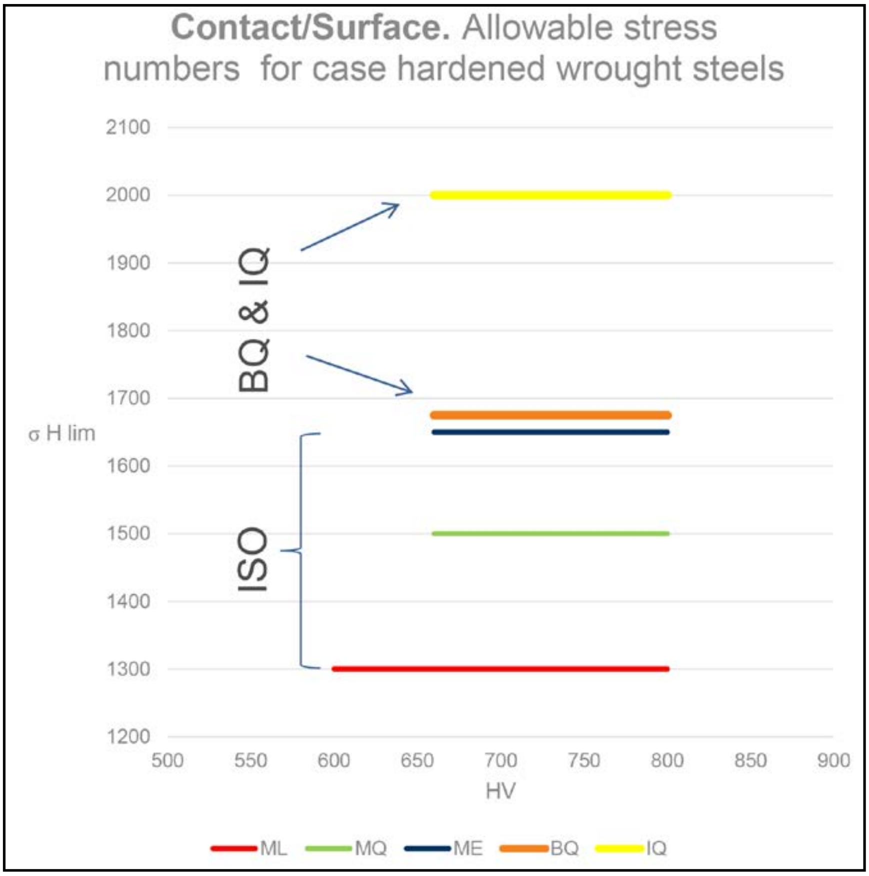

Figure 4 **Contact fatigue limits for BQ and IQ steels exceed those of the standard grades represented in standards such as ISO 6336-5.**

Rating of Helical Asymmetric Tooth Gears

A.L. Kapelevich and Y. V. Shekhtman, AKGears, LLC.

Introduction

Although gear geometry and the design of asymmetric tooth gears are well known and published, they are not covered by modern national or international gear design and rating standards. This limits their broad implementation for various gear applications, despite substantial performance advantages in comparison to symmetric tooth gears for mostly unidirectional drives. In some industries — like aerospace, that are accustomed to using gears with non-standard tooth shapes — the rating of these gears is established by comprehensive testing (Ref. 1). However, such testing programs are not affordable for many other gear drive applications that could also benefit from asymmetric tooth gears. Helical, asymmetric tooth gears (Fig. 1), though non-standard, have involute flanks similar to standard involute gears with symmetric teeth that are rated by national and international standards; a rating method for spur asymmetric tooth gears is described in (Ref. 2). It defines the stress conversion coefficients that allow using the existing gear standards for rating of spur asymmetric tooth gears. This article utilizes the same approach for helical, asymmetric tooth gears, which enables evaluating them using existing rating standards.

Figure 1 Helical asymmetric tooth gears (courtesy of Höganäs AB).

Direct Design of Helical Asymmetric Tooth Gears

The trademarked *Direct Gear Design* method (Ref. 3) presents an asymmetric tooth by two involutes of two different base circles — d_{bd} and d_{bc} — and a tooth tip circle d_a (Fig. 2).

Drive and coast transverse profile (pressure) angles α_{wd} and α_{wc} at operating pitch diameter d_w

$$\alpha_{wd} = \arccos(d_{bd}/d_w), \quad (1)$$

$$\alpha_{wc} = \arccos(d_{bc}/d_w), \quad (2)$$

Drive and coast normal profile (pressure) angles α_{wd} and α_{wc} at operating pitch diameter d_w

$$\alpha_{nd} = \arctan(\tan\frac{\alpha_{wd}}{2} \times \cos\beta), \quad (3)$$

$$\alpha_{nc} = \arctan(\tan\frac{\alpha_{wc}}{2} \times \cos\beta), \quad (4)$$

where β – helix angle.

Asymmetry factor K

$$K = \frac{d_{bc}}{d_{bd}} = \frac{\cos(\nu_c)}{\cos(\nu_d)} = \frac{\cos(\alpha_{wc})}{\cos(\alpha_{wd})} \geq 1.0 \quad (5)$$

Circular transverse tooth thickness S_w at operating pitch diameter d_w

$$S_w = \frac{d_w}{2} \times (\mathrm{inv}(\nu_d) + \mathrm{inv}(\nu_c) - \mathrm{inv}(\alpha_{wd}) - \mathrm{inv}(\alpha_{wc})) \quad (6)$$

Equally spaced teeth form the gear; the root fillet between teeth is the area of maximum bending stress. *Direct Gear Design* optimizes the root fillet profile, providing minimum bending stress concentration and sufficient clearance with the mating gear tooth tips in mesh (Ref. 4).

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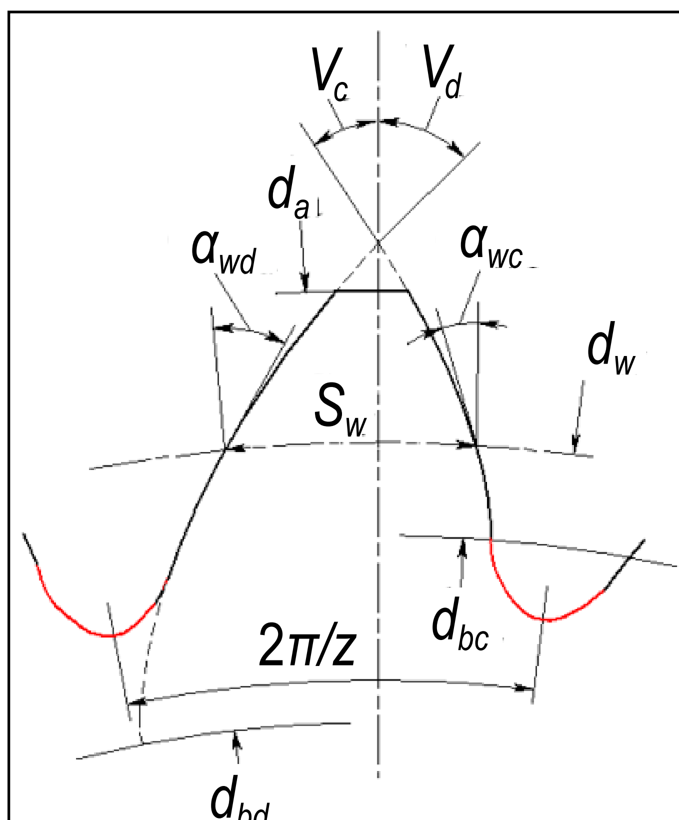


Figure 2 Asymmetric tooth profile (transverse section). z — number of teeth; d_{bd}, d_{bc} — base diameters; V_d, V_c — involute intersection profile angles; d_w — operating pitch diameter; α_{wd}, α_{wc} - profile (pressure) angles at diameter d_w; S_w — circular tooth thickness at diameter d_w; d_a — tooth tip circle diameter; symbols "*d*" and "*c*" for drive and coast tooth flanks.

Comparable Helical Symmetric Tooth Gear Definition

In order to apply existing rating standards to asymmetric tooth gear rating, they must be replaced by comparable symmetric tooth gears. Tooth geometry of these symmetric tooth gears should be described by symmetric generating rack parameters and addendum modifications (or X-shift coefficients). Parameters of this symmetric rack include (Fig. 3):

Symmetric generating rack normal module

$$m_n = \frac{d_{w1}}{z_1} \times \cos\beta = \frac{d_{w2}}{z_2} \times \cos\beta \tag{7}$$

where z_1 and z_2 are numbers of teeth of the pinion and gear.

Normal profile (pressure) angle

$$\alpha_n = \frac{\alpha_{nd} + \alpha_{nc}}{2} \tag{8}$$

Rack addendum coefficient

$$h_a = (d_{a1} - d_1 + d_{a2} - d_2)/4m_n \tag{9}$$

Full rack tip radius coefficient

$$r = \frac{\pi/4 - h_a \tan\alpha_n}{\cos\alpha_n} \tag{10}$$

Clearance coefficient

$$c = r(1 - \sin\alpha_n) \tag{11}$$

Addendum modification (X-shift) coefficients

$$x_1 = \frac{(s_{w1} - s_{w2}) \times \cos\beta}{4m_n \times \tan\alpha_n} \text{ and } x_2 = -x_1 \tag{12}$$

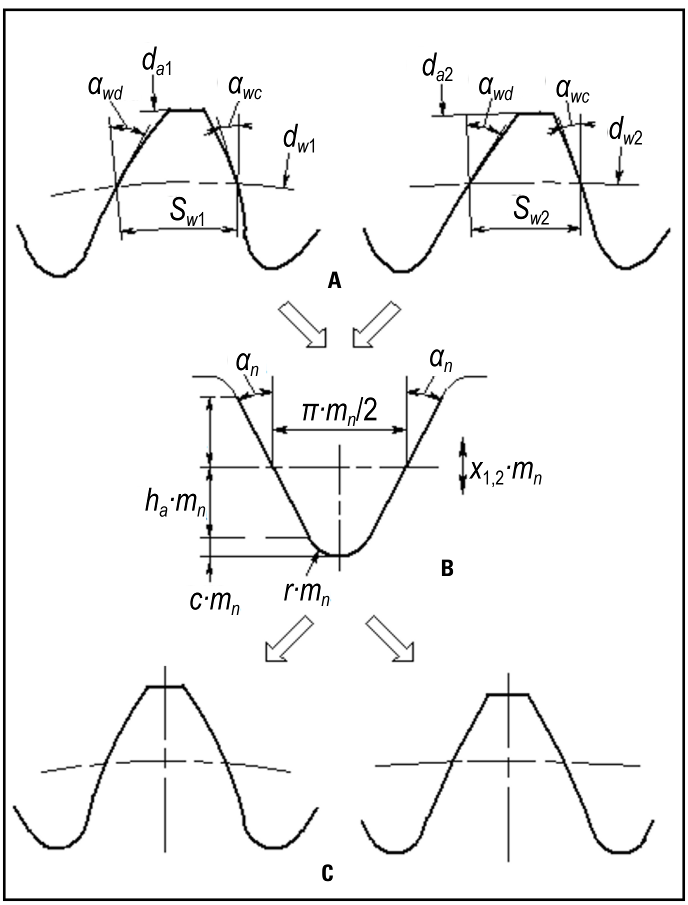


Figure 3 Definition of symmetric rack for comparable symmetric tooth gears generation based on Direct Gear Design of asymmetric tooth gear pair; A — mating asymmetric tooth pinion and gear profiles; B — symmetric rack; C —comparable symmetric tooth profiles.

The symmetric generating rack parameters defined by Equations 5–10 are used to design the comparable symmetric gears and obtain their rating data for required gear drive operating conditions. A sample of the helical asymmetric and comparable symmetric tooth gear geometry data is presented in Table 1.

Stress Calculation of Asymmetric and Comparable Symmetric Tooth Gears

Root bending stress and conversion coefficients. The standard procedure for bending stress calculation (based on the Lewis equation) cannot be used for the asymmetric tooth gears because a symmetric Lewis parabola does not properly fit into an asymmetric tooth profile. Finite element analysis (FEA) is a more suitable analytical tool to calculate the maximum root stress in the asymmetric and comparable symmetric tooth gears in order to define bending stress conversion coefficients. The *Direct Gear Design* technique utilizes the FEA tooth root bending stress calculation for asymmetric tooth gears. Although there are differences in the standard and FEA root stress calculation results, FEA allows for defining conversion coefficients between asymmetric and comparable symmetric tooth maximum bending stresses. In this study, the 2-D FEA procedure, developed by Yuriy Shekhtman, was used for tooth root bending stress calculations.

Since the standard bending stress definition procedure is applied to the virtual spur gears that represent a normal section of the actual helical gears, the FEA stress calculation is also done for the virtual spur representations of the asymmetric and comparable symmetric gears.

The finite element meshes and root stress images of the asymmetric and comparable symmetric gear teeth are shown (Table 2).

For the maximum root bending stress calculation, a normal load F_n is applied to the "highest point of single tooth contact" (HPSTC) of the drive tooth flank in the normal tooth section.

$$F_n = 2T_1/(d_{bd1}, \times \cos\beta) \tag{13}$$

where T_1 is the pinion driving torque, d_{b1} is the pinion drive flank base diameter. The pinion and gear conversion coefficients are

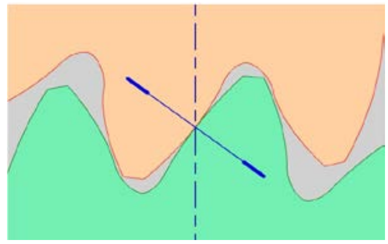
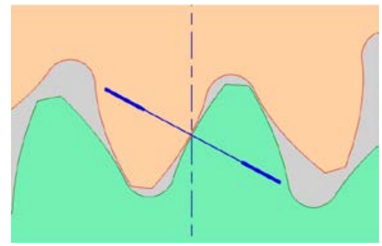
$$C_{F1,2} = \frac{\sigma_{F\,max(sym)1,2}}{\sigma_{F\,max(asym)1,2}} \tag{14}$$

where $\sigma_{Fmax(asym)1,2}$ and $\sigma_{Fmax(sym)1,2}$ are the maximum FEA root bending stresses of the asymmetric and comparable symmetric tooth pinion and gear.

Flank contact stress and conversion coefficient. The standard tooth flank contact stress calculation procedure (based on the Hertz equation) is suitable for both asymmetric and comparable symmetric tooth gears.

Similar to the bending stress calculation, the standard contact stress definition procedure is likewise applied to the virtual spur gears that represent a normal section of the actual helical gears. In this study the Hertz contact stress is also calculated for the virtual spur representations of the asymmetric and comparable symmetric gears.

The Hertz equation allows for calculating the maximum contact stress in asymmetric and comparable symmetric tooth gears to define the contact stress conversion coefficients.

Table 1 Helical asymmetric and comparable symmetric tooth gear geometry data				
	Asymmetric		Comparable Symmetric	
Gear Pair				
Number of teeth	17	23	17	23
Normal Module	4.000		4.000	
Normal Pressure Angle	35°/18°*		26.5°	
Asymmetry Factor	1.179		1.0	
Helix Angle	20°		20°	
Pitch Diameter (PD)	72.364		72.364	97.904
Base Diameter	58.026/ 68.391*	78.506/ 92.529*	63.924	86.485
Normal Tooth Thickness at PD	6.390	6.176	6.390	6.176
Center Distance	85.134		85.134	
Normal Generating Rack Angle	-		26.5°	
Addendum Coefficient	-		1.051	
Root Radius Coefficient	-		0.292	
Root Clearance Coefficient	-		0.162	
Profile Shift Coefficient	-	-	0.025	-0.025
Tip Diameter	80.845	106.236	80.985	106.100
Root Diameter	62.967	88.318	62.873	87.988
Root Fillet Profile	optimized	optimized	trochoidal	trochoidal
Face Width	40.00	37.00	40.00	37.00
Transverse Contact Ratio	1.20/1.54*		1.32	
Axial Contact Ratio	1.01		1.01	
Total Contact Ratio	2.21/2.54		2.33	

* Drive/coast flanks

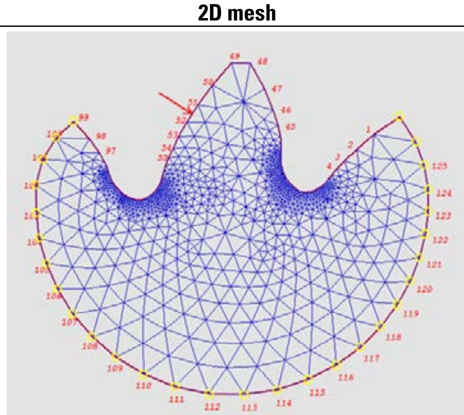
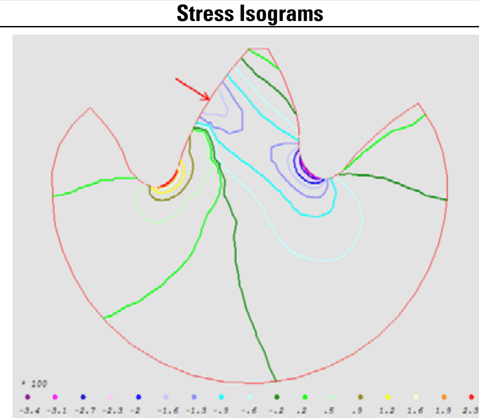
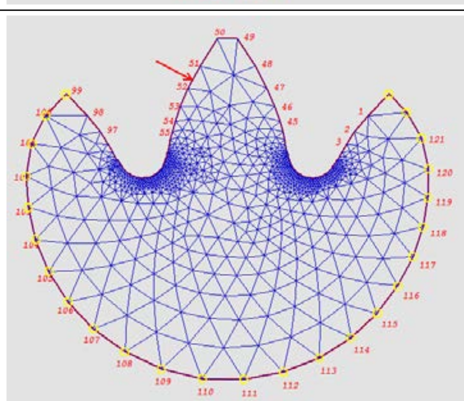
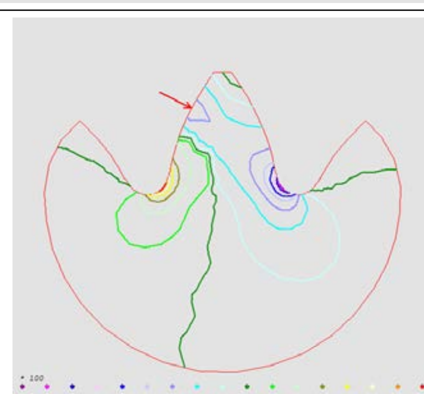
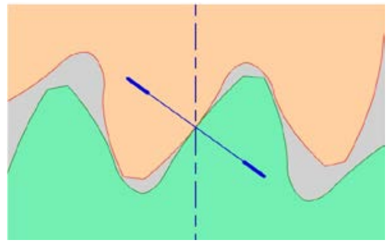
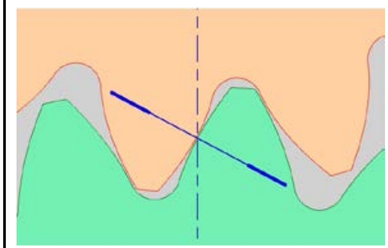
Table 2 FEA meshes and stress models of asymmetric and comparable symmetric teeth		
	2D mesh	Stress Isograms
Asymmetric tooth (normal section)		
Comparable symmetric tooth (normal section)		

Table 3 Asymmetric and comparable symmetric tooth gear stress analysis results

	Asymmetric		Comparable Symmetric	
Gear Pair				
Number of teeth	17	23	17	23
Module	4.000		4.000	
Normal Pressure Angle	35°/18°		26.5°	
Helix Angle	20°		20°	
Face Width	40.00	37.00	40.00	37.00
Torque, Nm	700	947	700	947
RPM	1000	739	1000	739
Service Life, hrs	2000		2000	
Material type	Carburized, case harden steel, like AISI 8620			
Bending Stress (FEA), MPa	271	285	298	315
Bending Stress, MPa	-	-	369*	392*
Contact Stress, MPa	-	-	1485*	1485*
Contact Stress (Hertz), MPa	1282		1340	
Bending Stress Conversion Coefficients, $C_{F1,2}$	1.100	1.105	-	-
Contact Stress Conversion Coefficients (Hertz), C_H	1.045		-	
Bending Safety Factors	2.64	2.51	2.40*	2.27*
Contact Safety Factors	1.06	1.07	1.01*	1.02*

* Calculation method: per ISO 6336 standard

The Hertzian contact stress is

$$\sigma_F = \sqrt{\frac{F_n}{\pi b} \times \frac{E}{2\,(1-\nu^2)} \times \left(\frac{1}{\rho_1} + \frac{1}{\rho_1}\right)} \quad (15)$$

where b is face width in contact, E and ν are modulus of elasticity and Poisson ratio, assuming mating pinion and gear materials are identical, ρ_1 and ρ_2 are pinion and gear drive flank curvature radii in contact. The contact stress conversion coefficient is

$$C_H = \frac{\sigma_{H\,max\,(sym)}}{\sigma_{H\,max\,(asym)}} \quad (16)$$

where $\sigma_{Hmax(asym)}$, $\sigma_{Hmax(sym)}$ are the maximum Hertz contact stresses of the asymmetric and comparable symmetric tooth gears pairs.

Standard Rating of Helical Asymmetric Tooth Gears

Rating of involute gears with symmetric tooth gears is established in national and international standards. In order to apply these rating standards to asymmetric tooth gears, the bending and contact safety factors defined for the comparable symmetric tooth gears should be multiplied by the contact and bending conversion coefficients accordingly. Then the rated bending safety factors of asymmetric tooth gears are

$$S_{F(asym)1,2} = C_{F1,2} S_{F(sym)1,2}, \quad (17)$$

where $S_{F(sym)1,2}$ are the root bending safety factor of comparable symmetric tooth gears defined by the rating standards.

The rated contact safety factor of asymmetric tooth gears is

$$S_{H(asym)} = C_H S_{H(sym)}, \quad (18)$$

where $S_{H(sym)}$ is the flank contact safety factor of comparable symmetric tooth gears defined by the rating standards.

A sample of the asymmetric and comparable symmetric tooth gear stress analysis results is presented in Table 3; geometric data for these gears is in Table 1.

Summary

This study outlined a simple and effective approach to rating helical asymmetric tooth gears based on a combination of well-established calculation methods: FEA for tooth root stress definition, contact stress Hertz equation, and standard rating procedure for comparable symmetric tooth gears.

Presented rating approach allows for expanding implementation of helical asymmetric tooth gears in many unidirectional gear drives, maximizing their performance.

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1. Brown, F.W., S.R. Davidson, D.B. Hanes, D.J. Weires and A. L. Kapelevich. "Analysis and Testing of Gears with Asymmetric Involute Tooth Form and Optimized Fillet Form for Potential Application in Helicopter Main Drives," ***Gear Technology,*** June/July 2011, 46–55.
2. Kapelevich, A. L. and Y. V. Shekhtman. "Rating of Asymmetric Tooth Gears," ***Power Transmission Engineering,*** April 2016, 40–45.
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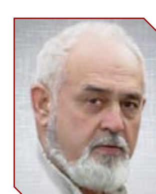
4. Kapelevich, A.L. and Y.V. Shekhtman. "Tooth Fillet Profile Optimization for Gears with Symmetric and Asymmetric Teeth." *Gear Technology*. September/October 2009, 73–79.

Dr. Alex Kapelevich operates the gear design consulting firm AKGears, LLC. He is a developer of modern Direct Gear Design methodology and software. He has over 30 years of experience in custom gear drive development, with particular expertise in gear transmission architecture, planetary systems, gear tooth profile optimization, asymmetric tooth gears, and gear drive performance maximization. Kapelevich is author of the book "Direct Gear Design" and many technical articles.



Dr. Yuriy Shekhtman is an expert in mathematical modeling and stress analysis. Drawing upon over 40 years' experience, he has created a number of computer programs based on FEA and other numerical methods. A software developer for AKGears, Dr. Shekhtman is also the author of many technical publications (*y.shekhtman@gmail.com*).

Three-Face Blade Technology

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Three-Face vs. Two-Face

In order to utilize the full potential of 3-face ground and all around coated blades the cutter head slot inclination of 4.42° as it is used in the Pentac-FH cutter system is not sufficient. In case of 2-face ground blades, the front face remains untouched during the re-sharpening of only pressure angle and clearance side of the blade. The front face of 2-face blades is parallel to the blade shank and has a permanent coating. After re-sharpening, the blades are ready to be built in the cutter head.

If blades should be all around coated, then it is recommended to grind in addition to the side relief surfaces also the front face. The reason is the continuous buildup of coating layer on the front face if no stripping between coatings occurs. Although it is possible to strip the front face coating chemically before every re-coating, this would involve additional cost and results in a degradation of the carbide under the repeatedly stripped surface. In case of all-around coating it is recommended to grind the front face of the blades also in order to remove the previous coating and utilize the possibility to achieve more optimal top rake and side rake angles with a different front face orientation. The "package" 3-face grinding and all-around coating can double the tool life, compared to 2-face grinding with permanent front face coating.

Three-face grinding of blades which will be utilized in a cutter head with 4.42° of slot tilt angle is very limited with the maximal achievable top rake angle, which is around zero in the left graphic in Figure 1. If the same blade was used in a cutter head with a 12° slot tilt angle as shown to the right in Figure 1, then the achieved top rake angle would be 7.58°. This freedom allows in all cases of different gear geometries and cutting kinematics to maintain a slightly positive top rake angle.

Another important factor for manufacturing cost per part is the relationship between slot tilt angle and number of re-sharpenings. In order to accomplish an effective top rake angle of e.g. 2° on a blade which is built in a cutter head with a 4.42° slot inclination angle, a Δ_δ (Fig. 1) of 2.42° is required. This is represented by the left graphic in Figure 2. The cleanup amount of Δs normal to the surface will require a large blade top down Δl_1. If a top rake angle of 2° in the cutting process should be realized in a cutter with 12° slot tilt angle, then the blade hook angle in blade grinding will be 10°, as shown in the right graphic in Figure 2. The relationship between top down Δl_2 and front face clean up Δs is becoming more favorable by increasing the slot tilt angle. The number of resharpenings for 3-face grinding in case of a 12° cutter slot tilt angle is 2.7 times higher than that of a 4.42° cutter slot tilt angle.

The limits for the highest realistic slot inclination angles in cutter heads are given

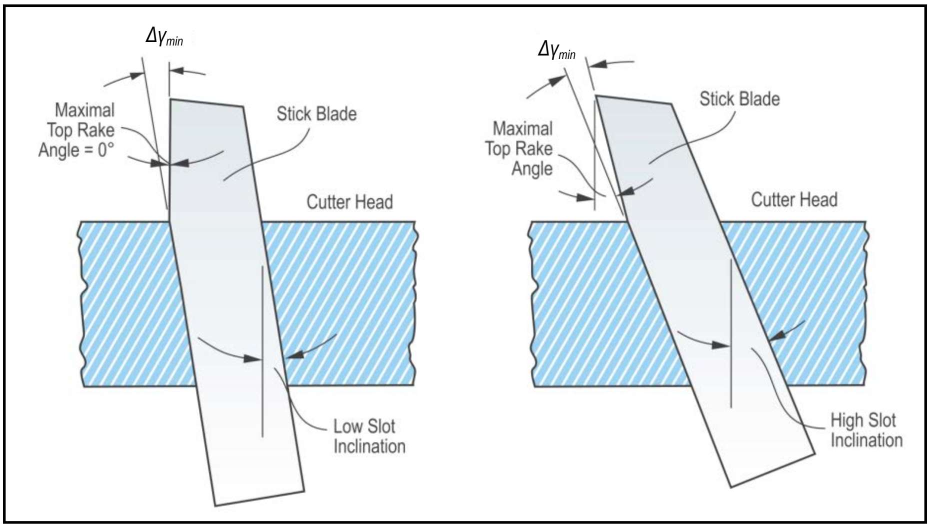

Figure 1 Top rake angle as function of slot inclination (slot tilt angle).

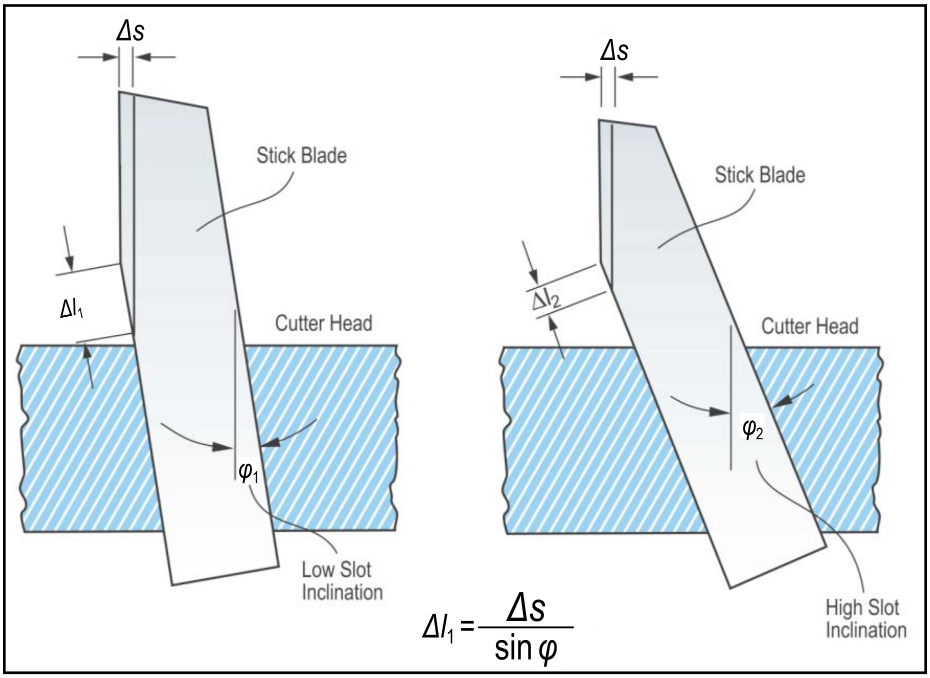

Figure 2 Relationship between top down amount and blade hook angle.

by the cutter design and manufacturing, as well as the higher tendency of the cutting forces to push the blades axially into the slots during the cutting process.

Blade Parameter Definitions and Geometry Calculation

Two of the most important input parameters of the blade geometry calculation after the pressure angle are the effective side rake angle, which indicates the "sharpness" of the blade, and the effective cutting edge hook angle, which indirectly defines the top rake angle. It might be important at this point to mention that for cutting performance and good tool life, the effective cutting edge hook angle is the most important parameter. Because top rake angle and effective cutting edge hook angle are connected, the 3-face blade calculation program attempts to define a blade geometry which achieves the desired effective cutting edge hook angle. Only in cases where this is not possible due to geometry limitations, the closest possible value will be used as the result.

In order to obtain the effective angles, the relationship between the cutting velocity vector (Fig. 3) and the blade coordinate system in Figure 4 has to be considered. The blade side rake angle shown in Figure 4 is equal to the effective side rake angle, if the indicated cutting direction is equal to the x-axis of the blade coordinate system. The effective cutting edge hook angle (vs. the blade hook angle) is shown in Figure 5. Each material removal from the blade front will change the cutting velocity vector direction in Figure 4 and therefore will also change the orientation of the cutting plane. This will in turn change the effective side rake angle as well as the effective cutting edge hook angle. If the gear engineer chooses a particular effective side rake angle, then the blade related side rake angle target has to be reduced or increased depending on the relationship between the cutting velocity vector and the X-axis of the blade coordinate system. This still would not deliver the desired kinematic side rake angle in one calculation step, because the slightly changed blade side rake angle will require a different front clean-up amount, which in turn changes the relative cutting velocity direction again. A complete and a partial front clean-up is shown in Figure 6.

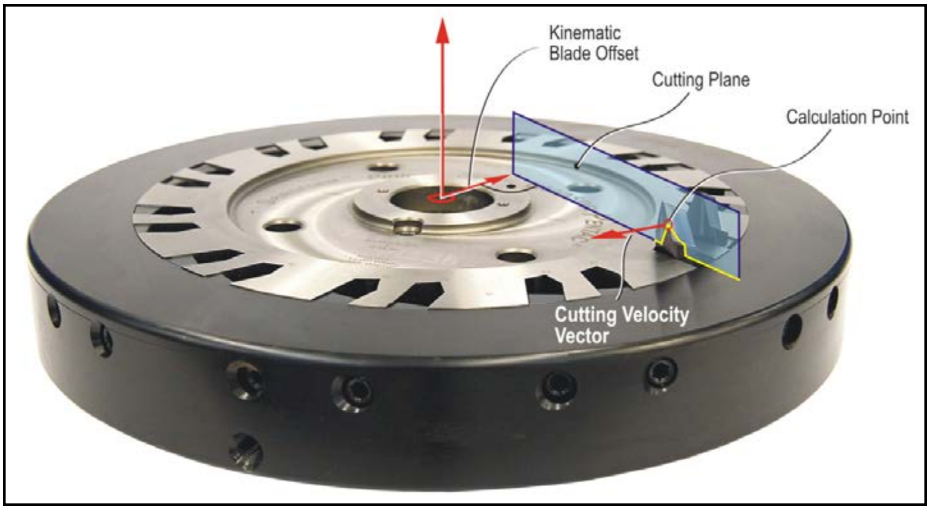

Figure 3 Cutting plane and kinematic velocity vector.

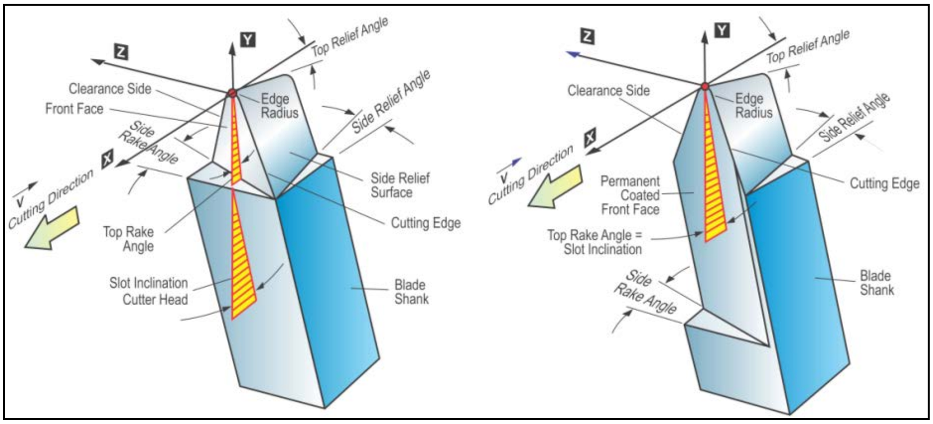

Figure 4 Blade coordinate system of 2-face blade (left) and 3-face blade (right).

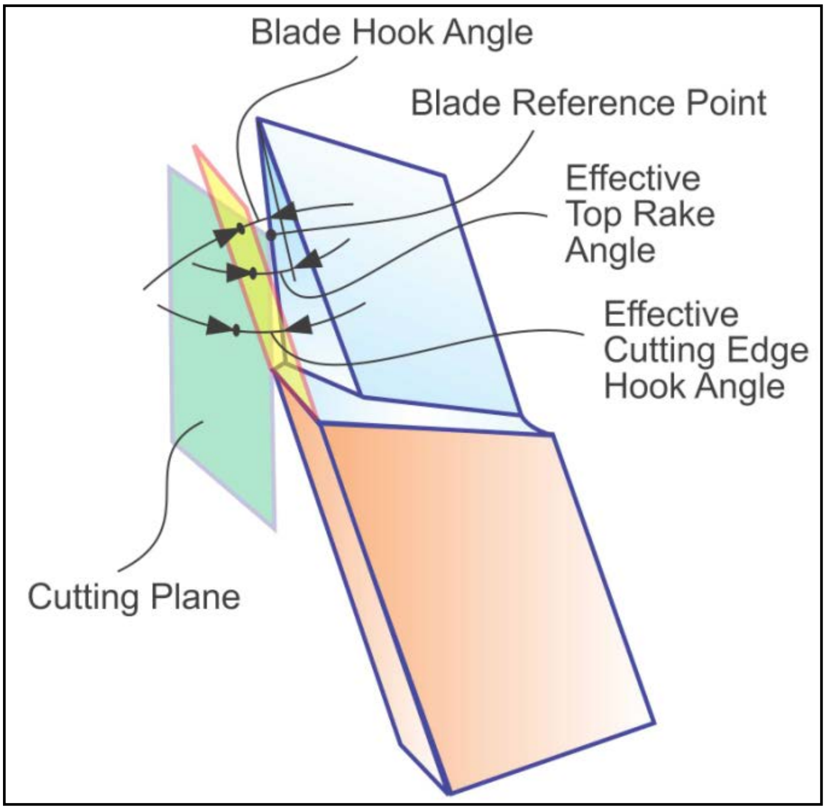

Figure 5 Effective cutting edge hook angle and effective top rake angle.

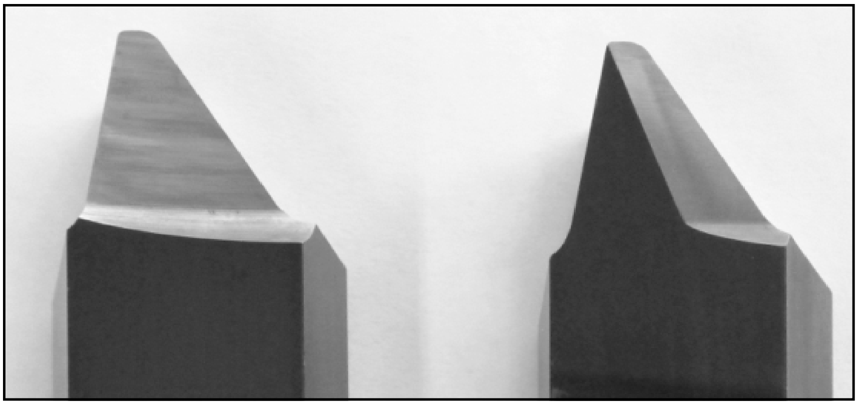

Figure 6 Complete front clean-up (left), partial but sufficient front clean-up (right).

Figure 7 Blade angle and clean-up iterations.

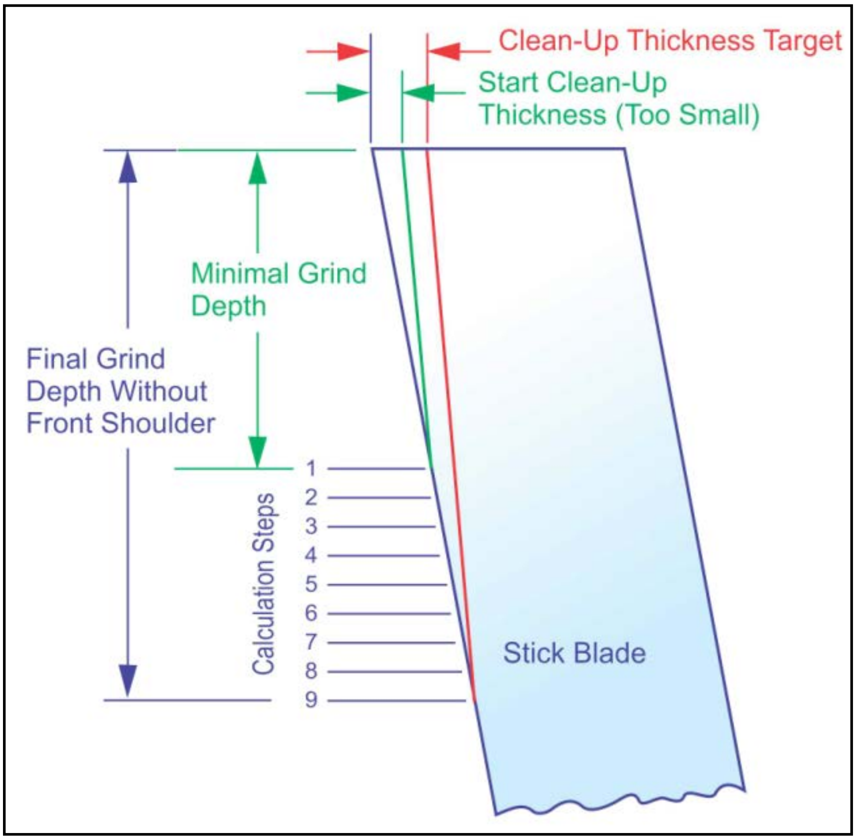

Figure 8 Front clean-up calculation strategy.

Because the amount of front clean-up depends on the chosen side rake and cutting edge hook angle, the physical blade offset (Fig. 3) will change, which also changes the cutting plane orientation relative to the blade. Because of the cross influences between the three parameters which are present in the solution formulae, a closed analytic solution of the 3-face blade geometry is impossible. In order to achieve a sufficient front clean-up and realize the effective input values, three imbedded iterations are required. The problem with imbedded iterations is to achieve a stable and convergent behavior of the calculations while keeping the iterations fast. This goal was achieved with the iteration strategy, symbolized in Figure 7.

The inner iteration loop No. 1 (Fig. 7) influences the top rake angle on the blade front face in order to achieve the given effective cutting edge hook angle. At the end of each calculation step, the effective cutting edge hook angle is calculated and the difference between this number and the desired input value is multiplied with a damping factor and then subtracted from the top rake angle used in the last step. After that, the calculation loop is repeated until the deviation between the actual and the nominal value is below the pre-determined limit.

The iteration loop No. 2 (Fig. 7) is next in the arrangement of iterations. The lead parameter of this iteration is the grind depth (Fig. 8). The calculation begins with the minimally required grind depth. This iteration has to accomplish two things at the same time. Firstly, the front clean-up has to cover the entire length of the cutting edge in order to correctly cut the whole depth of the gear. Secondly, the clean-up thickness at the tip of the blade needs to be equal or above a given minimal value. The calculation is a single direction step approximation rather than a true iteration. Figure 8 shows 9 steps, starting at the minimal grind depth to the final grind depth. After each step the clean-up thickness is checked if it is still below the minimal value, which will enable the next step with an incrementally increased grind depth. If the clean-up thickness calculated at the end of the loop passes for the first time the target value, the front clean-up loop ends and loop No. 3 (Fig. 7) completes the first step of calculating the effective side rake angle for a blade geometry which already shows the correct effective cutting edge hook angle as well as the correct front clean-up.

The result of the effective side rake after finishing the first step of the iteration will not deliver the desired value because the two inner loops (Fig. 7) sufficiently changed the cutting direction relative to the blade coordinate system that several corrective repetitions of this loop are required. Corrective input is the deviation (with negative sign) between actual and nominal effective side rake angle. Although this procedure makes this loop an iteration, the loop ends either if the deviation limit is satisfied or after maximally 5 steps.

In the first generation of 3-face blade geometry calculation, the resulting geometry of the above described calculations was used for the blade grinding, but with one exception for face hobbed bevel gears. The blade spacing between the reference points of outside and inside blade is in the ideal blade definition for face hobbing equal to 360° divided by twice the number of blade groups. The final 3-face blade bases on a blade positioning in a real cutter head and on a different front face geometry of outside and inside blade (Fig. 9). The result is a blade spacing S_X that is not equivalent to the theoretical value of 360° divided by twice the number of blade groups. Figure 10 explains how a blade spacing error of F_d causes in face hobbing a radial error of N_e. In other words, the deviation from equal spacing caused by a physically given cutter head and the 3-face blade geometry of outside and inside blade results in a tooth thickness error of the produced bevel gears. For face hobbing blades, the 3-face program uses a radial correction of each of the inside and outside cutting edge locations of $N_e/2$ (with alternating signs).

The initial gear design calculation either used a theoretical blade or a standard 2-face blade design. Although the radial compensation of the 3-face blade will re-establish the tooth thickness, there will be some side effects which are discussed in the following section.

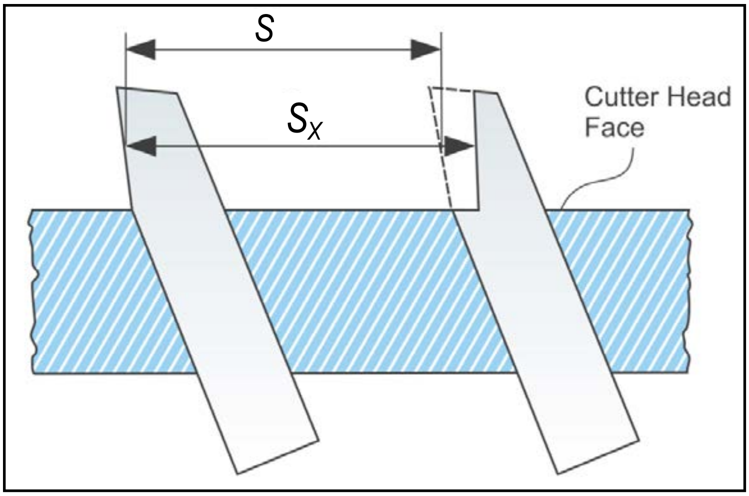

Figure 9 Blade spacing value changes due to 3-face grinding.

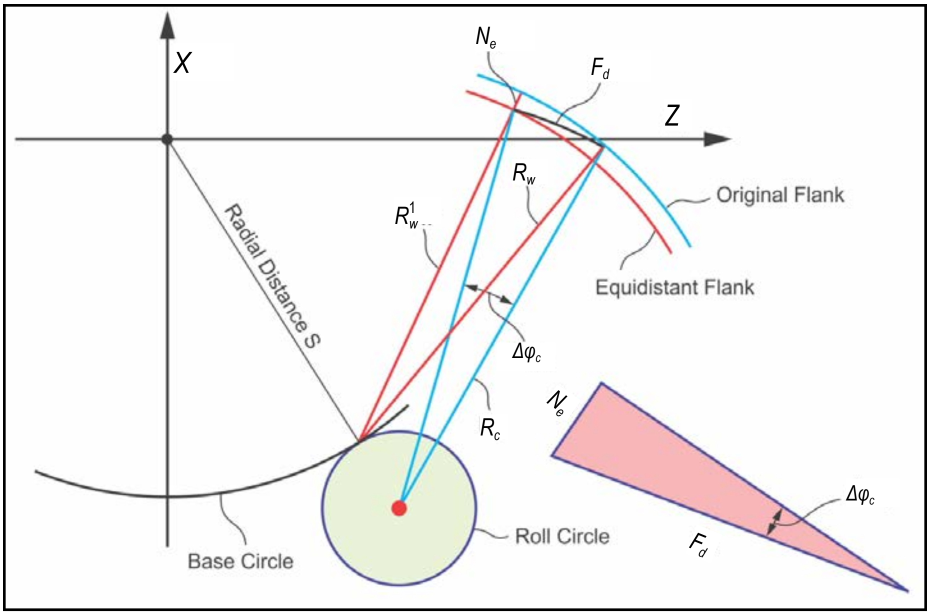

Figure 10 Radial compensation of spacing discrepancy F_d.

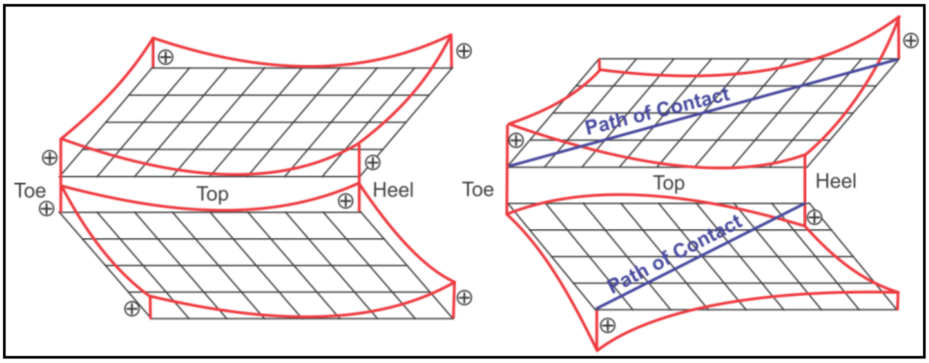

Figure 11 Side effect length crowning (left) and flank twist (right).

Length Crowning and Flank Twist Phenomenon

The change from 2-face ground blades in Pentac-FH cutter heads to 3-face ground and all-around coated blades in PentacPlus-FH cutter heads also requires a relocation of the blade front faces, as described in the previous section. Different front relocations of outside and inside blades cause a tooth thickness change, which can be compensated with small changes of the inside blade and outside blade radii as mentioned above. The alteration of the blade point radii compared to the calculated values causes a major side effect which is a length crowning error on both flanks (Fig. 11, left). The second side effect relates to the change of the effective cutting edge hook angle versus the initial 2-face value (or theoretical blade definition) which results in a flank twist (Fig.11, right).

An effective possibility to reduce the twist in the measurement result is to adjust the 3-face blade geometry closer to the standard 2-face blade geometry. This requires maintaining the original effective cutting edge hook angle; however, the length crowning error still remains in the flank surfaces without any available correction freedoms.

Influence of Blade Stepping

If the outside and inside blades in a face hobbing cutter are built to equal height above the cutter head, then a degradation of the tooth root geometry will occur if a gearset member has length crowning which is created by a cutter head tilt κ (Fig. 12). Figure 12 also aids in the understanding that if the lower outside blade was built to the same blade height above the face of the cutter head as the upper inside blade, then the root of the work would be severely stepped between the two flanks. In order to eliminate the stepping in the work gear root fillet, a stepping between the outside and the inside blade height above the cutter head face is required.

The initial blade stepping calculation uses the length crowning tilt component and applies the objective to keep the blade tips within the vertical generating plane (Fig. 12). After the stepping amount in the direction of the cutter head axis is determined, the cutting edge tangent vector is used to calculate the precise, extended or shortened blade tip locations by maintaining the correct radius and offset at the blade reference point. The effective blades with their original calculation point locations and their stepped blade tips (Fig. 12) are used in the generating software to calculate the correct effective tooth slot and root fillet geometry.

The described blade stepping procedure will not influence the blade reference point location and the geometry of the cutting edge surrounding surfaces. The blade stepping merely extends or shortens the blade dedendum S890 (Fig. 12).

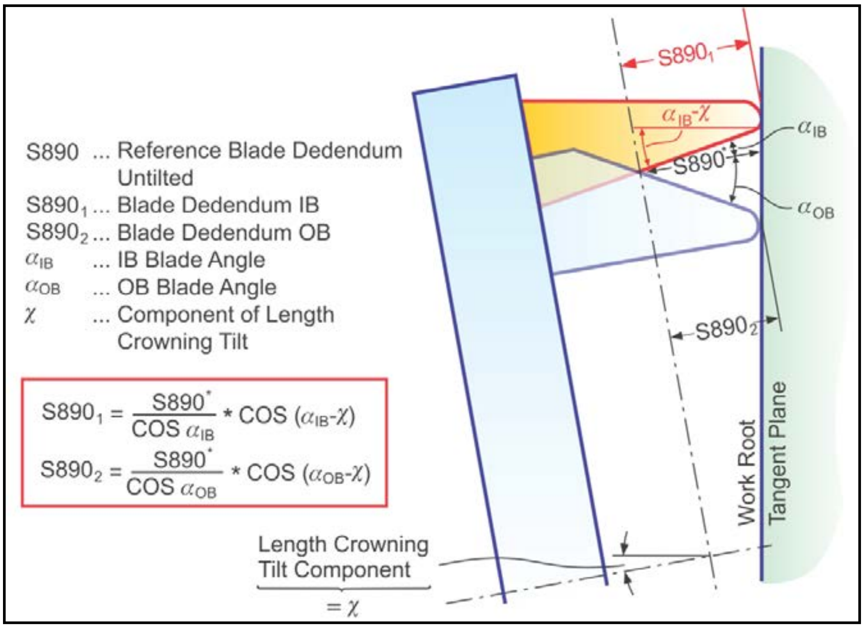

Figure 12 Stepping calculation in blade software.

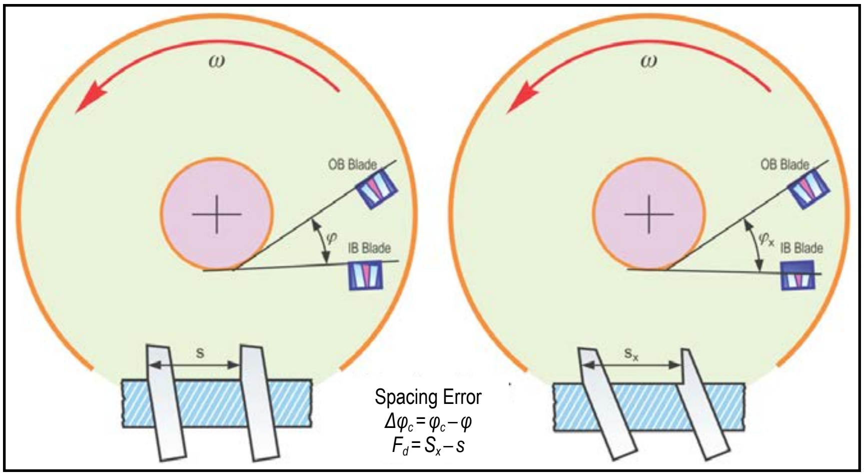

Figure 13 Cutting edge spacing φ.

Blade Spacing Correction in *TREFACE* Program

The 3-face blade calculation program *TREFACE* applies the strategy to establish the required cutter radii at the calculation point and define side rake and top rake angle correctly with respect to the relative cutting direction, given by the kinematic blade offset angle. While providing the requested blade geometry, the program has to assure a sufficient front face cleanup, which has an influence on the resulting timing angle between the outside blade and the following inside blade. The initial timing angle φ (Fig. 13) is derived from the original 2-face calculation that is always exactly or close to 360° divided by twice the number of blade groups (which is the slot spacing angle of the cutter head). This original timing angle in connection with the original point radius adjustment in the 2-face calculation assures the cutting of the correct tooth thickness.

Three-face ground blades result in a spacing angle φ_x, which will — according to Figure 10 — lead to a tooth thickness error N_e. As previously mentioned in the section "Length Crowning and Flank Twist Phenomenon," if the correct tooth thickness is re-established with small cutter point radius changes, then a length crowning side effect of gears cut with such a cutter will occur that cannot be corrected without changes in blade geometry and alterations of the machine settings.

An uncommon solution was developed, which achieves the correct blade spacing angle φ instead of φ_x (Fig. 13), and at the same time delivers the desired values for the effective cutting edge hook angle, the effective side rake angle, as well as providing a complete front face clean-up.

The new method is based on the idea that φ_x (Fig. 13) can be increased if the IB-blade receives a larger front clean-up thickness and φ_x can be reduced if the front clean-up thickness of the OB-blade is increased (Fig. 8). Only increasing of the front face clean-up thickness is permissible because only then is the minimal clean-up preserved.

The algorithm of iterations and approximation loops in Figure 7 now becomes even more complex in order to achieve the desired goal of re-establishing the original blade spacing. Two additional outer loops have to be added (Fig. 14). The first added loop (loop No. 4) repeats all previously discussed calculation loops for both blades involved in cutting one pinion or gear slot ("Inside & Outside Blade Loop" in Fig. 14). The additional outer loop (Loop No. 5) will calculate the actual blade spacing angle (which required that both, IB- and OB-blade calculations have been finished at this point) and processes this value in order to decide which blade (inside or outside) has to receive what amount of additional front clean-up thickness ΔS_x. The corrective repetition of all four inner loops uses a dampened amount of ΔS_x (reduced amount). All inner loops are repeated as described in the section "Blade Parameter Definitions and Geometry Calculation."

The outer blade spacing iteration loop repeats the calculations until the actually achieved blade spacing deviation from the original (desired) spacing is below a defined iteration limit, or if the deviation value changes its sign (or it aborts after maximally 6 steps). The dampening factor and the number of steps have been adjusted so that the overall system of loops works stably and the final results in all evaluated cases are within the acceptable accuracy limits (Fig. 15).

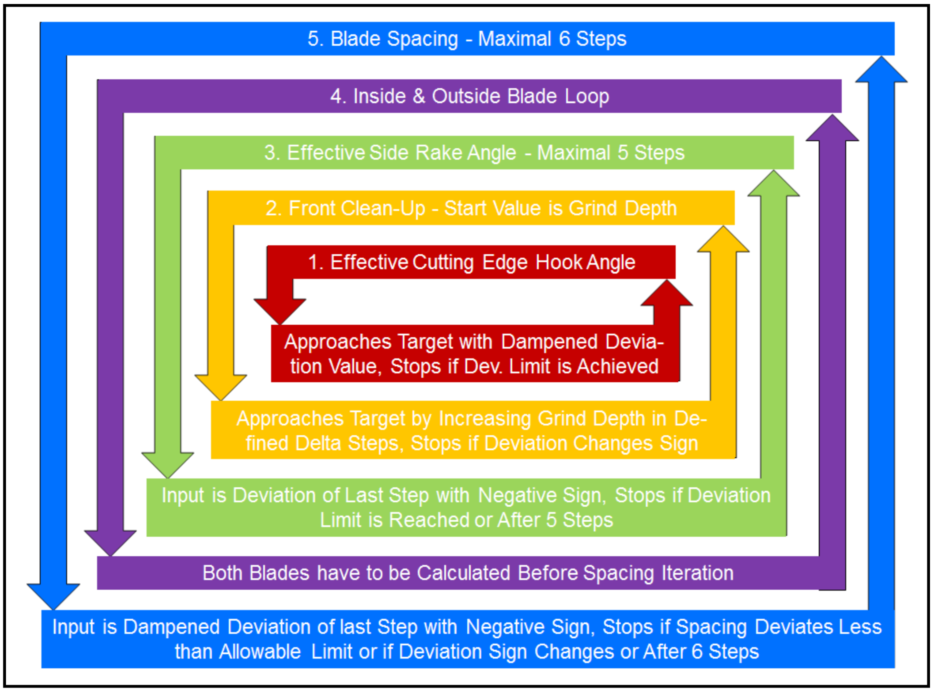

Figure 14 Five imbedded loops for 3-face blade calculation.

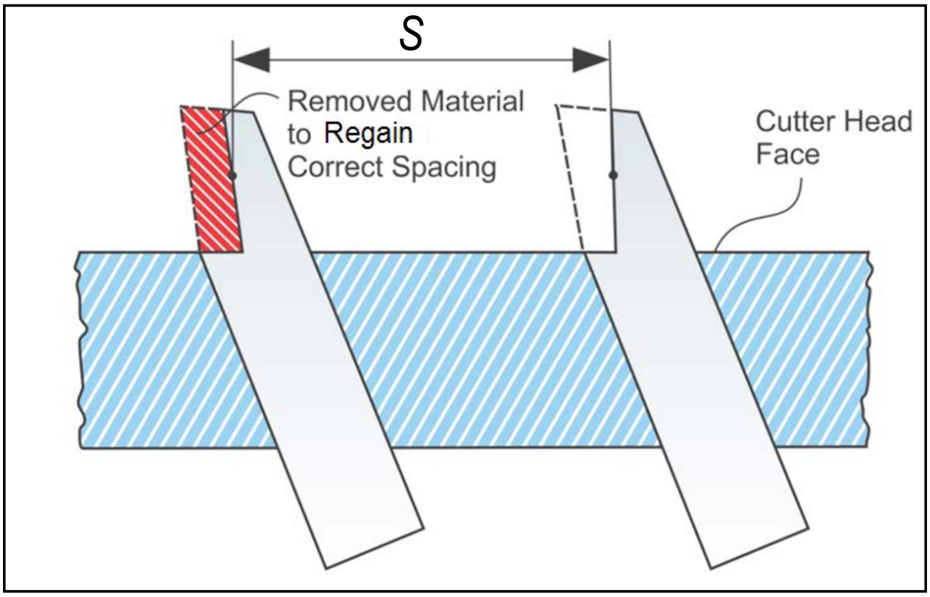

Figure 15 Regaining of correct blade spacing.

Figure 16 is the blade grinding summary output section with the effective blade geometry. The highlighted yellow shows the effective cutting edge hook angle of 1.00° and the effective cutting side rake angle of 4.50°. Those are exactly identical with the input values of the *TREFACE* program where the correct values have been achieved with one single run of *TREFACE*. The blade spacing was kept precisely at the value of the reference cutter. In the output in Figure 16 the blade spacing correction is evident by the fact that the effective tip clean-up thickness of the outside blade varies by a large amount from the target value (2.47 mm versus 1.00 mm).

Face milling designs do not require the outer iteration loop in Figure 14 because the tooth thickness is independent from the blade spacing.

A3F Feedback File to Create Relevant CMM-File

The goal of a 3-face ground blade is to duplicate the theoretical blade geometry used during flank form and tooth contact analysis development. This theoretical blade has in all common cases a standard, 2-face geometry. The decision of which system is used (2-face or 3-face) and the decision of which particular angles (especially the effective cutting edge hook angle) will be chosen for a 3-face blade geometry is made long after the original design calculation was conducted. In cases where the effective cutting edge hook angle of a 3-face blade geometry deviate largely from the original 2-face blade, a specially calculated feedback file (*A3F-file*) can be used to calculate the actual flank form of the gears that will be later manufactured with these blades (software function "create effective design"). The *A3F-file* contains the effective 3-face blade geometry and is processed in the standard flank form generator.

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GLEASON BLADE PROFILE GRINDING SUMMARY   V. 3.0
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EFFECTIVE VALUES IN CUTTER HEAD
                                              OUTSIDE      INSIDE
01. KIN. TOP RAKE VELOCITY ANGLE . . . . . . . -1.60deg    -1.60deg
02. EFF. CUTTING EDGE HOOK ANGLE . . . . . .   1.00deg     1.00deg
03. EFFECTIVE TOP RAKE ANGLE . . . . . . . . . 2.88deg     2.66deg
04. EFF. TOP RELIEF ANGLE. . . . . . . . . . . 15.00deg    15.00deg
05. EFF. CUTTING SIDE RAKE ANGLE. . . . . . .  4.50deg     4.50deg
06. MIN. TIP CLEAN UP TARGET . . . . . . . . . 1.00 mm     1.00 mm
07. EFF. TIP CLEAN UP THICKNESS. . . . . . . . 2.47 mm     1.00 mm

08. CUTTING PRESSURE ANGLE. . . . . . . . . . 22.53deg    20.53deg
09. CUTTER POINT RADIUS. . . . . . . . . . . . 86.41 mm    90.37 mm
10. CUTTER POINT WIDTH . . . . . . . . . . . . .80 mm      .80 mm
11. EFF. RELIEF ANGLE P.A. SIDE. . . . . . . . 15.00deg    11.00deg
12. EFF. RELIEF ANGLE CLEAR SIDE . . . . . . .  9.00deg    13.00deg
13. FRT CLEAN UP LENGTH W/O SHLDR. . . . .11.70 mm     12.21 mm

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Figure 16 Effective blade geometry output in program *TREFACE*.

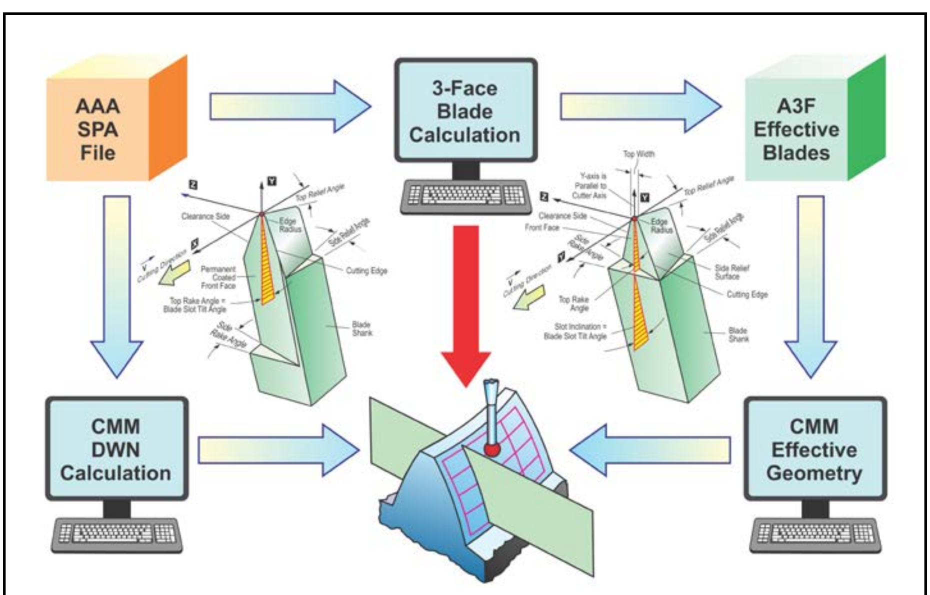

Figure 17 Two-face vs. three-face nominal CMM data file.

The two possibilities to arrive at a coordinate file for 3-D flank form measurement are shown in the data flow and processing chart in Figure 17. It begins with the basic settings and basic blade geometry *AAA-file* or *SPA-file*. The standard case is the CMM-download file calculation in *CAGE*, for example (Fig. 17, left). Parts cut with 2-face blades in a cutter head with 4.42° slot inclination are measured directly with this CMM-download file (right pointing blue arrow to the center bottom graphic in Fig. 17).

In the case of 3-face ground blades used in a cutter head with 12° slot inclination to cut a bevel gear, it is possible to use the parallel generated *A3F-file* with the effective blade geometry and go the path to generate the CMM-effective geometry calculation (Fig. 17, right) and measure the parts with this coordinate file (left pointing blue arrow to center bottom graphic in Fig. 17).

In cases where the post-revision 3-face blade calculation is used, and if the effective blade hook angle is between -1° and +1°, then the manufactured bevel gears can be directly measured with the standard CMM-download file (calculated for 2-face blades in a cutter with 4.42° slot inclination) which is indicated with the red arrow (Fig. 17).

Example Results: Pre- and Post-Revision Software

In order to judge the cutting results after the software revision, some baseline calculations have been made and will be discussed in the following paragraph. All measurement results in this section result from blades ground on the same BPG blade grinder which have been used to cut sample pinions on the same Phoenix cutting machine by utilizing a cutter head with 4.42° slot inclination and a cutter head with 12° blade inclination. The "sum-of-errors-squared" is defined as the summation of the squared deviation amounts of all 90 surface grid points (of both flanks, measuring a 9 × 5 grid). Per convention, the unit "inch²" is used — even if the surface evaluation is done in metric units, as in the present case.

The flank form measurement results in Figure 18 are the baseline for a pinion cut with a 2-face ground blade built in a cutter head with 4.42° slot inclination and measured with the standard *CAGE* download file, which is also based on a 2-face blade in a cutter with 4.42° slot inclination. The corner point deviation of less than 4 µm (Fig. 18) lead to a sum-of-errors-squared of 0.000 000 40 inch^2, which is an excellent result for cutting before heat treatment.

The second baseline measurement also uses the standard *CAGE* download file, but the measured pinion was cut with a 3-face ground blade that was built in a cutter head with 12° slot inclination; the blade grinding summary for this test had been calculated with the pre-revision software. Figure 19 shows the deviations of the cut pinion, which are nearly 14 µm. The sum-of- errors-squared is 0.000 00 231 inch^2, which is still acceptable for a soft cut pinion before heat treatment. However, the surface deviations are significantly larger than the ones in Figure 18. The 3-face blade geometry featured 4.5° effective side rake angle and 1° effective cutting edge hook angle, which compares to the 2-face blades with side rake angles of 12° and effective cutting edge hook angles between +1° and -1°. In particular the effective cutting edge hook angle causes the flank surface twist, visible on the concave flank (Fig. 19). The ΔR_W blade point radii correction that was used in the pre-revision software to maintain the correct tooth thickness causes the length crowning, which is more visible on the convex flank.

As a first step to represent the 3-face blade geometry and subsequently the flank geometry of the manufactured gears, a file that contains the effective blade geometry was created (so-called *A3F-file*). The same 3-face cut pinion measured before with the standard *CAGE* download file (Fig. 19) was also measured with a download file generated with the new *A3F-file*. The results of this measurement are shown (Fig. 20). This measurement achieved a sum-of-errors-squared of 0.000 000 20 inch^2, with corner point deviations in the single micron range — an excellent result.

However, the intention of using 3-face blades is the improvement of the cutting conditions without changing the initially developed flank surfaces. If the *A3F-file* was used to re-run the tooth contact analysis, then small changes in the path of contact bias direction, as well as changes in the length crowning amount, could be observed.

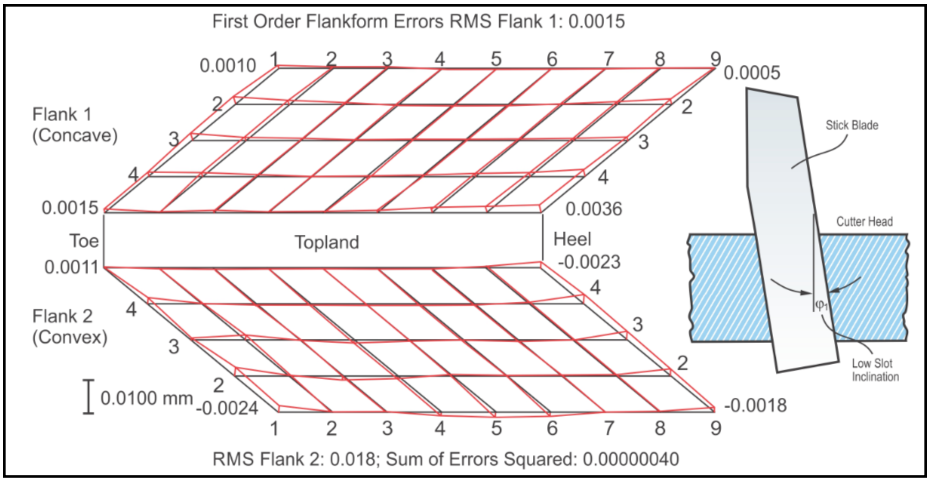

Figure 18 **Standard *CAGE* download file, part cut with 4.42° cutter slot inclination and 2-face blade.**

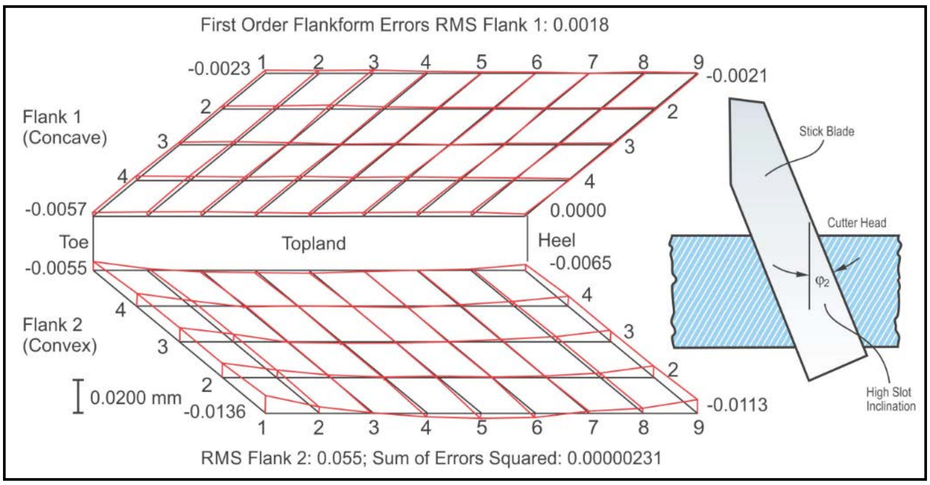

Figure 19 **Standard *CAGE* download file, part cut with 12° cutter slot inclination and 3-face blade with blade calculation before software revision.**

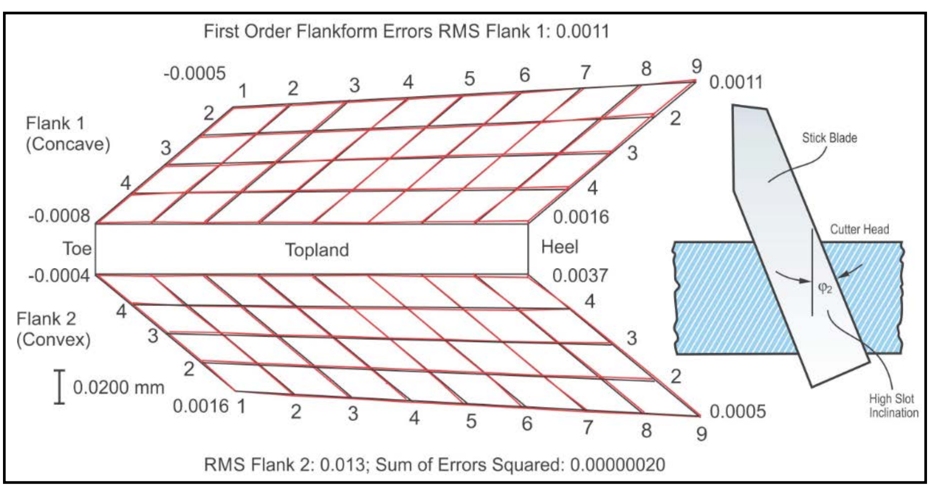

Figure 20 **A3F download file, part cut with 12° cutter slot inclination and 3-face blade.**

The development goal of the revised *TREFACE* software was to eliminate or reduce any differences between 2-face and 3-face blades and subsequently eliminate the differences between cutter heads with different slot inclination.

It became evident during a theoretical study of the cause of flank twist and length crowning that side rake angle and top rake angle are only indirect parameters with limited significance to the flank twist. The investigations resulted in the acknowledgement that the effective cutting edge hook angle is the sole blade feature causing the flank surface twist. And yet the theoretical investigations and the verification in practical cutting trials also showed that the flank twist is minimized if the effective cutting edge hook angle is selected between 0° and +1°.

The addition of the two outer calculation loops (Fig. 14) with the strategy of increasing one of the front clean-up depths (either on the inside blade or on the outside blade) resulted in a 3-face blade spacing that duplicated precisely the original 2-face reference blade. Calculations with the post-revision *TREFACE* program in connection with an input value for the effective cutting edge hook angle between 0° and +1° deliver new-generation 3-face blades that eliminate all length crowning errors and reduce about 85% of the flank twist experienced with the pre-revision software.

Practical proof of this is shown in the flank deviation graphic (Fig. 21). The 3-face blade calculation was repeated with the post-revision *TREFACE* program. As input for the effective hook angle values of inside and outside blade, the recommendation above was applied. Pinions manufactured with the new 3-face blade geometry in a cutter head with 12° slot inclination angle are measured with the standard *CAGE* download file (based on 2-face blades with 12° blade side rake angle used in a cutter with 4.42° slot inclination) result in a single micron flank form deviation with an excellent sum-of-errors-squared of 0.000 000 46 inch².

In face hobbing the cutting edge hook angle — as well as the spacing between outside and inside blades — has an influence on the flank geometry of the manufactured bevel gears. In an industrial environment the basic blade geometry (reference blade) is defined with the original job design early on, but the decision "2-face or 3-face blades" is made much later in the process. Manufacturers were not comfortable with the fact that their decision to use 3-face ground blades could change the flank geometry development of their already approved designs. This was the reason for a major revision of the Gleason blade summary calculation program *TREFACE*.

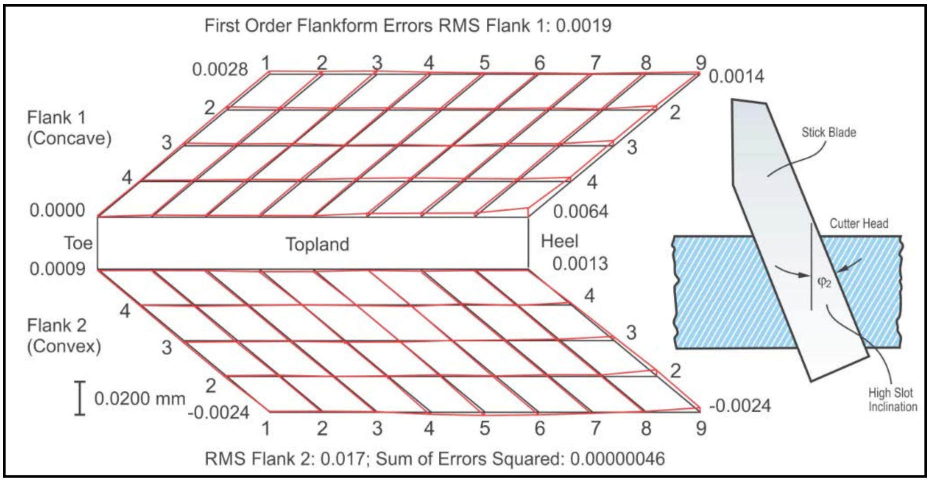

Figure 21 Standard *CAGE* download file, part cut with 12° cutter slot inclination and 3-face blade with bade calculation after software revision.

Three-face blades ground with summaries calculated with the post-revision *TREFACE s*oftware do not create length crowning differences, compared to the 2-face reference blade. All flank twist or bias differences between gears cut with 3-face blades versus the 2-face reference blade can be eliminated, or greatly reduced, if the effective cutting edge hook angle is chosen between 0° and 1°. The new calculation allows the user to make the decision to use cutters with slot inclinations higher than the reference cutter in connection with 3-face ground blades much later than the development of the gearset design. This enables a manufacturer to develop and manufacture in different location without the potential of discrepancies between desired and achieved flank geometry. It also makes manufacture of the same gearset design possible in different locations without noticeable differences.

In cases where a manufacturer likes to apply an effective cutting edge hook angle that is several degrees away from the recommendation, a certain flank surface twist in the manufactured parts versus the original development (and the standard *CAGE* download file) will occur. This problem can be resolved by utilizing the *A3F-file* with the effective blade geometry. A tooth contact analysis using the *A3F-file* will confirm that Ease-Off and tooth contact still reflect the original development, or will show that fine tuning is required in order to adjust the 3-face generated (and manufactured) gearsets to the original development. In either case, a download file generated with the basic data of the *A3F-file* (no standard *CAGE* download file) has to be utilized for the coordinate measurement.

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

Influence of the Defect Size on the Tooth Root Load Carrying Capacity

Prof Christian Brecher, Dr. Christoph Löpenhaus, Jens Brimmers, M.Sc., and Dr. Jannik Henser

In order to increase the power density of gears, a high level of information concerning the load carrying capacity is necessary. Calculation methods for the flank and tooth root load carrying capacity are well-established in the industry and are an important tool for the gear design engineer. The existing methods cover various types of gears, such as cylindrical, bevel, or beveloid gears. Calculating the flank and tooth root load carrying capacity for various gear types relies either on analytical formulae (Hertzian theory, fixed beam) or on results of FE-based tooth contact analysis software.

The existing calculation methods for the tooth root load carrying capacity derive the material strength either from fatigue limit tables, that are based on test rig results, or from the calculation of local material data (e.g. based on hardness, residual stress, and oxidation) by means of empirical formulae. The research of the influence of material defects, such as pores or inclusions, in the context of weakest-link models, has shown that the material fatigue depends on the distribution of defect size within the material. Models for the consideration of the defect size on the tooth root strength, such as the model according to Murakami, have not been applied in fatigue models for gears yet and are focused on in this report.

Therefore, the objective of this work is to introduce a method for the calculation of the tooth root load carrying capacity for gears, under consideration of the influence of the defect size on the endurance fatigue strength of the tooth root. The theoretical basis of this method is presented in this paper as well as the validation in running tests of helical and beveloid gears with different material batches, regarding the size distribution of inclusions. The torque level for a 50 percent failure probability of the gears is evaluated on the test rig and then compared to the results of the simulation. The simulative method allows for a performance of the staircase method that is usually performed physically in the back-to-back tests for endurance strength, as the statistical influence of the material properties is considered in the calculation model. The comparison between simulation and tests shows a high level of accordance.

Introduction

The latest trends in the design process of transmission show an attempt to steadily increase the power density of transmissions in automotive or industrial applications. In order to meet the requirements, the design engineer needs to have a high level of information concerning the load carrying capacity of the gears. The high level of information enables the engineer to avoid over-engineering of the gear and therefore avoid unnecessary weight increase. The calculation methods of the flank and tooth root carrying capacity are well-established within the industry and are based on either analytical formulae (Hertzian theory, fixed beam) (Ref. 1) or on results of the FE-based tooth contact analysis (Refs. 2–3).

In order to get a more detailed understanding of the load mechanism within the tooth root and to therefore get a more detailed knowledge of the tooth root carrying capacity, local calculation models for the tooth root carrying capacity were introduced. Those models derive the material strength either from fatigue limit tables, that are based on test rig results, or from the calculation of local material data (e.g. based on hardness, residual stress, and oxidation) by means of empirical formulae. The influence of material defects, such as pores or inclusions, onto the material strength have yet to be considered for the calculation of the tooth root carrying capacity of gears.

State of the art

The calculation of the load capacity of technical products is based on the comparison of the strain and the nominal material strength. The resulting quotient can be defined as a safety factor, which gives a clear overview of whether the technical products fail or not. In general, the properties of the nominal material strength are measured on specimens that have a plain geometry and therefore have a low testing complexity. The specimens also consist of a homogenous material structure and are tested with a homogenous cyclical load (Ref. 4). Gears in contrast have a rather complex geometry and are often times case hardened, which results in a changing material structure. Additionally, the strain of gears is not as homogenous as for the specimens (Ref. 5). Thus, the existing methods based on specimens have to be extended for the calculation of the load capacity of gears.

The design process of gears relies on the knowledge of key characteristics, such as the flank, tooth root, and scuffing safety. In order to make those characteristics applicable, a standardized calculation method based on empirical-analytical formulae is necessary. These methods are presented within industry standards such as ISO 6336 or AGMA 2101-D04 (Refs. 1, 6). The standardized procedure comes at a cost of necessary conventions and abstractions. The maximum tensile stress for the tooth root is calculated at the 30°-tangent in the tooth root fillet on the tensile strained tooth flank in ISO 6336 and the intersection of the Lewis parabola and the gear tooth fillet in AGMA

908 (Ref. 7). The underlying mechanical principle is based on the beam theory. Influences by different design parameters and properties of the gear on the tooth root stress are covered through correction factors (Refs. 1, 6). The nominal material strengths of different materials are measured by the standardized running test of reference gears. Differences between the analyzed gear and the reference gear are also considered by empirical-analytical correction factors.

In addition to the calculation methods presented in the industry standards, local calculation methods exist for the tooth root carrying capacity. The local approaches determine the strain in every spatial direction as well as the nominal material strength locally within the gear and are based on finite element analysis (FEA) results. Because of the lower level of abstraction compared to the standardized empirical-analytical approaches, technical products with inhomogeneous material structure and complex stress states can be investigated (Ref. 4). One possible approach of calculating the load capacity of machine elements is the weakest link model based on the research by Weibull (Ref. 8). The model was established to depict failure of ceramic parts. It states that defects are statistically distributed inside a quantity, which could be a volume, an area, or a length of a part. These defects can cause initial cracks that then lead to the failure of the whole part. Defects are all characterized as inhomogeneities of the material structure. This also includes surface roughness. If the strain at one of these defects excesses the bearable strain, a crack starts. An occurring crack propagates in just a few load cycles and ultimately leads to the part's failure. For every defect, the probability of survival within the quantity can be calculated based on the statistical distribution of the defects. The statistical distribution is based on the Weibull-Distribution that is named after Weibull (Ref. 8). The aggregated probability of survival for a homogenous machine element with homogenous load is calculated based on equation (1).

$$P_s = 2^{\frac{V}{V_0}\cdot\left(\frac{\sigma_a}{\sigma_D}\right)^k} \qquad (1)$$

where

P_s is aggregated probability of survival of a machine element.
V is volume of machine element.
V_0 is referential volume.
σ_a is stress amplitude.
σ_D is bearable material strain of the referential volume at a probability of survival of 50 percent.
k is Weibull parameter.

The referential volume is defined as = 1 mm [3] based on Boma et al. (Ref. 9). The bearable material strain is calculated based on the strain that leads to a 50 percent probability of survival for the referential volume . The statistical influence of the volume size is considered by the quotient of the volume of the machine element V and the referential volume . The statistical distribution of the defects is considered by the Weibull parameter k. High distributions of defects lead to small Weibull parameter k and vice versa. The influence of the different parameters on the aggregated probability of survival is depicted in Figure 1 (Ref. 4).

On the left side of the figure, the aggregated probability of survival in dependence of the stress is shown. The first example depicts the probability of survival of a referential machine element. For the second example, the bearable stress is equal to half of the bearable stress of the referential machine element . The curve of the probability of survival of the second example is therefore shifted to the left, which leads to the failure of the machine element in lower stress states, compared to the referential machine element. The third example's Weibull parameter k is doubled, compared to the reference . This leads to a change in the steepness of the curve. This fact allows for higher aggregated probability of survival for loads that are lower than the bearable load but lower aggregated probability of survival for higher load level . A fourth example has double the volume of the reference,

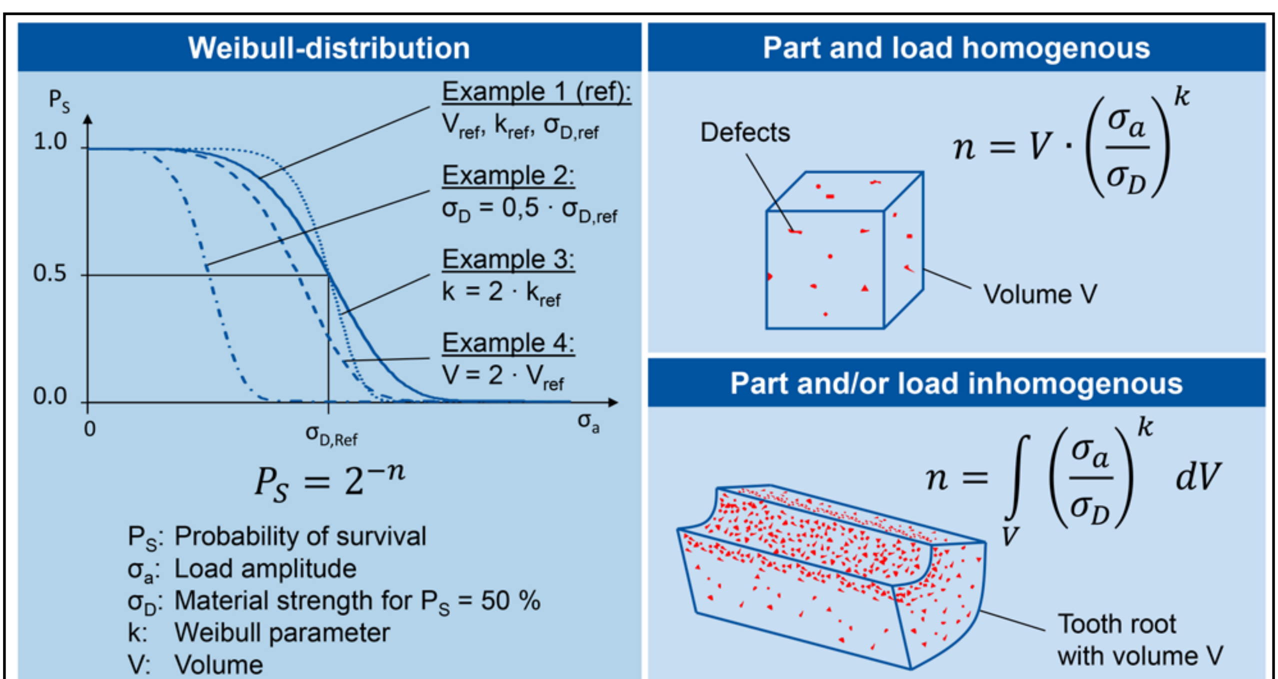

Figure 1 Calculation of the probability of survival and influence of the different parameters (Ref. 4).

which leads to lower aggregated probability of survival for all load levels. (Ref. 4)

Schleicher et al. extend the weakest link model of Weibull onto inhomogeneous materials, e.g. case hardened steel (Ref. 10). The extension allows for the calculation of the bearable stress based on a small sample of testing results. The main aspect of the extended model is the possibility to calculate the quotient of the stress and the bearable stress locally and for every part of the machine element. The aggregated probability of survival for the whole part is then calculated based on the product of the single probabilities, see equation (2). The local parameters can be defined in dependence of the global coordinates x, y, and z (Ref. 11).

$$P_s(V) = 2^{-\int_V \frac{1}{V_0} \cdot \left(\frac{\sigma_a(x,y,z)}{\sigma_D(x,y,z)}\right)^{k(x,y,z)} dV} \quad (2)$$

where
P_S is aggregated probability of survival of a machine element
V is volume of machine element
V_0 is referential volume
σ_a is stress amplitude
σ_D is bearable material strain of the referential volume at a probability of survival of 50 percent
k is Weibull parameter

Hertter develops a model to calculate local flank and root load carrying capacity of gears. To calculate the tooth root load carrying capacity, he uses a modified form of the normal stress hypothesis, as well as the local material strength according to the Goodman diagram based on material hardness (Ref. 12).

Stenico considers local tooth root load carrying capacity of case hardened gears based on experimentally determined characteristic values and empirical factors. He uses a material-based approach derived from the fracture mechanical Kitagawa diagram. This approach considers local material parameters as well as residual stresses in a two-dimensional space. To calculate the strain, he uses commercial FE-systems. He validates his calculations by experiments (Ref. 5).

Brömsen and Zuber develop a program to calculate the bending strength of any tooth root geometry that combines the local load carrying capacity according to Velten (Ref. 13) with the statistical weakest link model according to Weibull. The stresses in the tooth root are based on a finite element analysis. The local material strength properties are calculated based on empirical formulae that take the hardness, residual stress, surface roughness, and surface oxidation into account. Brömsen applies the method onto spur gears with the help of a two-dimensional FE-model (Ref. 14). Zuber extends the model onto three-dimensional FE-models and also applies it onto spur and helical gears (Ref. 11). The influence of the defect size onto the tooth root load carrying capacity is not part of the discussed models.

Objective and Approach

The state of the art shows that local calculation models for the tooth root load carrying capacity of gears do exist. The existing research works analyzed the tooth root load carrying capacity for spur and helical gears based on a weakest link model and finite element analysis results. The influence of the defect size onto the tooth root load carrying capacity has not been part of the investigations yet.

Therefore, the objective of the paper is to extend the existing local calculation models for gears by the influence of the defect size. In order to reach the objective, first, the existing model is extended by the influence of the defect size, and a method for determining the size and distribution of defects for gears is presented. After defining the method, it is applied to various example gears. The results of running tests on a test rig are compared to the results of the simulation method. With this, the proposed method is validated.

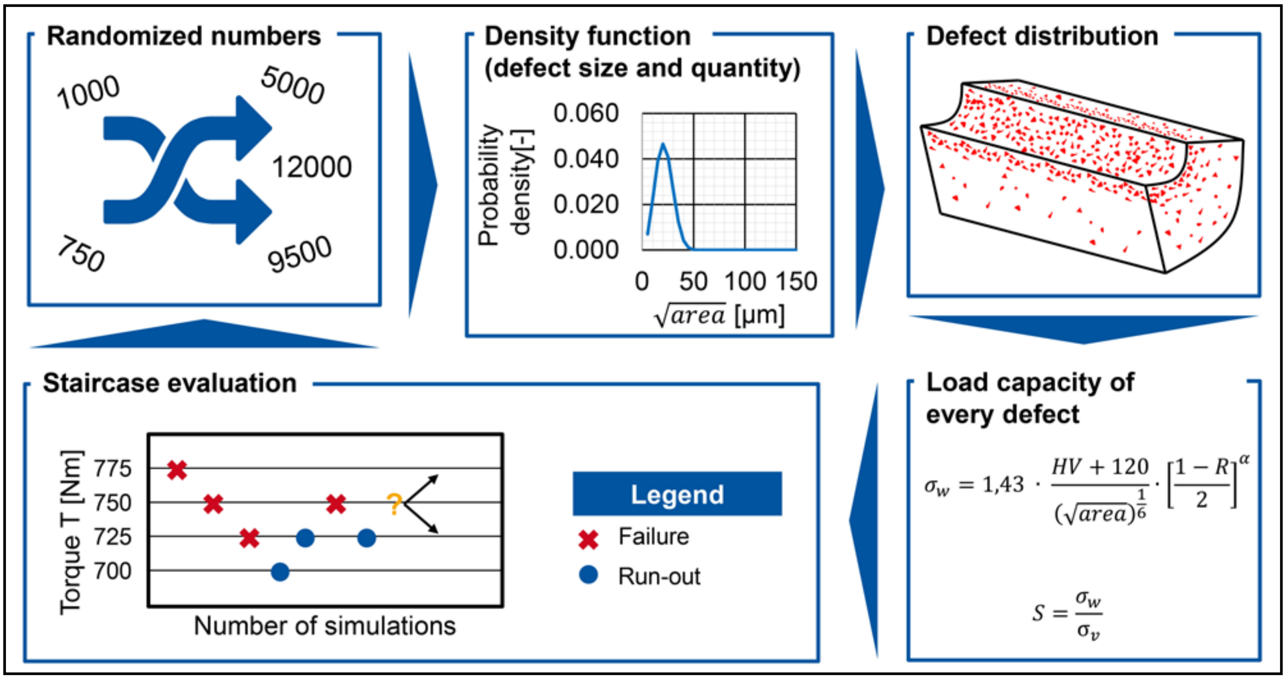

Figure 2 Approach to calculate the tooth root load carrying capacity with considering defect size and distribution (Ref. 4).

Definition of the Method

Local calculation methods exist for the calculation of the tooth root load carrying capacity, as the state of the art clearly shows. But the size and the statistical distribution of the material defects is not part of the input parameters into these models yet. As the results of Weibull showed, the initial crack often happens at one of those defects. Murakami's and CETI's research showed that the nominal material strength is clearly influenced by the defect distribution within the material (Refs. 15–17).

Murakami defines an empirical relation between the local hardness of the material HV, the defect size area, and the derived local fatigue limit under alternating stress σ_W, following equation for volumetric defects and equation for surface defects. The characteristic value area is equal to the square root of the perpendicularly projected largest cross-section of the defect onto the plane of principal stress. Additional parameters are the stress ratio R, considering the mean stress influence as well as the exponent α. The exponent α is based on the local hardness of the part and is defined based on extensive testing, see equations (3–5) (Refs. 4, 15–17).

$$\sigma_w = 1.43 \cdot \frac{HV+120}{(\sqrt{\text{area}})^{1/6}} \cdot \left(\frac{1-R}{2}\right)^{\alpha} \tag{3}$$

$$\sigma_w = 1.56 \cdot \frac{HV+120}{(\sqrt{\text{area}})^{1/6}} \cdot \left(\frac{1-R}{2}\right)^{\alpha} \tag{4}$$

$$\alpha = 0.226 \cdot HV \cdot 10^{-4} \tag{5}$$

where

σ_W is fatigue strength
HV is Vickers hardness
R is stress ratio
α exponent
$\sqrt{\text{area}}$ defect size

The proposed method by Murakami was performed and validated on plain specimens but has not yet been transferred to the complex geometry of gears. Thus, an approach for the calculation of the tooth root load carrying capacity is depicted in Figure 2, which is based on the research of Murakami (Refs. 4, 15–16). The approach can be divided into five different steps. First, a random number of defects are determined. The number of defects is then distributed according to the density function that takes the defect size and the quantity of the defects for each size into account. As a result, a defect distribution for the volume of the tooth root is defined. Following this step, the load carrying capacity of every defect is calculated based on the formulae derived from Murakami. If the safety ratio S—which is the quotient of the local fatigue strength σW and the local occurring stress σV—is below one, the gear fails at the defect. If the safety ratio is $S \geq 1$, the part does not fail at the certain defect, and the next defect is analyzed. The evaluation of the local occurring stress σv (e.g. von Mises stress) is based on the results of an FE-based tooth contact analysis. For every element within the tooth root, the stress tensor can be evaluated. In the last step of the approach, a simulated staircase test is performed. A certain level of torque is applied to the gear, and if only one defect has a safety ratio $S<1$, the part fails and the torque level will be reduced for the next step. If all defects have a safety ratio $S \geq 1$, the part is a run-out, and the torque level will be increased for the next step. The whole process is repeated for a number of iterations and then evaluated according to the method of Hueck. For every iteration, a new defect distribution is performed. The result of the approach is the bearable torque level for the analyzed gear (Ref. 4).

Determination of the defect distribution and the defect size

Murakami proposes a seven step procedure in order to get to the statistical distribution of the defects. He performs the measurement of the defect size on polished specimen. The defect size can also be measured on fractured surfaces, which is applied for the given approach, or generic defect sizes and distributions can

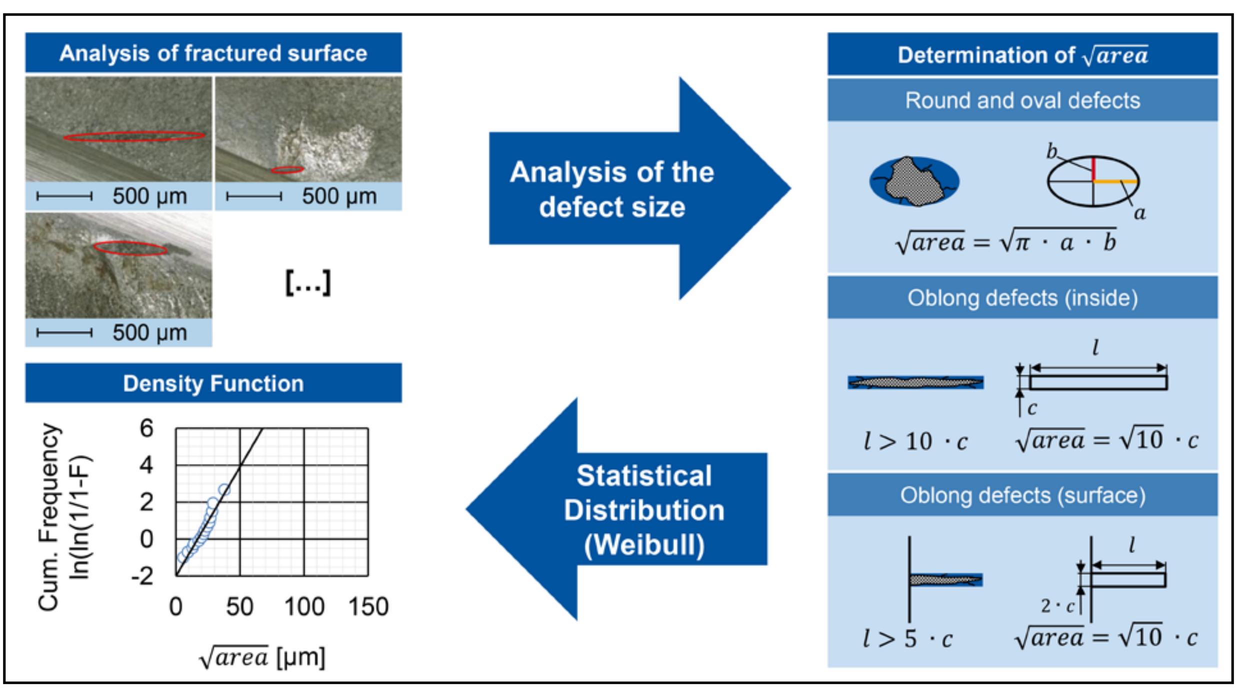

Figure 3 Determination of the defect size and distribution based on analysis of fractured surfaces (Ref. 4).

be used. The determination of the defect size and distribution on fractured surfaces is shown in Figure 3 (Refs. 4, 15).

First, the fractured gears from the running tests are prepared and cleaned for the microscopic analysis. The defects that led to the failure of the gear are determined, and the size of the defect is evaluated. In order to get the characteristic value of the defect size area, it is necessary to differentiate between three different types of defects. There are round and oval defects, oblong defects that occur in the inner part of the material and oblong defects that occur on the surface of the gear. Based on the type of the defect, the formulae of the characteristic defect sizes differ, see Figure 3. Once the defect sizes are determined, the statistical distribution of the defects, according to the Weibull-distribution, need to be evaluated. First the defects are ranked according to their size. For every defect *j*, an occurrence probability value *Fj* is calculated according to equation (Ref. 6).

$$F_j = \frac{j}{n+1} \quad (6)$$

where

F_j is occurrence probability

j is rank of the defect according to the size

n is total number of defects

The occurrence probability is then spread across a double logarithmic diagram, and a linear regression is performed. The

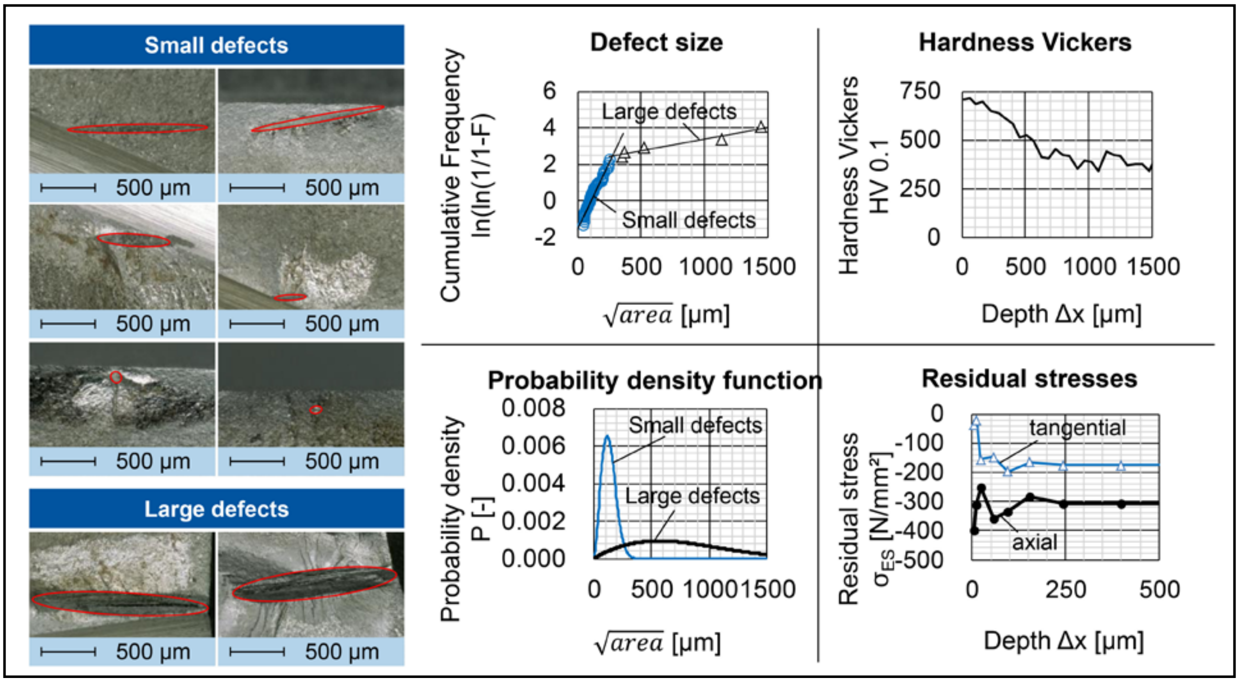

Figure 4 Material properties and defect distribution of the beveloid gears (Ref. 4).

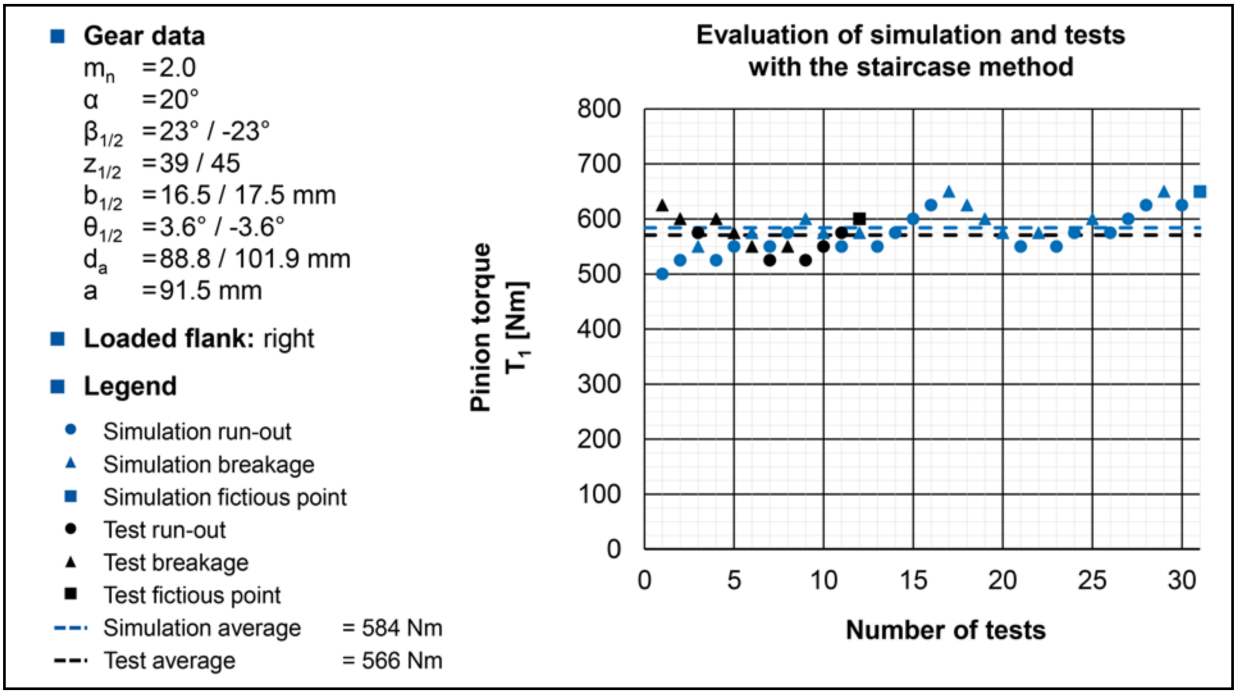

Figure 5 Comparison of the simulation and testing results for the beveloid gears (Ref. 4).

result is a Weibull function that leads to the Weibull distribution of the occurring defects (Ref. 4).

Validation of the Method

The proposed method is validated by comparing two different test series results with the results of the simulation based on the method. First, tests on beveloid gears are performed. Second, the influence of the defect size onto the tooth root load carrying capacity of helical gears is analyzed.

Validation on beveloid gears

The material properties and the evaluated defect distribution based on the analysis of the fractured surfaces for the beveloid gears are depicted in Figure 4. On the right side of the figure, the Vickers hardness characteristics and the residual stress characteristics in tangential and axial direction are shown. On the left side of the figure, sample pictures of defects as well as the defect size and the probability density functions are shown. The analysis of the defect size displays two different groups of defects that could be found within the beveloid gears, and that led to the breakage of the gear. One group consists of small defects with a characteristic size of $\sqrt{area} \leq 300\,\mu m$, and the other group consists of large

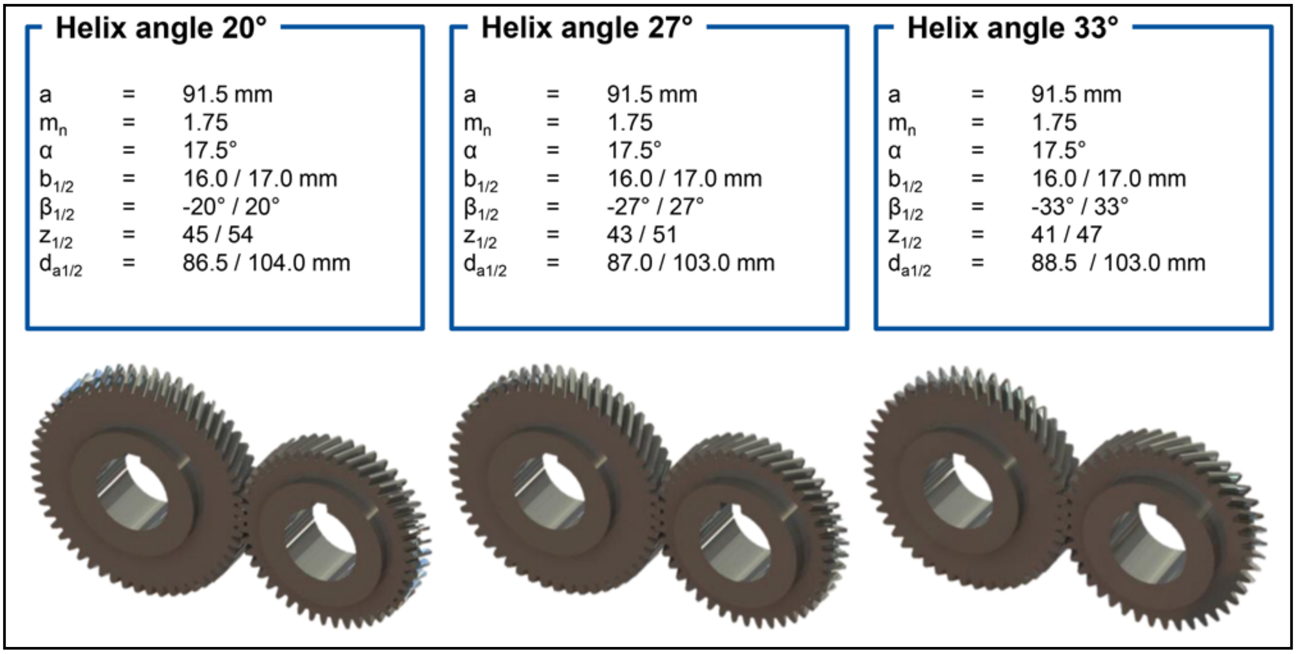

Figure 6 Gear data of the tested helical gears (Ref. 4).

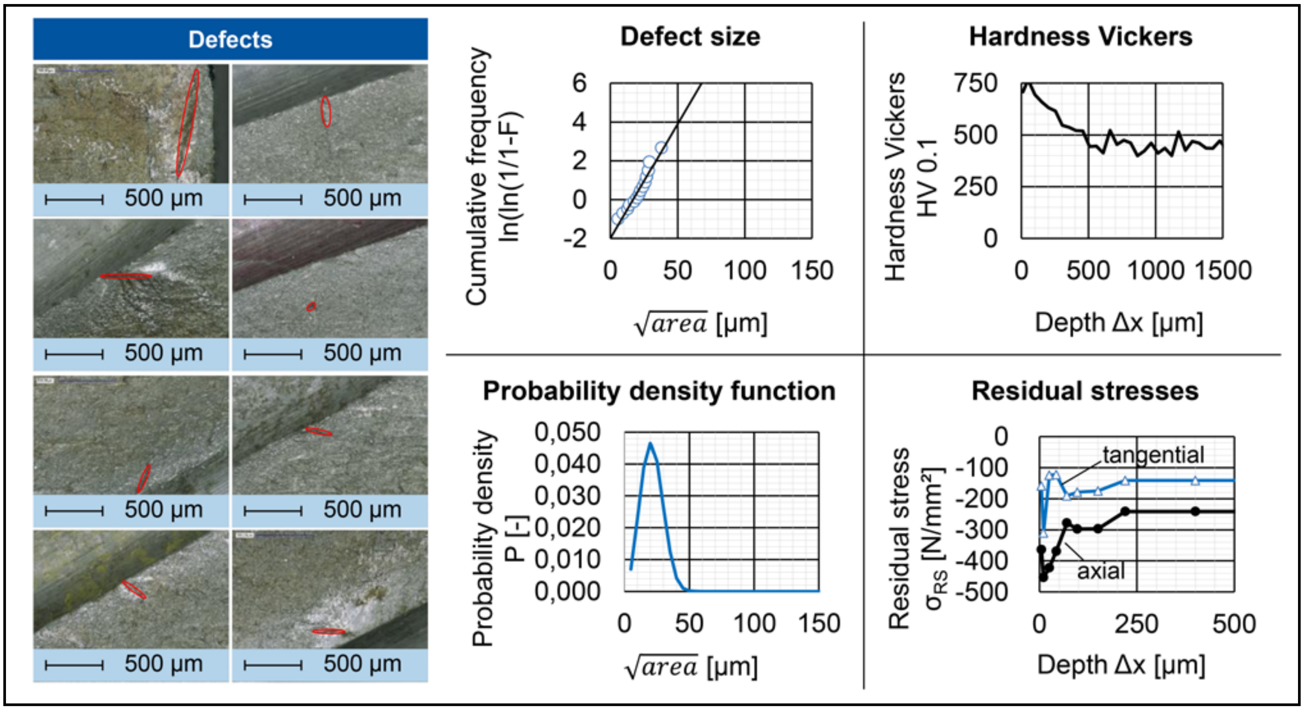

Figure 7 Material properties and defect distribution of the helical gears (Ref. 4).

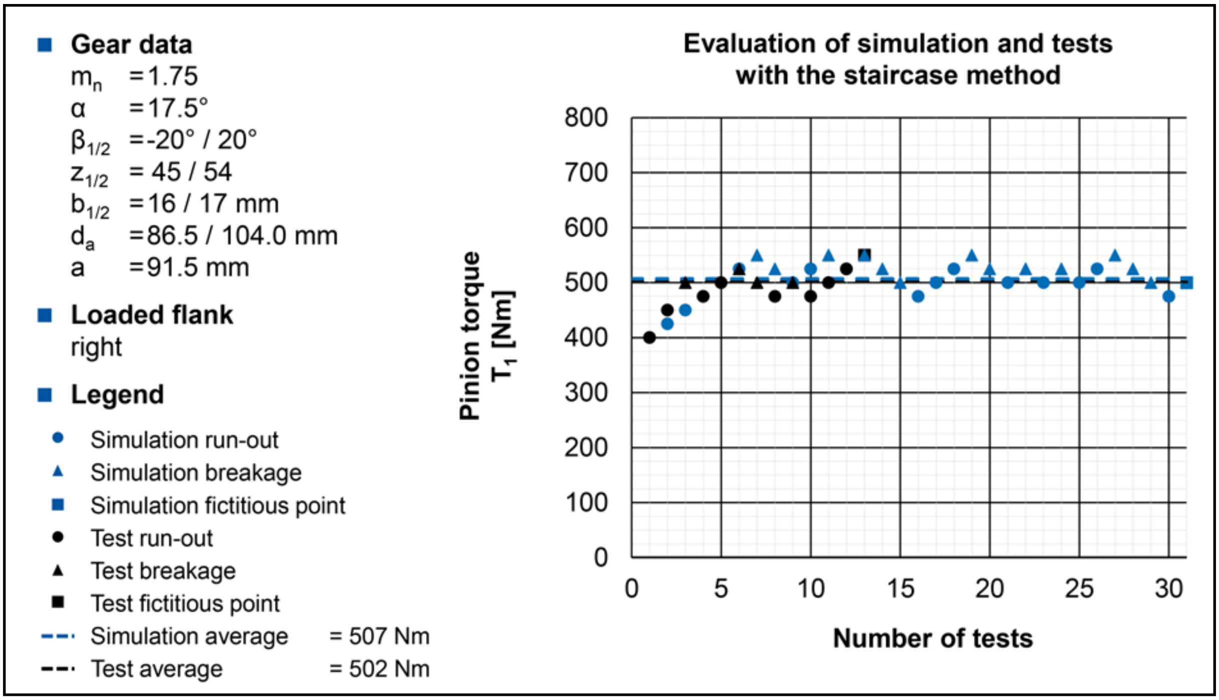

Figure 8 Comparison of the simulation and testing results for the helical gears (Ref. 4).

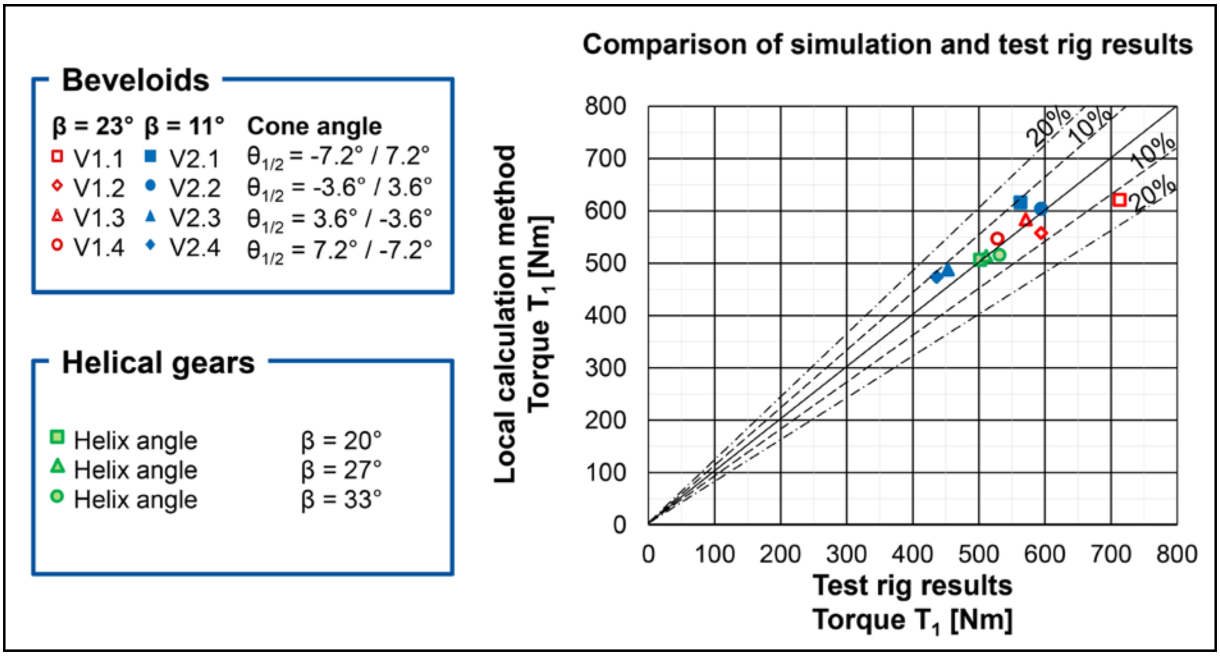

Figure 9 Overall comparison of the simulation and testing results for all tested gears (Ref. 4).

defects with a size of $\sqrt{area} > 300\,\mu m$. The probability of occurrence of both groups can be described with two different density functions, as depicted in the Figure 4 (Ref. 4).

For identifying this torque level, the staircase method was conducted by running tests on a test rig and also with the help of the proposed simulation method. The simulation method can also be used to calculate the torque level that leads to a 1 percent failure of the gears. The necessary data points are easily obtained by the simulation method. Because of the limited number of running tests, the torque level for 50 percent failure of the gears was calculated, as shown in Figure 5.

The analyzed beveloid gears have a normal module of $m_n = 2\,mm$, number of teeth of $z_{½} = 39/45$, and cone angle of $θ_{½} = 3.6/{-3.6}°$. For the running tests, eleven tests were conducted, and the results of the staircase method indicate an average torque level of $T_{1,50\%,test} = 566\,Nm$, shown in black. The simulation results of the beveloid gears conclude to an average torque level of $T_{1,50\%,sim} = 584\,Nm$. The deviation of the results of the running tests and the simulation is 3.1 percent. Therefore, it can be assumed that the proposed simulation method is capable of calculating the torque level, which leads to a 50 percent failure probability of the gear (Ref. 4).

In addition to applying the simulation method onto beveloid gears, it is also applied onto three types of helical gears. The gear data of the three types is shown in Figure 6. The main difference of the different helical gears is the variation of the helix angle of $\beta = 20°$, 27° and 33°. The normal module *m*n and the pressure angle α are constant for all three different helical gears. In order to match the center distance of $a = 91.5$ mm of the test rig, the number of teeth and the addendum modification factor of the gear are modified (Ref. 4).

Figure 7 depicts the material properties and defect distribution of the helical gears. The figure shows the Vickers hardness and the residual stresses on the right side. Because of the smaller normal module *m*n of the helical gears, the case hardening depth $CHD_{550HV} = 0.40$ mm is a bit smaller than the CHD of the beveloid gears. The characteristics of the hardness and residual stress are very similar to the beveloid gears. For the helical gears, only small defects can be identified, in contrast to the beveloid material properties shown in Figure 4. The defect size is measured on the fractured surface, and as the cumulative frequency indicates, it can be described by a Weibull-distribution (Ref. 4).

The comparison of the testing and simulation results for the sample helical gear with a helix angle of $\beta = 20°$ is shown in Figure 8. For the helical gear, the torque level that leads to a 50 percent failure probability of the gear is evaluated based on the staircase method.

The average torque at the pinion is equal to $T_{1,50\%,test} = 502$ Nm for the eleven test runs, marked in black. The average torque at the pinion of the simulation is equal to $T_{1,50\%,sim} = 505$ Nm, marked in blue. The deviation of the two torques is less than 1 percent. Because of the higher level of purity of the case hardened steel compared to the material of the beveloid gears, the deviation is much smaller. The comparison of the results of the helical gear with a helix angle of $\beta = 20°$ also shows that the accordance of the simulation model and the testing results is very high (Ref. 4).

The results of the beveloid gear, shown in Figure 5, and the results of the sample helical gear, shown in Figure 8, indicate that there is a high accordance between the proposed simulation method and the testing results. The diagram depicted in Figure 9 sums up the comparison of the simulation and testing results for all investigated gears. In total, eight different beveloid gears and three different helical gears are investigated. On the x-axis, the resulting average torque of the test results is shown. The y-axis shows the resulting average torque based on the local calculation method. For ten out of the total eleven different gear pairings, the deviation of the simulation and testing results is lower than 10 percent. The beveloid gear V1.1 has a deviation of 12.7 percent. So all in all, it can be concluded that the proposed calculation method is capable of calculating the torque level that leads to a 50 percent failure probability of the gear. It also shows that the influence of the defect size on the load capacity is represented by the method. The influence of the different levels of purity of the material is also predicted by the simulation method (Ref. 4).

Summary and Outlook

Nowadays, local calculation methods for gears are more and more applied in order to get a more detailed understanding of the load capacity in contrast to standards. Existing works show the application of the weakest link model on the gear in order to optimize the tooth root load carrying capacity. Although research on the influence of the defect size and distribution onto the load capacity exist, it has not been applied to gears. Therefore, the objective of this paper is the development of a local simulation method that takes the influence of the defect size and distribution onto the tooth root load carrying capacity into account.

The proposed simulation method is applied to several beveloid and helical gears. The comparison of the simulation and testing results show a high accordance. Although the level of purity of the material and the macro geometry of the gears differ, the proposed simulation method is capable of predicting the average torque level that leads to a 50 percent failure probability of the gear. The deviations of the testing and simulation results are lower than 10 percent in 10 out of 11 cases.

In future works, the proposed simulation method has to be applied onto other gears that differ in the macro geometry as well as the material properties. The beveloid and helical gears had a very similar normal module, and therefore, gears with a larger module have to be analyzed.

Furthermore, the sensitivity of the input parameters onto the tooth root load carrying capacity is unclear. A sensitivity analysis based on a broad design of experiment could indicate the significant input parameters for the load capacity. The simulation method was applied onto beveloid gears with a parallel axis. It can also be applied to beveloid gears with a crossing or skewed axis.

The defect distribution and the defect size was measured for the given paper on fractured gears of running tests. In order to estimate the defect distribution without the need of running tests, possible methods (e.g. optical emission spectrometer) are to be analyzed, based on the applicability onto gears.

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Prof. Dr.-Ing. Christian Brecher has since January 2004 been Ordinary Professor for Machine Tools at the Laboratory for Machine Tools and Production Engineering (WZL) of the RWTH Aachen, as well as Director of the Department for Production Machines at the Fraunhofer Institute for Production Technology IPT. Upon finishing his academic studies in mechanical engineering, Brecher started his professional career first as a research assistant and later as team leader in the department for machine investigation and evaluation at the WZL. From 1999 to April 2001, he was responsible for the department of machine tools in his capacity as a Senior Engineer. After a short spell as a consultant in the aviation industry, Professor Brecher was appointed in August 2001 as the Director for Development at the DS Technologie Werkzeugmaschinenbau GmbH, Mönchengladbach, where he was responsible for construction and development until December 2003. Brecher has received numerous honors and awards, including the Springorum Commemorative Coin; the Borchers Medal of the RWTH Aachen; the Scholarship Award of the Association of German Tool Manufacturers (Verein Deutscher Werkzeugmaschinenfabriken VDW); and the Otto Kienzle Memorial Coin of the Scientific Society for Production Technology (Wissenschaftliche Gesellschaft für Produktionstechnik WGP).

Dr.-Ing. Jannik Henser is managing director of the Powertrain Manufacturing for Heavy Vehicles Application Lab in Stockholm, Sweden which is a collaboration between KTH Royal Institute of Technology, Fraunhofer and RISE Research Institutes of Sweden. Prior to that Henser worked in Aachen, Germany at the Fraunhofer Institute for Production Technology IPT and the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University as research engineer and group leader of the group gear design and manufacturing simulation. Henser graduated from RWTH Aachen University in 2010. In 2015 Henser received his Ph.D. (calculation of tooth root load carrying capacity of conical involute gears) and has received the Borchers Medal of RWTH Aachen University in 2016.

Gear Technology

HOSTS DINNER FOR TECHNICAL CONTRIBUTORS TO THE GEAR INDUSTRY

On October 23 on the eve of Gear Expo in Columbus, Ohio, the editors and staff of *Gear Technology* and *Power Transmission Engineering* were pleased to host a dinner for many of our technical editors, authors, regular contributors and others who share our vision and passion for advancing the collective knowledge of the gear industry. In attendance were (seated, from left to right): **Don Houser,** Professor Emeritus, OSU GearLab; **Dave Friedman,** Associate Publisher & Sales Manager, *Gear Technology*; **Dipl.-Ing. Christian Güntner,** FZG; **Joseph R. Mihelick,** *Gear Technology* technical editor and Principal, Gears Plus Inc.; **Randy Stott,** Associate Publisher & Managing Editor, *Gear Technology*; **Frank Uherek,** *Gear Technology* technical editor and Principal Engineer - Gear Software Engineering Development, Rexnord; **Tony Norselli,** Gleason Dr. Hermann J. Stadtfeld, VP Bevel *Gear Technology* and R&D, Gleason; **Irebert Delgado,** Researcher, NASA Glenn Research Center; **Alex Cannella,** Associate Editor, *Gear Technology*; **Robert Shandro,** Researcher, CETIM; **Dr.-Ing. Karsten Stahl,** Head of the Gear Research Centre, FZG; **John Lange,** *Gear Technology* technical editor and Instructor, Gleason; and: (Second Row, Standing, from Left to Right) **Octave Labath,** *Gear Technology* technical editor and independent consultant; **Jack McGuinn,** *Gear Technology* Senior Editor; **Carlo Gorla,** Professor, Politecnico di Milano; **Michael Hein,** Team Leader, FZG; **Todd Praneis,** Chairman, AGMA Technical Division Executive Committee and Director of Product Development,

Seco/Warwick

WINS INTELLIGENT DEVELOPMENT AWARD 2017

Seco/Warwick has been granted the Intelligent Development Award 2017 for the development of the innovative UniCase Master system, which challenges traditional heat treatment methods. It significantly reduces the mechanical distortion created during the heat treatment process of hardening, in result the automotive industry can save billions of euros a year.

Seco/Warwick received the award in October at the Gala of the Polish Intelligent Development Award 2017, a prestigious event that constitutes a meeting point for business and science, bringing together leaders of development and investment, who give the direction of the innovative economy.

The UniCase Master, which has been recognized by the Intelligent Development Program chapter, is the latest technology for continuous heat treatment based on vacuum carburizing and tempering in high pressure gas. It is used mainly in the auto-

Photo by David Ropinski, *Gear Technology* Art Director.

Cotta Transmission; **Michael Otto,** Department Leader, FZG; **Dr. Alfonso Fuentes,** Professor, Rochester Institute of Technology; **Dr. Oliver Winkel,** Head of Applications Engineering, Liebherr; **Dr. Michel Octrue,** Senior Mechanical Engineer, CETIM; **Matthew Croson,** President, AGMA; **Michael Goldstein,** Publisher & Editor-in-Chief, *Gear Technology*; **Julian Theling,** Researcher, WZL-RWTH Aachen; **Matthew Jaster,** Senior Editor, *Gear Technology*; **Jim Bregi,** Chairman of the Board, AGMA and President, Doppler Gear; **Dr. Thomas Tobie,** Head of Department for Load Carrying Capacity of Cylindrical Gears, FZG; **Alex Kapelevich,** President, AK Gears; Charles Schultz, *Gear Technology* technical editor and Principal, Beyta Gear Service.

motive industry for hardening toothed gears and bearing rings.

"Unlike conventional methods, UniCase Master ensures high repeatability, and thanks to a dedicated, single chamber detail equipped with an omnidirectional gas cooling system with simultaneous 4D Quenching, minimizing such common and cumbersome hardening deformations," explains Maciej Korecki, vice president, segment of vacuum equipment, Seco/Warwick.

Hardening of steel parts by carburizing and hardening is the most common heat treatment technology used in mass production of mechanical transmission components such as gear wheels, shafts, rings, etc. Traditional hardening is based on atmospheric carburization and oil hardening - a process characterized by low precision and accuracy as well as large deformations that require expensive finishing. At present, the factories spend about 20 billion euros per year only on repairing distortion.

Hardening deformation correction is one of the most expensive processes in gearbox manufacturing. This technology eliminates all the weaknesses of traditional methods, so that using the innovative UniCase Master system will allow the entire automotive industry to save billions of euros a year.

"The experience gained from the various parts demonstrates the perfect precision and reproducibility of the results and reduction of deformation to such an extent that some finishing operations can be completely eliminated," Korecki said. (*www.secowarwick.com*)

Oelheld

CELEBRATES GRAND OPENING OF NEW U.S. HEADQUARTERS BUILDING

Oelheld recently celebrated the grand opening of the company's new U.S. headquarter building in West Dundee, IL. Along with co-presidents Philipp and Martin Storr guests included officials from the village of West Dundee, customers, vendors and neighbors.

All in all more than 200 guests enjoyed the "Oktoberfest-style" open house which featured authentic Bavarian food, music and door prizes. The day concluded with a family-style party for employees, spouses and friends.

The new 24,000 square foot building increases production and warehouse capacity and features a new R&D laboratory. With a state of the art tanker unloading station and a sunken floor in the warehouse designed as a spill containment the facility exceeds all environmental safety requirements. With automatic LED lighting and radiant floor heat it is also very energy efficient. The property allows for future expansion to 42,000 square feet. (*www.oelheld.com*)

Ipsen

EXPANDS SERVICE OFFERINGS

Ipsen has expanded their offerings to include calibration and survey services that adhere to strict Nadcap requirements. As Ipsen continues to focus on providing advanced aftermarket support, this new service will fill a niche demand and help those that need to meet the requirements of highly regulated industries.

Ipsen's technicians will perform NIST-traceable calibrations and periodic testing of heat-treating systems so companies can comply with AMS 2750E, which is recognized as the gold standard for both Nadcap and MedAccred. This includes calibrating and testing the furnace's temperature and vacuum control systems, as well as verifying those systems are operating properly. If any non-conformances are discovered, Ipsen's trained technicians are capable of quickly analyzing, troubleshooting and correcting them.

Key services include:

- Calibration of the temperature controlling, monitoring and recording instruments
- Calibration of vacuum process and recording instruments
- Full reports that comply with the requirements of AMS 2750E, complete calibration results (including "As Found/As Left") and data for Ipsen's NIST-traceable standards used
- Temperature Uniformity Surveys (TUS) using data acquisition (DAQ) and software fully compliant to ASM 2750E and 21 CFR-Part 11
- System Accuracy Tests (SAT)
- Certificate of conformance (*www.ipsenUSA.com*)

U.S. Powder Metals

APPOINTS DIRECTOR OF SALES AND BUSINESS DEVELOPMENT

U.S. Metal Powders, Inc. (USMP) has announced that Benjamin Giralico has joined its subsidiary, Ampal, Inc. filling the role of Director of Sale and Business Development for the Palmerton, Pennsylvania based company.

USMP is the largest domestic aluminum powder producer with the production facilities in both Palmerton, PA and the town of Hermillon in the French Alps.

"We are very excited to have Ben join our team and welcome him to our company," said Louise Ramsey Thomas, the president of the company. "His focus will be on enhancing our sales and customer engagement process and developing new business opportunities for the company beyond the market segments we currently serve. Ben brings a wealth of technical sales experience and will be a huge asset to our team."

Before joining USMP, Ben held sales management positions in the metals processing, chemical, and semiconductor material segments. His most recent position was with Dow Chemical in its electronic materials division. (*www.usmetalpowders.com*)

Hexagon Manufacturing Intelligence

OFFERS METROLOGY EQUIPMENT AT FULLERTON COLLEGE

Hexagon Manufacturing Intelligence recently announced that its portable and stationary coordinate measuring machine (CMM) technologies will be integrated into a new Metrology Program offered at Fullerton College, North Orange County, in Fullerton, CA. Fullerton College is one of the largest and best equipped machinist trade schools in California. Starting in Fall 2018, students will learn how to use a wide array of measurement and inspection tools including ROMER Absolute arms, laser scanners, CMMs and more. The new curriculum will enable students to study the science of measurement and acquire job skills that are in high demand by science laboratories and industries using advanced manufacturing technologies such as aerospace, defense, automotive, medical, and power generation. Students can begin work toward a Metrology Certificate of Achievement with several compulsory courses currently available.

The Metrology Program is a natural extension of the Machine Technology curriculum already in place at Fullerton College. Course study will cover fundamental metrology concepts and offer hands-on usage of shop floor CMMs and portable measuring machines (PCMMs) for practical measurement and inspection operations conducted in machine shops and manufacturing cells. The ROMER articulating arm is a versatile measurement tool designed to meet the needs of almost any measurement application, whether scanning or touch-probing. This portable CMM provides the foundation for Fullerton College's rigorous program of electives designed to prepare students for scientific research and today's data-driven manufacturing environments. The ROMER Absolute arm with integrated RS4 laser scanner will provide the means for precision 3D data capture across a range of surfaces and applications.

"Our new metrology program will add additional certificates and skills competencies making our students even more valuable and employable within our local industries," states Dan

O'Brien, instructor and machine technology department coordinator at Fullerton College. "Manufacturing companies are challenged with filling employment positions that utilize new digital manufacturing and measuring technologies. This program intends to help fill this critical gap."

"Hexagon Manufacturing Intelligence is very pleased to support the new Metrology Program being offered next year at Fullerton College, a premier academic institution that strongly supports vocational programs," states Zvonimir Kotnik, business unit manager, portable products, Hexagon Manufacturing Intelligence. "Measurement professionals will be in very high demand for the foreseeable future. Metrology education can open many career doors and introduce students to data-driven manufacturing and other diverse applications requiring 3D data for analysis, measurement, automation alignment, visualization, and more. The ROMER Absolute Arm with Integrated Scanner is the ideal teaching toolset as industry uses this technology for point-cloud inspection, product benchmarking, reverse engineering, rapid prototyping, virtual assembly and CNC milling."

(*http://machine.fullcoll.edu*) (*hexagonmi.com*)

Heller Machine Tools

APPOINTS VP OF SALES FOR NORTH AMERICA

Heller Machine Tools has announced that **Stephen Pegram** has joined the company as vice president of sales for North America. He will be based at the Heller USA headquarters and manufacturing facility here.

Pegram joins Heller after a long and successful career in the machine tool industry which included management positions within Mazak, DMG and Hyundai Wia.

"My focus is to grow our special machine tool business including our very profitable applications into new market segments," Pegram said. "Heller has always been a supplier of full production solutions, which we will continue into the future. Total client satisfaction is at the very top of our business plan."

"The Heller product range is of the very highest quality, and this includes several new products including 5-axis horizontal machining centers. It is these new products and applications that will help provide future business growth both for Heller and our customers," he said. (*www.heller-us.com*)

December 7–9—PRI 2017 Indianapolis, Indiana. Performance Racing Industry 2017 features 1,100 companies that will display the latest advances in racing products and race engineering. Technologies include engine parts, suspension components, data acquisition, safety gear, new metal alloys and coatings, machining equipment, race electronics and racing fuel. The high performance testing and computing zone will draw racing squad owners as well as the world's top racers to test and try the latest models in racing cars. Arriving from 70+ countries and all 50 states, buyers will scour the displays to source the new technology that will be winning races next year. Conferences and seminars include information on vehicle dynamics, advanced engineering, fuel pump design and performance, software, the essentials of operating a shop, lubrication and more. For more information, visit *www.performanceracing.com*.

January 8–12—SciTech 2018 Kissimmee, FL. 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. The AIAA Science and Technology Forum and Exposition (AIAA SciTech) has continued to grow in each succeeding year, drawing participants from around the globe. SciTech participants tackle the most pressing issues impacting the future of aerospace, while the technical program presents innovative research and technologies that offer solutions. For more information, visit *www.aiaa-scitech.org*.

January 22–26—World of Concrete 2018 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*.

January 23–25—AGMA Gearbox System Design Las Vegas, Nevada. Attendees will explore the supporting elements of a gearbox that allows gears and bearings to do their jobs most efficiently. Learn about seals, lubrication, lubricants, housings, breathers, and other details that go into designing gearbox systems. Gear design engineers; management involved with the design and manufacture of gearing type components; metallurgists and materials engineers; laboratory technicians; quality assurance technicians; furnace design engineers; and equipment suppliers should attend. Instructors include Ray Drago and Steve Cymbala. For more information, visit *www.agma.org*.

January 25–30—IMTEX 2018 Bangalore International Exhibition Center, Bangalore, India. IMTEX 2017 provides a range of metal-cutting machine tool technologies, products and solutions to meet the demands of the manufacturing industry. With global focus shifting towards the country's "Make in India" initiative, the manufacturing industry is poised for growth. The event attracts visitors from a wide spectrum of manufacturing and ancillary industries starting with key decision and policy makers sourcing the latest technologies and manufacturing solutions for their production lines. Products include milling, turning, gear manufacturing, grinding, honing machines, flexible manufacturing systems, machining centers, and more. Co-located with IMTEX is ToolTech 2018, an International Exhibition of Cutting Tools, Tooling Systems, Machine Tool Accessories, Metrology and CAD/CAM. For more information, visit *www.imtex.in*.

January 30–February 1—IPPE 2018 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 2017 IPPE featured more than 8,018 international visitors from over 129 countries. Mexico and Latin American/Caribbean countries represent the largest region of international visitors, but there has been continued growth in numbers coming from Europe. Canada represents the largest single country outside the United States with regards to number of attendees. For more information, visit *www.ippexpo.org*.

February 5–7—AGMA Gear Materials Clearwater Beach, FL. Learn what is required for the design of an optimum gear set and the importance of the coordinated effort of the gear design engineer, the gear metallurgist, and the bearing system engineer. Investigate gear-related problems, failures and improved processing procedures. Gear Engineers, gear designers, application engineers, people who are responsible for interpreting gear designs, technicians and managers that want to better understand all aspects of gear design should attend. Instructors include Ray Drago and Roy Cunningham. For more information, visit *www.agma.org*.

February 22–24—IPTEX 2018 Mumbai, India. Designed to meet the growing need for excellence in all aspects of the gears and power transmission to an imperative for all players to stay competitive. IPTEX 2018 is an important event for all relevant stakeholders in automobile, aerospace, or energy as well as manufacturers, buyers, partners, and consultants. IPTEX will provide a consistent channel of communication to the members of this industry to come together under one roof and participate in technical seminars, share knowledge and expertise with industry leaders and to be a part of discussion on policy codes, standards and challenges faced by the industry. Grindex 2018 is co-located with IPTEX 2018. For more information, visit *www.iptexpo.com*.

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a. Requested and Paid Electronic Copies	2,976	3,157
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5 → My company's principal product or service is:____________________

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

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- ☐ I DESIGN gears (23)
- ☐ I am a SUPPLIER to the GEAR INDUSTRY (please specify product or service) (24)

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For Christmas and Beyond

Jack McGuinn, Senior Editor

When discussing the thinning of this country's potential manufacturing workforce, it is often maintained that technical training opportunities should be made available to grade school-age children who express interest. Get their attention while they're young and impressionable, the thinking goes — and hope their parents don't talk them out of it.

And then there are those individuals of any age, young and old, who simply like to work with their hands — and brains — to make things.

And one more thing: it's almost Christmas.

What most reading — and writing — this probably didn't know is that since 2014 a Ukrainian-based start-up — UGEARS — has been striving to satisfy the three niches identified above: education, the hobbyist, and great gift ideas. What's more, the company has an established presence back here in the USA (*ukrbridge@gmail.com*; and *https://ugearsmodels.com/catalogue/mechanical-models.html*). With an apparently designer-intensive makeup of engineers, UGEARS was formed "to create their own production of modular mechanical models, in which everything is REAL!" At this writing "more than 17 models" are available, with more on the way.

UGEARS models are "self-propelled, mechanical wooden model assemble kits" intended to "introduce parents and children to a cool world of mechanics and to bring families together, as a team, working on assembling 3-D puzzles."

Can World Peace be far behind?

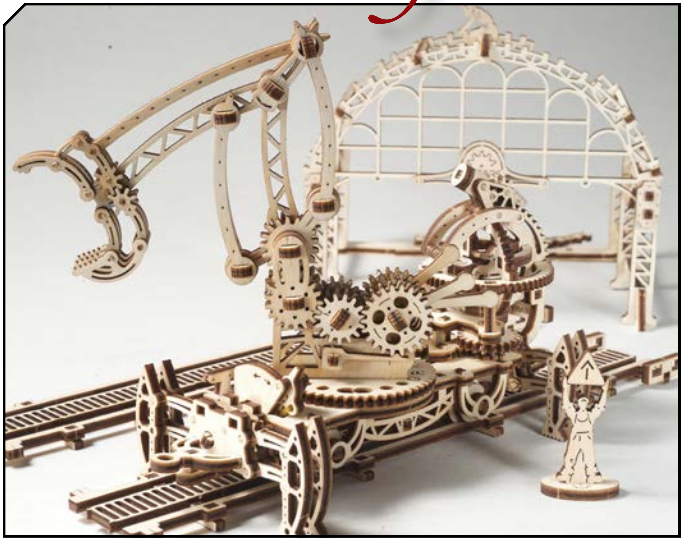
Many design models replicate everyday mechanisms and rolling stock while others "bring to life the imaginative, elegant and even whimsical designs" of UGEARS staff.

The company believes the fun is in the building — although the faithfully engineered models undergo "meticulous product testing and quality control" — and it shows. For proof, check out the UGEARS catalog on their website (see above).

Indeed, UGEARS believes they "give people what they want — the feel of real motion mechanics that they can build and bring to action by themselves." Some of the models are "sophisticated versions of real-life mechanisms," while others reflect not only the imaginative but also the whimsical bent of UGEARS colleagues. According to the company —

- The models are "recyclable, eco-friendly wood materials" (read plywood).
- Simple assembly (defining "simple" would be helpful here); *no glue needed.* Can be assembled at home on a dining room-type table.
- All that's needed are your own two hands, patience, and assembly instructions.
- And one bottle of Stolichnaya (kidding!)

All UGEARS models are made from "high-quality plywood boards, using precision-cut parts." A "high-accuracy, laser cut method" is used "to ensure quality." Detailed, step-by-step instructions are included with each kit.



UGEARS claims each creation "helps people to understand the principles of mechanics" through the self-assembly of motion models. The models also "contribute to developing logical thinking, enhancing attention and concentration skills as well as improving attention to detail skills."

Here are just three examples:

Hurdy-Gurdy. The Hurdy-Gurdy model was successfully launched on *Kickstarter* in July, 2017. Inspired by the art of Celtic and Scandinavian Medieval craftsmen and enriched by smart engineering of the 21st century, the Hurdy-Gurdy is a triple-threat mechanical model kit that is all-in-one: model for self-assembly, toy (gift), and fully fledged musical instrument. The Hurdy-Gurdy plays dancing melodies that bridge medieval times and the present day.

A newer addition to what UGEARS refers to as its "Mechanical Town" collection is the ***Rail Manipulator*** (pictured)**.** The Manipulator is a purely utilitarian model, which by no means makes it less entertaining than the other models in the range. Like the rest of the UGEARS models, the Manipulator is designed to make sure the fun goes on after the assembly is completed. With a number of extras that come in the box, the model guarantees hours of an exciting new pastime.

Speaking of extras, with the Manipulator itself, you also receive two sections of rails, the shed under construction, two shipping crates with doors, crane, freight carriage, and five characters.

The Robot Factory — officially known in Mechanical Town as the Mechanical Wonder Works — is very much what both of its names imply: a model of a factory that produces robots (Made of wood — and isn't that ironic?) and undoubtedly, a wonder of wooden mechanics. The model features a steampunk style workshop with a fully functional assembly line to help you build your robots: arrange the parts of the robot in proper places along the line, wind it up, push the button, and – voila! – your automatic assembly line produces a mechanical wooden robot, all new and ready to serve whatever ingenious game plan you have in mind.