gear TECHNOLOGY®

NOV/DEC 2019

BUYERS GUIDE

GEAR SKIVING

www.geartechnology.com

P.9

GEAR TECHNOLOGY — TO BE CONTINUED

Solutions for all your gear cutting tool needs

Gear cutting tools and services

Star SU offers a wide variety of gear cutting tools and services, including:

- Gear hobs
- Chamfer hobs
- Milling cutters
- Shaper cutters
- Scudding® and Power Skiving cutters
- Shaving cutters
- Chamfer and deburring tools
- Rack and saw cutters
- Master gears
- Ring and plug gauges
- Advanced coatings including ALTENSA and ALCRONA PRO
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Control your tool costs and let Star SU manage your tool room. From new tools to design work to re-sharpening and recoating, we have the equipment and resources to help keep your gear cutting operation running smoothly.

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Economical hob sharpening and in-house tool maintenance

The **NEW** Star NXT linear CNC tool and cutter grinding machine sharpens both straight and spiral gash hob designs up to 8” OD x 10” OAL. With a small footprint and maximized grind zone, the NXT also sharpens disk, shank and helical type shaper cutters, Scudding® cutters, and a wide range of round tools, making it a versatile tool room machine.

SICMAT Profilator

www.star-su.com

gear TECHNOLOGY®

contents

NOV/DEC 2019

24

Page 40 — BUYERS GUIDE

features

technical

Vol. 36, No. 8 GEAR TECHNOLOGY, The Journal of Gear Manufacturing (ISSN 0743-6858) is published monthly, except in February, April, October and December by Randall Publications LLC, 1840 Jarvis Avenue, Elk Grove Village, IL 60007, (847) 437-6604. Cover price $7.00 U.S. Periodical postage paid at Arlington Heights, IL, and at additional mailing office (USPS No. 749-290). Randall Publications makes every effort to ensure that the processes described in GEAR TECHNOLOGY conform to sound engineering practice. Neither the authors nor the publisher can be held responsible for injuries sustained while following the procedures described. Postmaster: Send address changes to GEAR TECHNOLOGY, The Journal of Gear Manufacturing, 1840 Jarvis Avenue, Elk Grove Village, IL, 60007.

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Worldwide the only gear cutter with integrated complete machining

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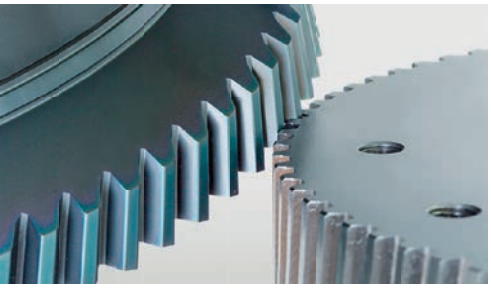
Vol. 36, No. 8

departments

Liebherr Performance.



New gear skiving machine LK 300-500
Machine, tool and process from a single source

In the LK 300 and 500 gear skiving machines, process, tools and machine including tool changer and automation system come from a single source because in skiving[3] the delivery of an integrated solution for the customer is of primary interest. Skiving[3] is especially suited for internal gears of medium size and quantity, as it is much faster than shaping and more economical than broaching. The machine can be operated using the touch-based LHGe@rTec control system.

Machine
- Automation
- Deburring and tool changer
- Stiffness

Tool
- Design
- Manufacturing
- Reconditioning

Process
- Technology design
- Implementation
- Optimization

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THE GEAR INDUSTRY'S INFORMATION SOURCE

www.geartechnology.com

Klingelnberg Remanufacture and Refurbish

A machine's lifecycle is also greatly influenced by routine machine care. After several years of operation, a replacement of used components during an overhaul is therefore often unavoidable. Component replacement ultimately ensures the quality of your machines and production for years to come. Learn more here:

www.geartechnology.com/videos/Klingelnberg-Overhauls-Bevel-Gear-Grinding-Machine-/

Kapp Niles KNG 12P Master

The machines in the Kapp Niles master series are for high-precision machining of external and internal gears as well as special profiles. High thermal stability and rigidity are achieved through an optimized design and matching components. The inherently rigid machine base enables easy installation without anchoring in the hall floor. Learn more here:

www.geartechnology.com/videos/Kapp-Niles-KNG-12P-Master-/

Gear Talk

Resident blogger Charles Schultz looks at the differences between "how" and "why" as they pertain to gear design. Learn more here:

www.geartechnology.com/blog/education-vs-training-2/

Event Spotlight: Gearbox CSI

AGMA's Gearbox CSI session lets attendees gain a better understanding of various types of gears and bearings. Learn about the limitation and capabilities of rolling element bearings and the gears that they support. This event takes place in Alexandria, Virginia. Learn more here:

www.geartechnology.com/news/9269/Gearbox_CSI_/

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Connect with us on LinkedIn *www.linkedin.com/groups/3893880/*

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To: Yours
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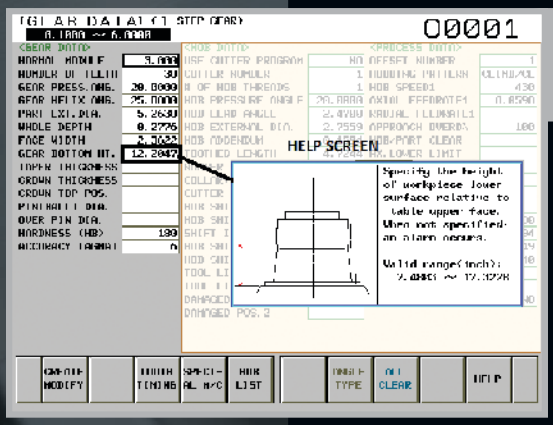
HEAVY INDUSTRIES AMERICA, INC.

Our Technologies, Your Tomorrow

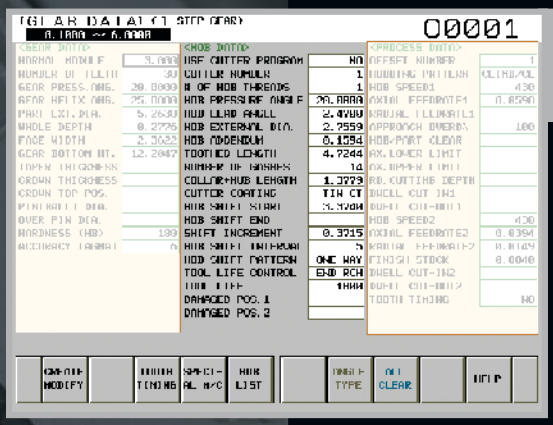
CNC Gear Machine Programming:

Easy as 1-2-3



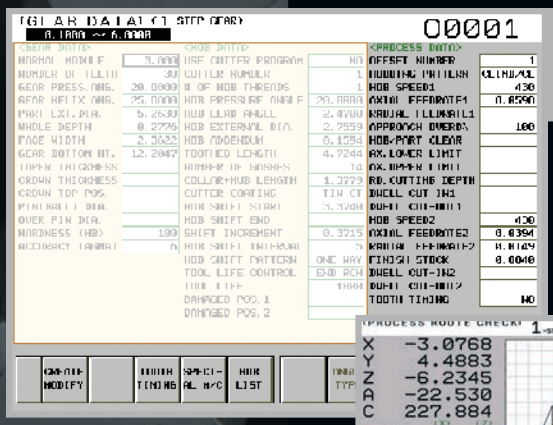
1

Input Gear Data from process sheet or part print. Input distance from work table to bottom of gear.



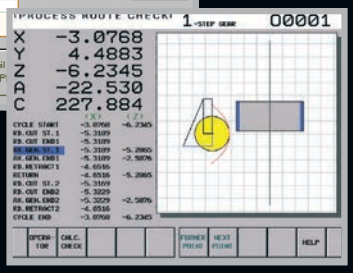
2

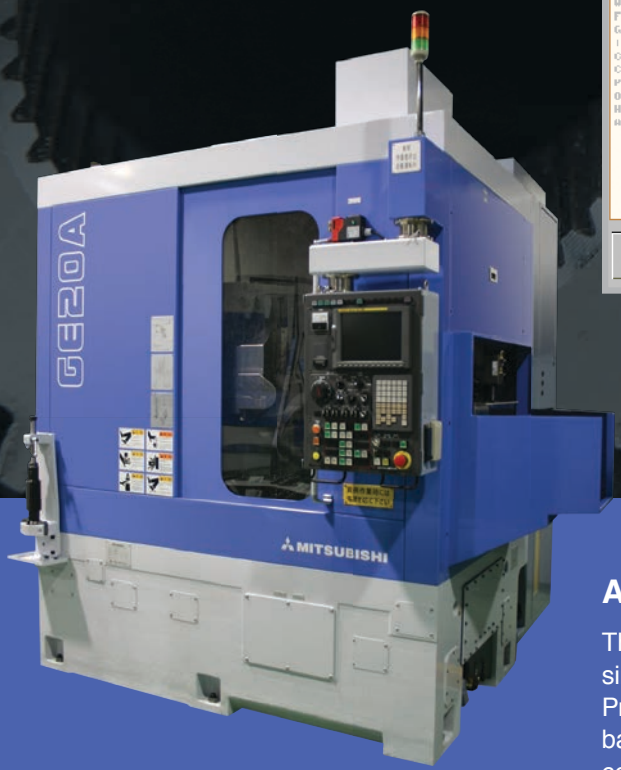
Input Cutter Data from cutter drawing or box.



3

Cutting speeds and feeds automatically calculated as well as cutter paths.





For more information visit
mitsubishigearcenter.com
or contact **Sales at 248-669-6136**.

Advanced Gear Cutting Capabilities at Your Finger Tips

The many-generations-improved Mitsubishi CNC gear cutting machine simplifies programming like never before. It features Conversational Programming with built in macros for calculating cutting speeds and feeds based upon material hardness and gear class with no need to know complicated G-code programming like traditional CNC machine tools. Easy to understand graphics and help screens allow new operators to master programming within a day after installation—and shops that have never cut a gear before can quickly cut their teeth and expand production.

Gear Technology — To Be Continued

Publisher & Editor-in-Chief
Michael Goldstein

When I started *Gear Technology* more than 35 years ago, my intention was to create something of lasting value for the gear industry. It was a way of giving back to the industry that had been so good to me and my family.

As a third-generation machinery dealer who specialized in gear manufacturing equipment, I spent a lot of time traveling the world, and I saw first-hand a desperate need for knowledge and technical information about gear manufacturing. It was available and people needed the information, but they just weren't getting it.

Sure, there were technical conferences such as AGMA's Fall Technical Meeting, and papers were being presented at this and other conferences around the world. Unfortunately, that information wasn't being widely disseminated. Back then, the engineering manager for a big gear company might have attended one of those conferences. He'd go and listen to the presentations and come back to his office with new insights and a blue binder full of technical papers. The problem was, by the time he got back home, his desk was already piled high with all the work he'd missed, and the blue binder got put up on a shelf and forgotten while the engineering manager got back to catching up on the work nobody did while he was gone.

A lot of other people could have used that information, I thought. And so the idea for *Gear Technology* was born. In 1984, we published our first three issues, and we've never looked back.

In fact, we've come a long way since those first issues. Today, in addition to the print magazine, we communicate with you now via the Internet, e-mail and social media. In 2007 we launched *Power Transmission Engineering*. But through the years our core mission has never changed. Our goal is still to bring that educational information to the widest possible audience.

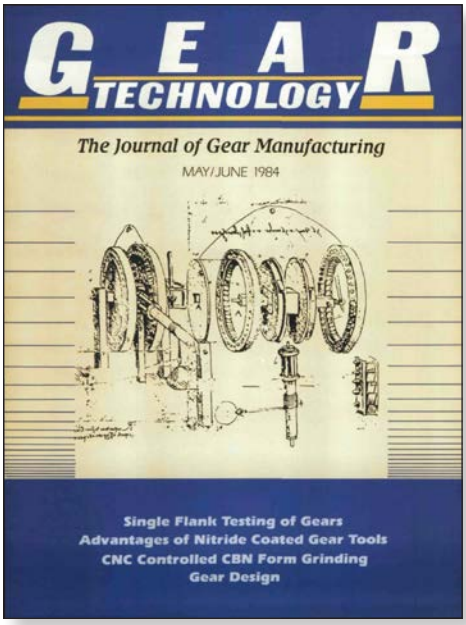
That's why one of the things I'm most proud of is the online library of technical content we provide to the industry, free of charge, and without any kind of restriction, registration or roadblock. Thousands of articles from our 35-year history are available for anyone who wants to read them.

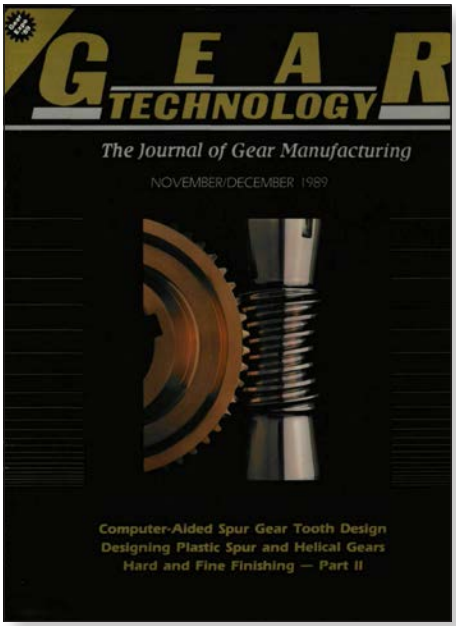
Some of the most valuable articles we ever published were the "Back to Basics" articles we ran in the early years. These articles explain in simple terms the interrelationships between cutting tools, parts and machines, making it easier to conceptualize the mechanics of how designs are transformed into gears.

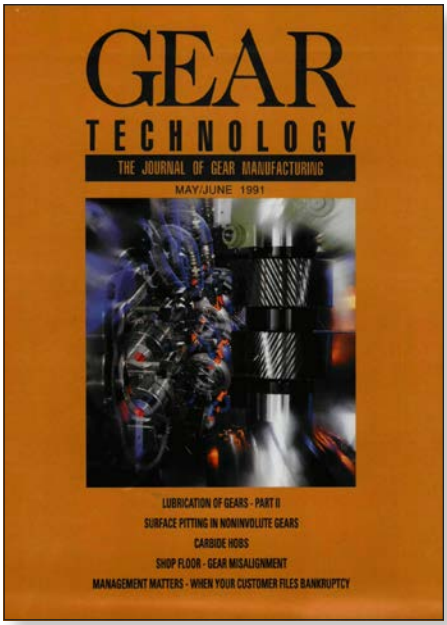
All of our back issues have been painstakingly indexed and organized so that you can find articles on carburizing, crowning, carbide hobbing or any number of other subjects. More than 10,000 unique visitors make use of those articles on our website every month.

I consider that content to be my legacy, and I want it to be available forever.

No one wants to consider his own mortality, but in October I turned 77, and over the past couple of years I've been thinking a lot about how to ensure that what I've built not only will be







remembered, but also will continue to grow and be useful long after I'm gone.

So some time ago I approached the American Gear Manufacturers Association about purchasing the magazines, an idea which they enthusiastically supported. During the recently held Motion+Power Technology Expo in Detroit, we announced that we've come to an agreement. Effective January 1, 2020, AGMA will acquire all the assets of Randall Publications LLC, including *Gear Technology*, *Power Transmission Engineering*, *Gear Technology India*, and all the corresponding websites, e-mail newsletters and other products we publish.

It's a bittersweet moment for me. *Gear Technology* has been at the core of my identity for a significant part of my life, occupying my nights and weekends for 35 years. So, on the one hand, this transition has been one of the hardest things I've ever done. But on the other, I'm extremely proud to know the work we've done will continue long after I'm gone.

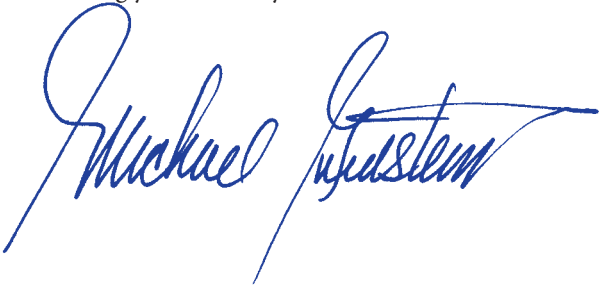
In fact, I'm honored to report that AGMA has agreed to rename our online library of technical content as the Michael Goldstein Gear Technology Library.

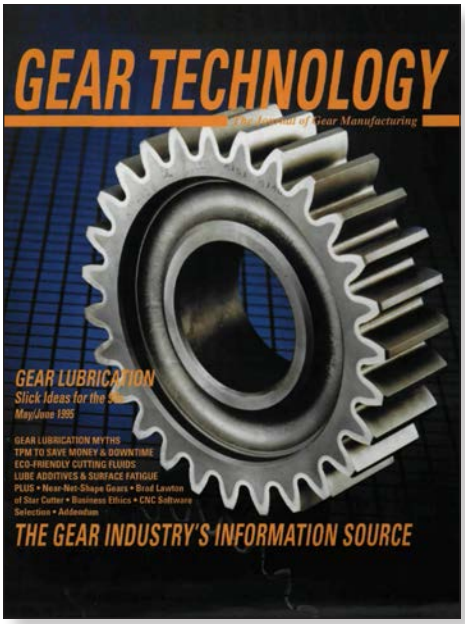
The truth is, although *Gear Technology* will always be a big part of who I am, I never really built it for myself. I built it for all of you. That's why I'm so confident that AGMA is exactly the right organization to continue what I started. Their goals and missions so closely align with my own original objectives that, frankly, I couldn't imagine anyone *other* than AGMA taking over from here. You're in good hands.

I can say that especially because AGMA has agreed to keep all of our current staff. Although I came up with the idea 35 years ago, these people are the ones who bring that idea to life every day. Most of them have been on this journey with me for decades, and I'm grateful to know that they'll enjoy continuity and security, because they've been instrumental in everything Randall Publications and *Gear Technology* have accomplished over the years. I don't think I could have done this without knowing that all of them would be taken care of.

Starting in January, I'll be stepping back a bit. I'm not going away completely, though. Over the course of the next year, I'll be working with AGMA in a consulting role in order to ensure a smooth transition. You may not see me or hear from me as much, but you can continue to contact me through the magazine (*michael@geartechnology.com*), and I hope you'll share your thoughts and ideas about the history of *Gear Technology* as well as its future.

But mostly, I hope you'll keep reading. The greatest honor has been serving you all these years.





BIG BANG
for your buck.

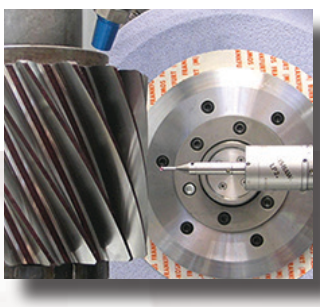
KAPP NILES KN^{e}3P

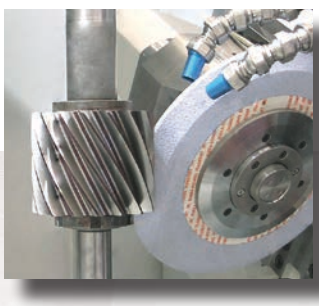
gear profile grinding

Installation and set-up in a blink!

The KN^{e}3P comes with machine mounted electrical panel and is easily accessible. New KN^{grind} software graphically guides you through applications.

Not rocket-science to operate! Well-known KAPP NILES quality.





KAPP NILES

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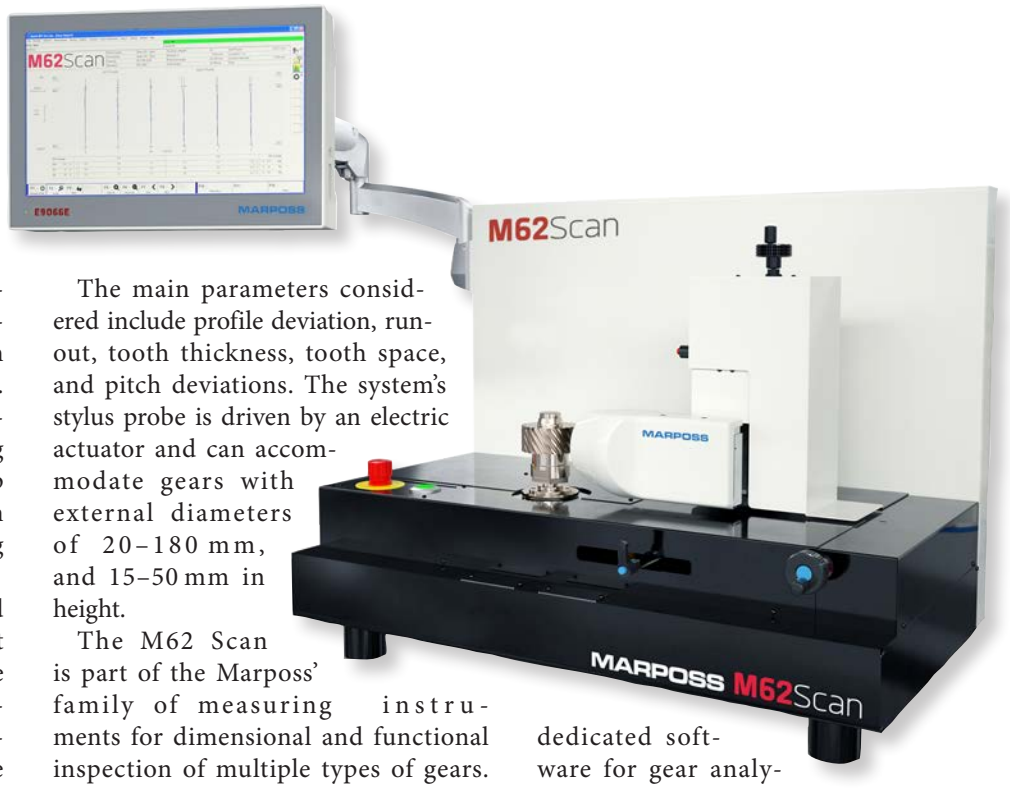
Marposs

OFFERS FAST GEAR MEASURING SYSTEM WITH M62



Marposs recently announced its M62 Scan, a universal gear inspection system that performs a very quick and efficient inspection of cylindrical gear tooth profiles in a production environment. The M62 Scan helps to relieve the workload of gear lab machines by enabling an interim check directly on the shop floor. The compact robust system can reach speeds of up to 50 mm/s, helping to improve production processes.

The M62 system uses a special shaped stylus with a universal ball point contact that scans the involute profile on the transverse section of each flank dynamically with part rotation. During inspection, the stylus is auto-retracted by the opposite gear flank, guaranteeing effectiveness and velocity of the process. In a very short time, the system can capture the entire involute profile of spur or helical cylindrical gears with no flanges, evaluating them according to international standards.

The main parameters considered include profile deviation, run-out, tooth thickness, tooth space, and pitch deviations. The system's stylus probe is driven by an electric actuator and can accommodate gears with external diameters of 20–180 mm, and 15–50 mm in height.

The M62 Scan is part of the Marposs' family of measuring instruments for dimensional and functional inspection of multiple types of gears. Utilizing highly precise tools and robust technology, Marposs' solutions for gear verification offer the appropriate method of measurement t to control l the manufacturing process ins a shop floor environment. All the M62 systems are suited for the use of the *Gear AddOn*, a dedicated software for gear analysis compatible with Microsoft Windows.

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

ANCA

LAUNCHES GCX LINEAR TO MEET GROWING SKIVING CUTTER DEMANDS

The new GCX Linear offers a purpose-built solution for manufacturing and sharpening skiving cutters. With a five axis CNC grinder powered by LinX linear motor technology on X, Y and Z axes, the GCX Linear also comes with features specially designed for skiving cutters and shaper cutters.

"ANCA is responding to the increasing popularity of skiving and resulting surge in demand for skiving cutters. We want our customers to have a complete solution for manufacturing and sharpening skiving cutters and the GCX Linear will set the new benchmark for skiving cutter grinding," said Xiaoyu Wang, product manager at ANCA.

"Dressing the complex wheel profile is critical, ANCA developed the latest acoustic emission monitoring system (AEMS). AEMS can be taught to pick up the right sound of perfect dressing even in a noisy production environment. Built upon supervised machine learning algorithm, AEMS ensures the wheel profile is dressed within micron accuracy with the least possible time while minimizing the reduction in size," Wang added.

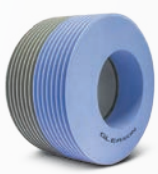
The GCX Linear offers a comprehensive gear cutting tool package and was recently featured during the Motion + Power Technology Show in Detroit.

For more information:
ANCA
Phone: (248) 926-4466
www.anca.com

Finish First

New Genesis® GX Series takes gear grinding quality and productivity to an entirely new level, with single-tool setup, integrated automation, twist-controlled and polish grinding – and Closed Loop networking with GMS® inspection.

www.gleason.com/GX



Total Gear Solutions Gleason

Kennametal

EXPANDS CARBIDE END MILL LINE

Kennametal has announced the latest addition to its best-selling HARVI line of high-performance solid end milling tools, the HARVI I TE four-flute solid carbide end mill. The HARVI I TE delivers performance benefits in a broad range of materials, including steel, stainless steel, high-temperature alloys and cast iron — with tool life to match. And thanks to significantly reduced cutting forces, this tool can be used on any machining center or mill-turn center in the shop.

"The HARVI I TE consistently outperformed competing four-flute end mills in both wet and dry machining tests on a variety of materials and applications, with unprecedented tool life in many cases," said Bernd Fiedler, manager, solid end milling. "It performs exceptionally well on heavy roughing and finishing cuts alike — from deep cavities and full width slots to shoulder and dynamic milling."

Kennametal engineers designed the HARVI I TE to address four key problems that plague more than 90% of all milling applications: chip evacuation, tool deflection, corner stability, and breakage due to radial cutting forces. The result is a tool that's durable and versatile enough to tackle the lion's share of milling applications.

"The HARVI I TE improves process stability, surface quality and chip evacuation," said Fiedler. "Most importantly, it maintains these benefits even at increased feeds, speeds, and depths of cut — delivering maximum metal removal, tool life and productivity."

For more information:
Kennametal Inc.
Phone: (412) 248-8281
www.kennametal.com

Mitutoyo

INTRODUCES QS-L VISION SERIES

Mitutoyo America Corporation is pleased to announce the release of the QS-L Vision Series to its Vision Measuring System Line. The new scope series features a high definition and high-speed auto focus 3-megapixel camera, a four-quadrant LED ring light using high-intensity to provide better observation performance and an interchangeable objective lens zoom unit producing a very sharp image due to a high numerical aperture.

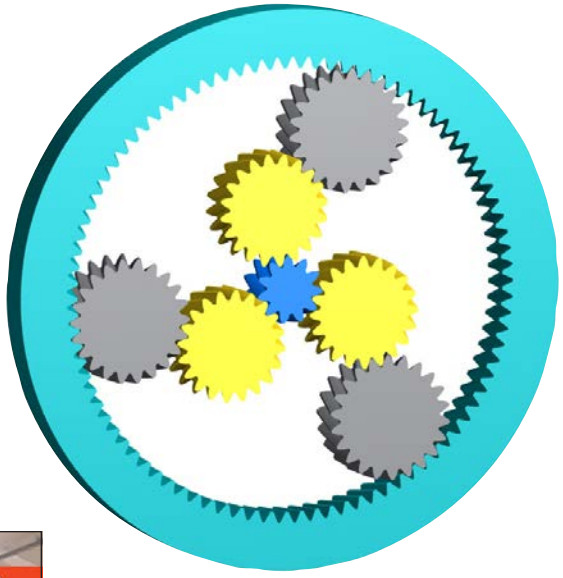
Key features include:

- Instant Image Auto Focus: Height measurement is performed efficiently as non-contact measurement requires the workpiece to be lightly fixed to the stage. Additionally, in contrast to a laser-equipped microscope, measurement is less influenced by the surface roughness of the workpiece.
- Four-quadrant LED ring: Light LED sources are standard for all illumination methods. Color tone is kept constant even after illumination intensity adjustment so high color-reproducibility observation is possible. Additionally, four-quadrant reflected illumination is provided to enable contrast of surface features to be adjusted so that edge detection accuracy is maximized.
- Interchangeable objective lens zoom unit: The newly designed 7×-zoom unit and optional interchangeable objectives provide magnification from 13×–184× on the monitor. A wide range of measurement is covered: wide view measurement at low magnification to micro-measurement at high magnification.

For more information:
Mitutoyo America Corporation
Phone: (630) 820-9666
www.mitutoyo.com

KISSsoft

OFFERS DOUBLE PLANETARY STAGE CALCULATIONS



Today, various types of planetary gearboxes are increasingly being used in the hybridization of drivetrains. Since the *KISSsoft Release 2019*, it is now possible to calculate double planetary stages (module ZA9). Due to their two intermeshing planets, double planetary stages achieve a subsequent reversal of the direction of rotation between the two central gears. The application in speed ranges of 7,000–20,000 rpm requires an exact analysis of the teeth with regard to noise as well as an evaluation of the planetary bearings concerning their service life.

The engineer can first calculate the strength of all gears and check the geometric assembly situation of the planets. Subsequently, all center distances can be varied in the fine sizing of the double planetary stage and the influences of the meshing forces on the bearings can be compared from all possible solutions. At the same time, the minimum bearing diameters of the planetary gears and the largest possible installation space for the ring gear can be defined. Finally, the planetary stage can also be displayed in a 3D graphic for a visual check.

For more information:
KISSsoft AG (A Gleason Company)
Phone: (585) 494-2470
www.kisssoft.ag

Schunk

OFFERS 6-JAW POWER LATHE CHUCK

The Schunk ROTA NCR-A sealed 6-jaw pendulum compensation chuck has special seals at the jaw interface and the piston to keep the grease from being washed out and the clamping force from being gradually lost.

The Schunk ROTA NCR-A consists of a central chuck piston, carrying three inner pendulums aligned at 120°. Each pendulum is connected to two base jaws. This ensures workpiece centering between six contact points, which can be adjusted in pairs. As the clamping forces are directed towards the chuck, optimum centering is achieved without redundant dimensioning of the workpiece. The chuck with its oscillating jaws perfectly adapts to the workpiece. In case of a conventional jaw clamping, this configuration ensures maximum roundness of the workpieces.

The Schunk ROTA NCR-A is available in sizes from Ø 190 mm to Ø 1,000 mm with maximum clamping forces between 36 kN and 300 kN, and jaw strokes from 6 mm to 25 mm. The power lathe chucks of sizes 190 to 225 are equipped with tongue and groove; from size 250 it is equipped with a versatile fine serration (1.5 mm × 60° or 1/16" × 90°). From size 630 on, the lathe chuck is prepared for the use on vertical lathes. Depending on the chuck size, the pendular compensation amounts between ±1 mm and ±6 mm, and the maximum speed is 600 rpm to 4,000 rpm.

For more information:
Schunk
Phone: (919) 572-2705
www.schunk.com

Seco/Warwick

INTRODUCES SUPER IQ FURNACE TO NORTH AMERICAN MARKET

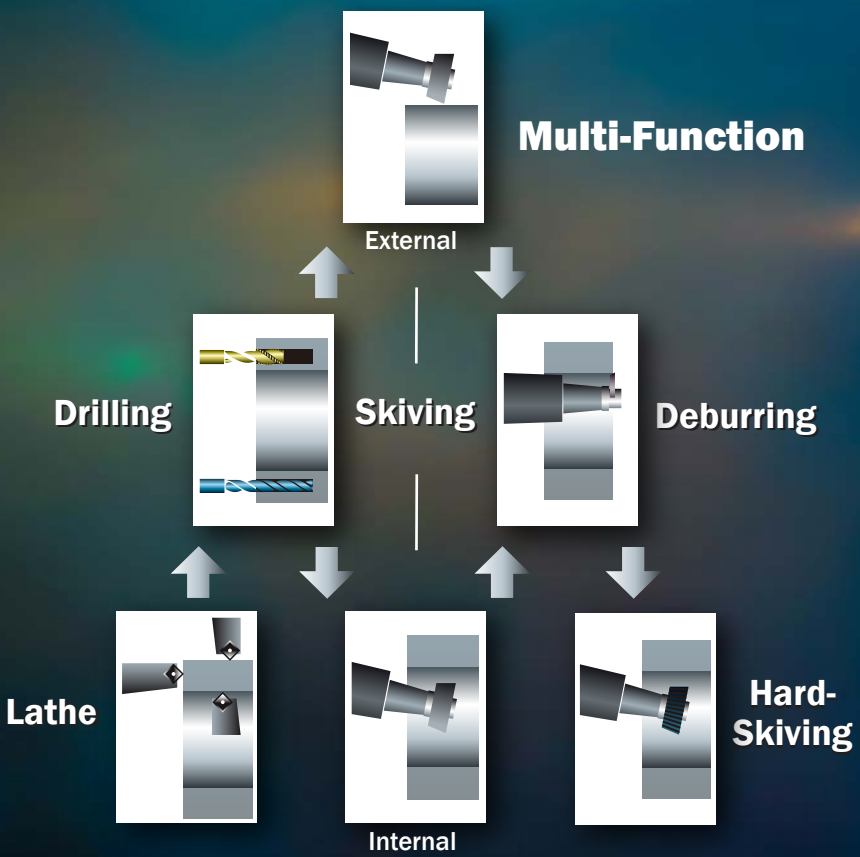
Seco/Vacuum Technologies, Seco/Warwick Group's company, is pleased to introduce to the North American market Super IQ (integral quench furnace), the industry's next-generation carburizing furnace with more built-in features to simplify your life. The American premiere took place at ASM2019 in Detroit.

The Super IQ offers all the benefits of low-pressure carburizing with none of the added costs. The system combines clean processing with the exceptional performance of oil quenching using the most innovative integral quench furnace design in decades. With a Super IQ, users get super-clean parts while still getting the benefit of a simple atmosphere oil quench without any additional costs.

According to Jarosław Talerzak, vice-president business segment thermal, Seco/Warwick, "The concept for a new alternative to the integral quench furnace was born of calls from heat treatment facility managers and owners demanding a cleaner, faster, more efficient method for carburizing. We introduced the Super IQ this year with a multitude of benefits over traditional methods, especially productivity: Because the Super IQ operates at

NACHI

GMS200 Skiving Machining Center for Gears



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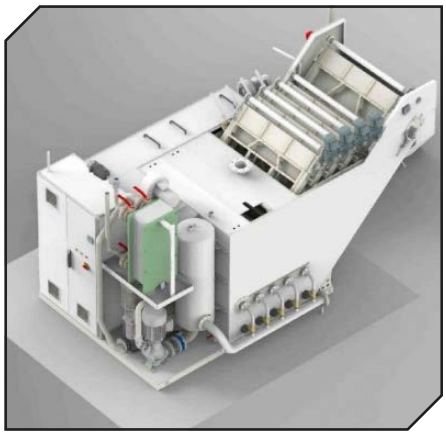


For more information:
Oelheld U.S., Inc.
Phone: (847) 531-8501
www.oelheld.com

Starrett

INTRODUCES AUTOMATED DIGITAL HARDNESS TESTERS

The L.S. Starrett Co. has introduced two new digital Rockwell/Superficial Rockwell Benchtop Hardness Testers (Nos. 3823 and 3824) with fully automated load/ unload procedures, and capable of providing highly accurate readings. The new Starrett Hardness Tester models utilize a closed-loop control unit with a load cell, a DC motor and an electronic measurement and control unit instead of traditional dead weights, enabling high accuracy measurements at all test loads up to 0.5%. The testers are part of a significantly expanded line of new hardness testing solutions that Starrett is now offering.

The Starrett No. 3824 Hardness Tester has an automated Z-Axis. The user simply presses the START key, and

the entire test process is automatically completed. The Starrett testers feature programmable scale conversions, dwell times, statistical capabilities and a test counter and are capable of testing in a wide range of 30 different Rockwell hardness scales for carbon steel, alloy steel, cast iron and non-ferrous metals.

Suitable for both internal and external testing via a dolphin nose design, the Starrett No. 3823 and 3824 Digital Testers are high precision testing solutions that meet ISO 6508-2 and ASTM E18 standards. They feature a built-in micro-printer, touch screen control on a high definition LCD display, USB output, and are furnished with PC-based software. For memory, a maximum of 400 items of test results are stored automatically. Testing capacity is 12" (300 mm) vertical and 8.8" (220 mm) horizontal. A full range of accessories from test blocks to anvils, to dust cover are also included.

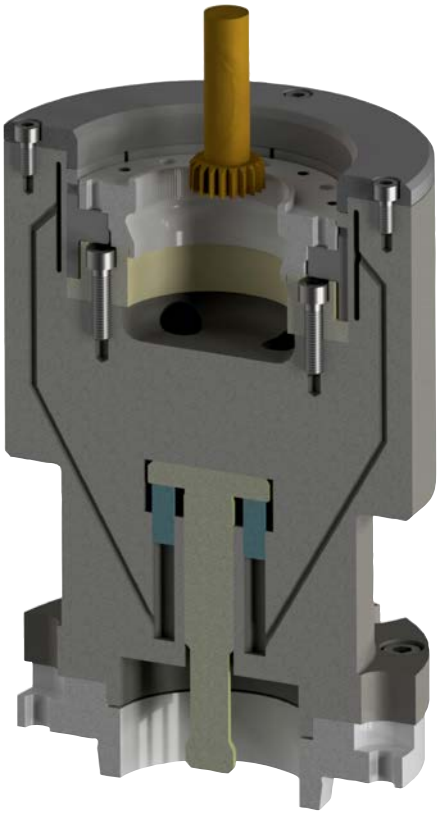
Featuring a manual Z-Axis instead of an automated Z, the No. 3823 Digital Superficial Rockwell Hardness Tester is a good value alternative to the No. 3824 Tester. Both the Starrett No. 3823 and No. 3824 feature auto load test force control.

For more information:
L.S. Starrett Company
Phone: (978) 249-3551
www.starrett.com

Mytec HydraClamp

OFFERS POWER SKIVING AND GEAR SHAPING BENEFITS

Skiving has been around for a long time, but recent advances in technology have improved the speed and effectiveness of this gear-making process making it a more viable manufacturing option for gear producers. It's long been recognized that skiving would be a much more productive process than shaping for cutting many internal gears. Mytec HydraClamp clamping tools are robust and rigid enough to minimize vibrations caused by the high spindle rpms and significant cutting forces generated by the



new "Power Skiving" process.

Today's demands also include clamping very thin parts for the robotic gear boxes (flex spline gear box). Mytec HydraClamp clamping tools are designed to clamp components the entire length of the clamping area. If the component is irregularly shaped, we clamp around it to achieve the highest accuracy. View the graphic as an example of a clamping situation with such a component used in the robotic gear box. Note the external shape is irregular and the clamping area is very short. We designed a hydraulic chuck in combination with a changeable back stop and slotted collet. This gives the customer options to clamp different diameters and components with one hydraulic chuck. This hydraulic chuck is used to machine the spline in the "Gear Shaping" process on a Liebherr machine.

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

Liebherr

EXAMINES UNIVERSAL CHAMFERING

Johannes Weixler has developed a new universal chamfering application – with the dynamic mathematical assistance of colleagues.

"The chamfer has become a significant factor in both gear design and manufacturing. By implementing the ChamferCut technology, we are very well set up at Liebherr in the area of chamfering, too. When it comes to chamfering internal gears on ring gears or cluster gears with interfering contour, however, the procedure often reaches its limits," Weixler said. "Where the ChamferCut unit cannot reach, a tapered end mill can be used for deburring. The idea is to mount the tool directly on the machining head of the ChamferCut with its own drive and own swivel axis. The tapered end mill can then be controlled via the NC axes – and this is where our mathematicians came in."

What initially appeared quite simple became a challenging mathematical task

from the perspective of his colleagues, Robert Würfel and Johannes van Hauth. Würfel remembers: "Johannes Weixler came to us with a request to convert his idea into a mathematical description and to solve it numerically. He wanted a constant feed, which can only be achieved through an uneven rotating speed of the workpiece. We originally wanted to use just one axis and faced the question: How do we achieve a nice chamfer that looks even from tip to foot?"

A mathematical model was created that van Hauth implemented in a test program for calculations. Since then, not only has a patent been registered for the

concept of the end mill on the NC axis but also for the axial movements during milling. The reason: "This method is of interest for practically any customer with difficult geometries," said Weixler.

The background: The number of gears in gearboxes is growing, but at the same time the amount of space available is decreasing. Where space had to be allocated for four gears in the past, these days it is often seven gears. The gears are therefore becoming smaller and they are required to perform at a higher level, particularly at the edges, which is only possible with perfect chamfering. "Chamfering therefore extends the limits of possibility," he added.

With the new method, the ChamferCut unit can machine the upper and the lower gear. However, it cannot reach the middle one. "A tapered end mill is used for deburring here: first, a meshing sensor finds the tooth space and then the travel is calculated. Our milling tool only moves from the top down so there is no risk of collision. The swivel option enables it to reach all edges: tilted downwards, it can machine the bottom contour, while tilted upwards it is able to machine the top one," said Weixler. "Internal gears from ring gears can also be machined in the same way – even if there are contours on the inside. This means that a chamfer is possible on practically any gear."

Tapered end mill deburring is possible alongside the main tasks of gear hobbing, gashing, shaping, and skiving. A standalone solution – e.g. for retrofitting – is also feasible. For manufacturers with small batch sizes, a tapered end mill without the ChamferCut tools could also be of interest:

"ChamferCut tools are workpiece-specific and are only worth the investment for higher batch-size volumes," Weixler said. "The tapered end mill is a completely normal tool, made of carbide, a catalogue part. We offer a tool changer for the machine that can also exchange tapered end mill cutters. In addition, the tapered end mill is able to create variable chamfer shapes. With this broad range of possibilities, completely new perspectives are presented for many applications."

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

The Skiving Evolution

Machine Tool Providers Discuss the Latest Benefits, Technologies and Considerations

Matthew Jaster, Senior Editor

Gleason offers Power Skiving machines in different sizes for internal and extrenal gears. (Photo courtesy of Gleason).

EMO 2019 (Hannover, Germany) and Motion + Power Technology 2019 (Detroit, Michigan) introduced the latest and greatest skiving technologies available to gear manufacturers. Both trade shows featured several booths with technical experts on-hand to deliver news on flexibility, tool life, machine uptime and the productivity benefits produced from the skiving process.

Liebherr offers machines for various cutting processes

Liebherr introduced the new Gear Skiving machine LK 280 DC at EMO 2019. This machine can handle parts with up to 280 mm outside or rotating diameter. To be able to handle various processes, the machine is equipped with a tool changer with 12 stations.

"Besides identical skiving tools to continue production, roughing and finishing tools can be loaded to reduce the wear of the finishing cutter," said Dr. Oliver Winkel, head of technology application, Liebherr-Verzahntechnik GmbH, Germany. "In addition to skiving, the machine is prepared for other cutting processes like turning, drilling and milling as well as handling a measuring probe. This gives the customer the flexibility for today and tomorrow's gear cutting applications not only for internal but also for external gears or shafts."

Liebherr also introduced a new chamfering process called "FlexChamfer." Using the 6-NC-axes of the chamfering unit, the machine moves an end mill in such a way that even complex contours like internal gears can be easily chamfered without any special tools. This is especially useful for job shops or small volume productions and will give a high value to today's needs of precise chamfering, according to Winkel.

Liebherr's skiving technology works well with internal gears with medium to high batch sizes. (Photo courtesy of Liebherr)

The acquisition of Wenzel Gear Tech gear measuring machines enabled Liebherr to complete its Liebherr Open Connect IoT-solution, where measuring data are transferred back and forth between gear checker and gear cutting machine using the new GDE (gear data exchange) format. This transparent and open kind of "closed loop" give the customer the chance to minimize manual inputs and maximize uptime of the machines while giving the chance to integrate existing machine tools (even, if not made by Liebherr).

Regarding tooling and workholding, Winkel said that the clamping fixtures are very important and often totally different to what customers are used to from shaping and broaching which are more or less "stationary processes" regarding table rpm.

"For skiving, very high table rpms are required, so the dynamic forces are much higher. The clamping fixture design must take care of that, meaning higher prices for tooling. We had a similar situation, when generating grinding of bigger modules came up, and customers wanted to use their existing fixtures that they successfully used for profile grinding many years," Winkel said.

For Liebherr, the main application for skiving is the manufacturing of internal gears with medium to high batch sizes. Whenever shaping is too slow and broaching is too expensive or geometrically not possible.

"Industrial gearbox manufacturers as well as construction or agricultural equipment manufacturers as well as job shops might benefit the most. But even the automotive industry has in seen an increasing number of applications, whenever collision contours or medium volume outsourcing come into play. This is particularly true for external gears with interference contour or the skiving of two gears

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with a positioning between them," Winkel added.

Winkel believes that every company with medium to bigger lot sizes should have a gear skiving machine. The flexibility to machine external and internal gears on a high productivity level is very attractive for today and the future. He expects an increasing amount of applications in this area because engineers see great potential for their gear designs. Furthermore, the tool life and the knowledge about skiving technology will continue to improve.

For more information:
Liebherr Gear Technology, Inc.
Phone: (734) 429-6278
www.liebherr.com

Super-Skiving with MHI

With highly engineered maximum rigidity and advanced high-speed spindle synchronization, the MSS300 takes full advantage of the cutting performance of MHI's Super Skiving tools. These three-tiered tools can reduce cycle time by up to 40% while improving tool life 40%–300% compared to an ordinary pinion type skiving tool.

Because of the North American debut of the newest gear grinder, the ZE26C, at Motion + Power Expo, there wasn't room to display the MSS300. However, external gear skiving using the three-tiered Super Skiving cutter is a recently added option for the MSS300.

"Gear skiving, and Super Skiving in particular, have applications primarily for internal gears which traditionally would have been shaped or broached. Faster than shaping and slower than broaching, gear skiving offers enhanced control and efficiency. This is beneficial to automotive as well as truck and off-road industry sectors. The "quick change" concept also applies to agricultural equipment manufacturers and industrial applications with high mix and low to medium volumes. External parts with interfering geometry, such as a shoulder, are good candidates for gear skiving as well," said Dwight Smith, vice president at Mitsubishi Heavy Industries America.

To benefit from the speed and greatly improved tool life of the three-tiered Super Skiving cutters, the workholding needs to be designed to allow the cutter to feed past the end of the facewidth of the part. Rigidity and balance are also important due to the high speeds and process dynamics.

Smith said that the Super Skiving tool has three times as many cutting blades involved in the process (compared to conventional pinion type cutters) and a much higher metal removal rate. Therefore, the work holding must have sufficient rigidity to resist these forces. Mitsubishi engineers, using advanced simulation software developed in-house, can model the forces created at each discreet point in the generating process. This data is then applied to the work holding design.

Smith said that the software powering the MSS300 is continuously evolving. Maximizing machine motions to accomplish specific cutting operations will broaden capabilities and flexibility. In the engineering arena, the cutting simulation software provides specific cutting tool design information to improve tool life and ultimate part quality. In the design of the MSS300 and future iterations, advanced FEM and MBD (Multibody Dynamics) analyses are used, and extensive natural frequency analysis is performed to further refine the designs.

By optimizing machine rigidity and axis synchronization, MHI has improved tool life to allow Super Skiving to challenge broaching in high volume production applications. At the same time, Super Skiving can supplant or replace shaping for many internal and external applications and offers much better throughput. The ability to make corrections and the ease of tool change makes gear skiving a viable choice for many jobs.

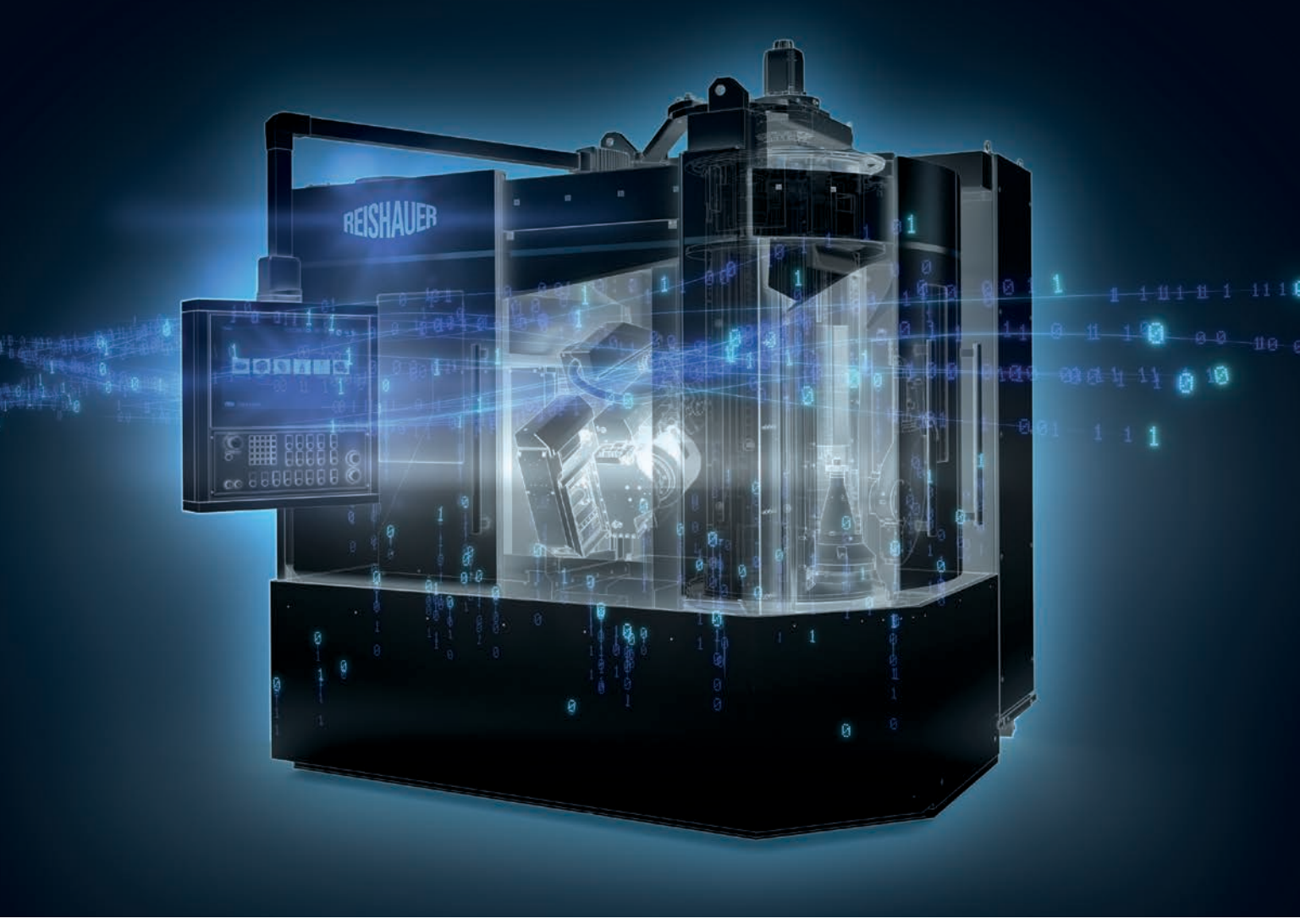
"Driven by customer needs, MHI will continue to integrate additional features into the MSS series of Super Skiving machines. The recent research project in conjunction with WZL Aachen Gear Research has yielded valuable data to further improve skiving tool life and productivity. Another study, recently presented at the VDI symposium in Munich, showed reduced residual compressive stress in internal ring gears cut with Super Skiving. This suggests a potential reduction in distortion for carburizing and hardening of this type of parts," Smith said.

The MSS 300 Super Skiving machine features FEM and MBD analyses. (Photo courtesy of Mitsubishi Heavy Industries America)

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

Power Skiving enhancements at Gleason

Gleason is building Power Skiving machines in different sizes for internal and external gears including the 100PS, 300PS, 400PS, 600PS, 800PS. Together with these machines, they offer customers technology software to design the process and skiving cutters with all the necessary calculations and analysis. Alternatively,



GENERATING GEAR GRINDING MADE TRANSPARENT

Process monitoring

The dressing and grinding intensities are measured and monitored by smart real-time data processing and tested algorithms. For each workpiece, all data generated during dressing and grinding are recorded and stored in a database and remain 100% traceable. Using the stored process and tooling data, including workpiece identification via DMC, offers the means of comprehensive analysis. Due to process interaction, and using preset evaluation limits, workpieces that exceed or fall short of these limits are automatically removed.

Component monitoring

Recurring automatic testing cycles measure and evaluate all the relevant grinding machine axes involved in the process, and thus enables early detection of electromechanical deviations. Maintenance costs are optimized both in terms of planning and diagnosis, and some potential EOL anomalies may be avoided.

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All the calculation and analysis for the skiving process is provided by Gleason's software technology.

Gleason provides this service including process and cutter design directly to their customers for any new job. On the base of this analysis, they manufacture cutters and also dedicated workholding that is specially adapted to the Power Skiving process and the customer application.

Although "one-way" wafer cutters for the shaping process have been in use for some time, such cutters do not improve the current Power Skiving process by much, according to Dr. Edgar Weppelmann, manager application engineering at Gleason-Pfauter. Resharpening the cutter in the Power Skiving machine enhances the process in virtually all aspects due to the more frequent cutter changes required because of the much faster Power Skiving Process compared to shaping.

"For this reason Gleason has developed for their 300, 400 and 600PS machines an integrated unit to resharpen cutters in the machine in a very short time. The cutter face can now be resharpened fully automatic in the machine after it has cut a certain number of gears — without any operator involvement. The cutter geometry is adjusted automatically considering the removed stock and the serial production is continued without further interruption. Recoating the cutting face is not required because the original coating on the flanks protects the cutter teeth sufficiently," Weppelmann said.

Frequent cutter changes are no longer required, a single cutter can stay on the machine for several days or weeks before it is fully used up. The time that has been used in the past by the operator for a cutter change is now being used for three to four automatic cutter grinding cycles with a reduced stock removal per grinding cycle to keep the cutter constantly sharp for a high and constant gear quality, he added.

First part inspection and machine correction after cutter resharpening are no longer necessary because the same cutter is continuing the production which also relieves the cost and capacity in the inspection room.

In addition, cutter management and handling logistics to ordering new cutters in time, to ensure a continuous production, is highly reduced. Cutter inventory can also be drastically reduced because there is no longer the need to circulate cutters through an external re-furbishing cycle.

"Because the cost for external cutter refurbishing is avoided, the tool cost per gear is drastically reduced. However, the total savings are considerably higher if one considers the other benefits described above. When carbide cutters are used for soft or hard skiving the savings from avoiding the external re-furbishing are even higher. Also, the danger of damaging expensive carbide cutters by manual handling is highly reduced as the cutters stay much longer in the process without being touched. The productivity of the power skiving process is not jeopardized by the missing coating on the cutter face because resharpening now happens more frequently compared to the cutter life of the current process with external cutter re-furbishing," Weppelmann said.

Not all internal ring gear geometries can be skived due to collision and chip evacuation requirements. Due to the cross-axis angle required for Power Skiving the process needs a larger distance to collision shoulders at the end of the cut to avoid a collision between the cutter and the workpiece.

Weppelmann said, however, typical skiving applications are internal ring gears, spur and helical gears in soft and hardened state. Electromobility with the higher quality requirements to reduce noise, light and heavy truck gears, gears for agriculture and construction equipment, aircraft and robotic gears as well as a wider range of gears for many industrial applications, typically served by job shops.

"Power skiving is taking over more and more gears from the shaping process as long as they are suitable for Power Skiving. It is now also used for hard finishing of higher quality gears mostly in electro- mobility and robotic applications which require higher qualities that cannot be achieved without a hard finishing process after heat treatment. Gleason Power Skiving machines with integrated cutter resharpening ideally support these requirements.

Hard Power Skiving is the technology where Weppelmann said we will see significant developments in close combination with integrated cutter resharpening. This is to meet the requirements for quieter and more precise gears. Integrated cutter resharpening will become increasingly accepted to lower cost and tool inventory and to increase gear quality.

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

Star-SU Discusses Skiving/Scudding Benefits

Star-SU and its partners Samputensili and GMTA provide the tooling as well as the application knowhow to provide the latest advancements in skiving. These advancements can lower overall manufacturing costs by reducing the longer cycle times found in areas like shaping operations.

"We're currently working with GMTA on their Profilator equipment," said Deniz Sari, sales manager at Samputensili. "These machines are designed for dry cutting, offer excellent chip evacuation and increased cutting speeds."

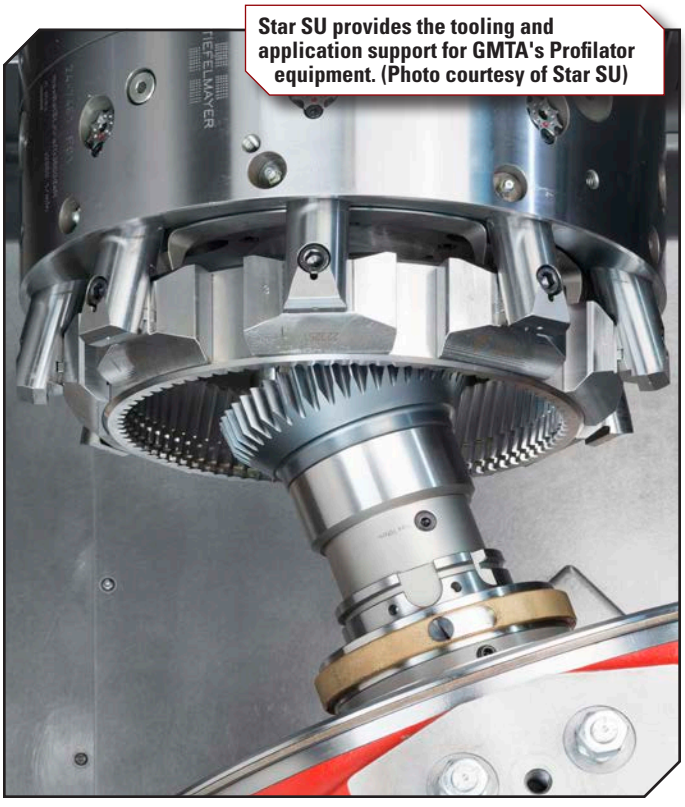
Scudding from GMTA takes traditional power skiving technology for gear production and makes it much more accurate and versatile. The process is extremely competitive in shaping, broaching and other gear cutting applications for gears and splines.

Sari says that many customers today are looking for machines that combine a variety of machining operations (with skiving) on a single platform. This seemed to be the consensus from attendees at both EMO in Hannover and the Motion + Power Technology Expo in Detroit.

The challenge, according to Tom Ware, product manager, gear tools at Star-SU, is when machine tool providers want to include skiving in their 5-axis milling operations.

"They typically do not have the background in gears that is necessary, so they rely on the tool supplier to be the process engineer," said Ware. "This can be a huge drain on the engineering capacity of the cutting tool provider. There are some inherent mechanical issues regarding horsepower and rigidity that need to be carefully examined in order to optimize the skiving process."

Sari said that Star-SU and its partners are finding ways to work through these various challenges.



Star SU provides the tooling and application support for GMTA's Profilator equipment. (Photo courtesy of Star SU)

"These 5-axis machines are capable of producing gears now, mostly low-quality splines or prototypes and this makes a lot of sense," Sari said. "They will never adequately replace dedicated gear equipment when you start looking at larger batch sizes, however."

Ware believes the greatest benefit of skiving today lies in the internal ring gear whether it's for an automotive application or a more elaborate gear design in truck or tractor applications. "Wherever you can move away from the helical broaching process, I think we're going to continue to see growth in skiving. Double gear applications are another area that can benefit from skiving."

Sari agrees that automotive holds great potential for the skiving process moving forward, particularly the electrification trend taking place today. "The electric gearbox with all of its advanced, integrated parts offers new opportunities for the skiving process."

While the tooling for skiving has not required a lot of new manufacturing technology recently, Ware said they are focused on developing high-speed skiving tools that will provide longer machine runs and better performance, "Anything new that is happening in the skiving process is currently taking place on the design side."

But for flexibility, productivity and enhanced machining operations, scudding/skiving continues to provide gear manufacturers with additional cutting options.

"Gear designers like to use all the profile and lead corrections," Sari said. "This is something that cannot work with broaching. In skiving, you can add the lead corrections into your machine control with the latest CNC technology and it's not an issue."

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

The Evolution Continues

Those manufacturers looking to manufacture quieter, more precise gears will continue to consider skiving technology. The changing landscape of both the aerospace and automotive industries will provide plenty of opportunities for the skiving process. What's fascinating in 2019 is the different styles, methods, tooling and workholding procedures that each machine tool provider is focusing their efforts on. These different technologies were on display at both EMO and the Motion + Power Technology Expo and it's fair to say that the technology will continue to evolve by the time IMTS 2020 rolls around next fall.

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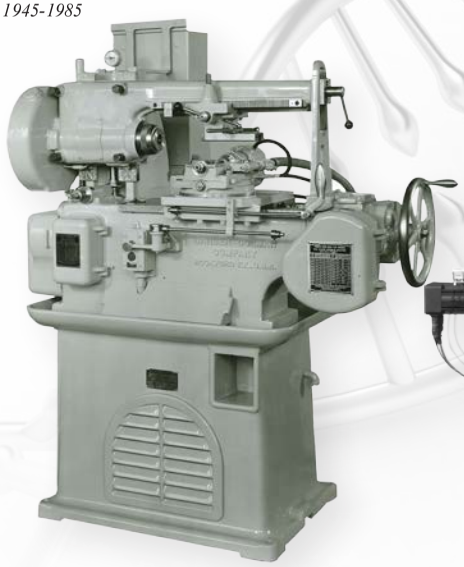

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The 2019 ***Gear Technology*** **Buyers Guide** was compiled to provide you with a handy resource containing the contact information for significant suppliers of machinery, tooling, supplies and services used in gear manufacturing.

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

But Wait! Where are the Gear Manufacturers Listed?

If you are looking for suppliers of gears, splines, sprockets, gear drives or other power transmission components, see our listing of this issue's power transmission component advertisers on page 53. In addition, you will find our comprehensive directory in the December 2019 issue of ***Power Transmission Engineering*** as well as in our online directory at *www.powertransmission.com.*

Handy Online Resources

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

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

How to Get Listed in the Buyers Guide

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

CUTTING TOOLS

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

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Fax: (224) 220-1311
alex@dragon.co.kr
www.dragon.co.kr
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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

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
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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 P13,30

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 P13,30

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 P13,30

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

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

Greg Allen Company
www.gallenco.com

Guardair Corporation
www.guardair.com

Guven Bronz Metal
www.guvendokum.com

Hanik Corporation
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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Harbin Tool Works
www.hrbtool.com

Helios Gear Products
635 SCHNEIDER DRIVE
SOUTH ELGIN IL 60177
Phone: (847) 931-4121
Fax: (847) 931-4192
sales@koepferamerica.com
heliosgearproducts.com
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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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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
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118 E. MICHIGAN AVENUE, SUITE 200
SALINE MI 48176
Phone: (734) 470-6278
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HUECKESWAGEN 42499
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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

LMT USA
www.lmt-fette.com

LOUIS BELET SA
www.lbsa.ch

Lalson Tools Corporation
www.lalsoncuttingtools.com

Leistritz Advanced Technology Corp.
www.leistritzcorp.com

Liebherr America
1465 WOODLAND DRIVE
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

Machine Tool Solutions, Inc.
machtoolinc.com

Maheen Enterprises
www.maheenbroaches.com

Matrix Precision Co. Ltd.
www.matrix-machine.tw

Maxwell Tools Co. USA
www.maxwelltools.com

Maxwell Tools Company
www.maxwelltools.com

Miller Broach
www.millerbroach.com

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

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
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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

Permanent Steel Manufacturing Co.,Ltd
www.permanentsteel.com

Philadelphia Carbide Co.
www.philacarbide.com

Pinpoint Laser Systems
pinpointlaser.com

Pioneer Broach Co.
www.pioneerbroach.com

PlasmaRoute CNC
www.cncplasmacutterinc.com

Polygon Solutions
www.polygonsolutions.com

Productivity Inc.
www.productivity.com

QC American
www.qcamerican.com

R.A. Heller
www.raheller.com

Rotec Tools Ltd.
www.rotectools.com

Russell Holbrook & Henderson
www.tru-volute.com

S.S.Tools
www.sstools.net

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

SWG Solutions
www.swgsolutions.com

Saazor
www.saazor.de

Samputensili S.p.A.
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

Schnyder SA
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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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Seco Tools Inc.
www.secotools.com/us

Shape-Master Tool Company
www.shapemastertool.com

Slater Tools Inc.
www.slatertools.com

Slone Gear International, Inc.
www.slonegear.com

Solid Metalworking INC. Limited
www.atcarbide.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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sales@star-su.com
www.star-su.com
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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

Work Out Ind. Com. Imp. e Exp. de Maq. ltda
www.workout.com.br/index-en

Yash International
www.yashtools.com

GEAR BLANKS & RAW MATERIAL

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

A. Finkl & Sons Co.
1355 E. 93RD ST.
CHICAGO IL 60619
Phone: (773) 975-2510
Fax: (773) 348-5347
www.finkl.com
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Accurate Specialties Inc.
www.accuratespecialties.com

Aksan Steel Forging
www.aksanforging.com

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

American Friction Welding
www.teamafw.com

Amorphology
145 N. ALTADENA DRIVE
PASADENA CA 91107
www.amorphology.com
SEE OUR AD P28

Anihas Castings
www.anihas.com

ArcVac ForgeCast Ltd.
www.arcvacsteel.com

Atlas Bronze
www.atlasbronze.com

Aviva Metals
www.avivametals.com

BGH Specialty Steel Inc.
www.bgh.de

Bharat Forge Ltd.
www.bharatforge.com

Boltex Manufacturing
www.boltex.com

Brooker Bros. Forging Co.
www.brookerbrosforgings.com

Buehler - An ITW Company
www.buehler.com

CFS Machinery Co. Ltd.
www.dropforging.net

Canton Drop Forge
www.cantondropforge.com

Castalloy
www.castalloycorp.com

Celanese
www.celanese.com

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

Concast Metal Products
www.concast.com

Cornell Forge
www.cornellforge.com

Crucible Industries LLC
www.crucible.com

DSM Engineering Plastics
www.dsm.com

Dayton Forging and Heat Treating
www.daytonforging.com

Deco Products Company
www.decoprod.com

DuPont
plastics.dupont.com

Dura-Bar
www.dura-bar.com

Earle M. Jorgensen Co.
www.emjmetals.com

ElectroHeat Induction
www.electroheatinduction.com

Ellwood City Forge
www.ellwoodcityforge.com

Erasteel Inc.
www.erasteel.com

Eutectix, LLC
eutectix.com

Excel Gear
www.excelgear.com

Fomas USA
www.fomasgroup.com

Forging Solutions LLC
www.forging-solutions.com

Fox Valley Forge
www.foxvalleyforge.com

Fuji Machine America Corp.
www.fujimachine.com

Galaxy Sourcing Inc.
www.galaxysourcing.com

Guven Bronz Metal
www.guvendokum.com

Hunter Chemical LLC
www.hunterchem.com

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

Intech Corporation
www.intechpower.com

Interstate Tool Corp.
itctoolcorp.com

Kuraray America, Inc.
www.kuraray.com

Lalson Tools Corporation
www.lalsoncuttingtools.com

Larson Forgings
www.larsonforgings.com

Mackeil Ispat & Forging Ltd.
mackeilforgings.com

Maguire Technologies
www.maguiretech.com

Martin Tool & Forge
www.martinsprocket.com

Masternet Ltd.
www.masternetltd.com

Maxwell Tools Co. USA
www.maxwelltools.com

McInnes Rolled Rings SEE OUR AD P17,43
1533 EAST 12TH STREET
ERIE PA 16511
Phone: (800) 569-1420 or (814) 459-4495
Fax: (814) 459-8443
sales@mcrings.com
mcinnesrolledrings.com

McKees Rocks Forgings
www.mckeesrocksforgings.com

Midwest Themal-Vac Inc.
www.mtvac.com

Moore-Addison Precision Plastic Blanking
www.mooreaddison.com

Mosey Manufacturing Co. Inc.
www.moseymfg.com

National Bronze Mfg. Co.
www.nationalbronze.com

Ovako AB
www.ovako.com

PCK Buderus India
www.pck-buderus.com

Parag Casting Co.
www.paragcasting.com

Patriot Forge
www.patriotforge.com

Penticton Foundry Ltd.
www.pentictonfoundry.com

Permanent Steel
www.permanentsteel.com

Permanent Steel Manufacturing Co.,Ltd
www.permanentsteel.com

Perry Technology Corporation
www.perrygear.com

Presrite Corporation SEE OUR AD P35
3665 E. 78TH STREET
CLEVELAND OH 44105
Phone: (216) 441-5990
Fax: (216) 441-2644
www.presrite.com

QSC Forge & Flange
www.qscforge.com

QuesTek Innovations LLC
www.questek.com

Reade Advanced Materials
www.reade.com

Renishaw Inc.
www.renishaw.com

Rewitec GmbH
www.rewitec.com

Rotek Incorporated
www.rotek-inc.com

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

Schmiedewerke Groeditz GmbH
www.stahl-groeditz.de

Scot Forge
www.scotforge.com

Sedlock Companies
www.sedlockcompanies.com

Sensor Products Inc.
www.sensorprod.com

Somers Forge
www.somersforge.com

Southwest Metal Products Ltd.
www.southwestmetal.com

Spectrum Machine Inc.
www.spectrummachine.com

Steuby Manufacturing Company, Inc.
www.steubymfg.com

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

TimkenSteel Corporation
www.timkensteel.com

UMC - United Metals Co.
www.umcmetals.com

United Cast Bar, Inc.
www.unitedcastbar.com

Viking Forge
www.viking-forge.com

Voestalpine High Performance Metals
www.voestalpine.com

Walker Forge
www.walkerforge.com

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

Willman Industries Inc.
www.willmanind.com

Yarde Metals
www.yarde.com

Yash International
www.yashtools.com

GEAR MACHINES

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

ANCA, Inc.
www.anca.com

Abtex Corp.
www.abtex.com

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

AccuBrass
accubrass.com

Acme Manufacturing Co.
www.acmemfg.com

Advico
www.advico.co.uk

Affolter
www.rotectools.com

Alliance Broach & Tool
www.alliancebroach.com

American Broach & Machine Co.
www.americanbroach.com

Anderson Cook Inc.
www.andersoncook.com

Apex Broaching Systems
www.apexbroach.com

BTS Broaching Tools
www.brostakimsanayi.com.tr

BUDERUS Schleiftechnik GmbH
www.buderus-schleiftechnik.de

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

Blackbox Technologies
www.blackboxtech.in

Bourn & Koch Inc. SEE OUR AD P33
2500 KISHWAUKEE STREET
ROCKFORD IL 61104
Phone: (815) 965-4013
Fax: (815) 965-0019
sales@bourn-koch.com
www.bourn-koch.com

Breton USA
www.bretonusa.com

Broaching Machine Specialties
www.broachingmachine.com

C & B Machinery
www.cbmachinery.com

CNC Center
www.cnccenter.com

Capital Tool Industries
www.capital-tool.com

Chamfermatic Inc.
www.chamfermatic.com

Clemco Industries Corp.
www.clemcoindustries.com

Cleveland Deburring Machine Co.
cdmcmachine.com

Colonial Tool Group
www.colonialtool.com

Comco Inc.
www.comcoinc.com

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

D.C. Morrison Company
www.dcmorrison.com

DMG MORI USA
www.dmgmori-usa.com

DVS Technology America, Inc. SEE OUR AD P3
44099 PLYMOUTH OAKS BLVD.
PLYMOUTH MI 48170
UNITED STATES
Phone: (734) 656-2073
Fax: (734) 656-2091
ralf-georg.eitel@dvs-technology.com
www.dvs-technology.com

DVS Universal Grinding GmbH SEE OUR AD P3
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63128
GERMANY
Phone: +49-6074-30406-81
Fax: +49-6074-30406-55
sabri.akdemir@dvs-universal-grinding.de
www.ugrind.de

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

Dianamic Abrasive Products Inc.
www.dianamic.com

Donner+Pfister AG
www.dpag.ch

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

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

Electronics Inc.
www.electronics-inc.com

Eltro Services, Inc.
www.eltroservices.com

Engineered Abrasives
www.engineeredabrasives.com

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

FFG - Modul
www.star-su.com

Federal Broach & Machine
www.federalbroach.com

Fellows Machine Tools
www.bourn-koch.com

Felsomat USA Inc.
www.felsomat.com

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

Fuji Machine America Corp.
www.fujimachine.com

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

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Fax: (734) 973-3053
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www.gmtamerica.com

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Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
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Gleason Works (India) Private Ltd. SEE OUR AD P13,30
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WHITEFIELD ROAD, MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com

Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

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

Greg Allen Company
www.gallenco.com

HÖFLER - A Brand of KLINGELNBERG
www.hofler.com

HARO Technologies
harotechnologies.com

Haas Multigrind LLC
www.multigrind.com

Hamai Co. Ltd.
www.hamai.com

Hanik Corporation SEE OUR AD P30
201 E. OGDEN AVE., SUITE 34
HINSDALE IL 60521
Phone: (847) 364-4800
Fax: (847) 364-4840
info@hanikcorp.com
www.hanikcorp.com

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

Hartech
www.hartech.com.tw

Havlik International Machinery Inc.
www.havlikinternational.com

Helios Gear Products SEE OUR AD P4,41
635 SCHNEIDER DRIVE
SOUTH ELGIN IL 60177
Phone: (847) 931-4121
Fax: (847) 931-4192
sales@koepferamerica.com
heliosgearproducts.com

Heller Machine Tools
www.heller-machinetools.com

IMPCO Microfinishng
www.impco.com

ITW Heartland SEE OUR AD P23
1205 36TH AVENUE WEST
ALEXANDRIA MN 56308
Phone: (320) 762-0138
Fax: (320) 762-5645
info@itwheartland.com
www.itwheartland.com

Index Corporation
us.index-traub.com

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

International Tool Machines (ITM)
www.itmfl.com

Involute Gear & Machine Company
www.involutegearmachine.com

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

JRM International, Inc
www.jrminternational.com

JX Shot Blasting Machine Manufacturer Co., Ltd.
www.jxabrasives.com

James Engineering
www.james-engineering.com

Kapp Technologies SEE OUR AD P11,18,32,51
2870 WILDERNESS PLACE
BOULDER CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

Kinefac Corporation
www.kinefac.com

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

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SALINE MI 48176
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Fax: (734) 316-2158
kla.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

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

Lambda Technologies
www.lambdatechs.com

Leistritz Advanced Technology Corp.
www.leistritzcorp.com

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Fax: (734) 429-2294
info.lgt@liebherr.com
www.liebherr.com

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GERMANY
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Fax: +(49) 831-7861279
info.lvt@liebherr.com
www.liebherr.com

Machine Tool Builders SEE OUR AD P21
7723 BURDEN ROAD
MACHESNEY PARK IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
KCWarren@MachineToolBuilders.com
www.machinetoolbuilders.com

Matrix Precision Co. Ltd.
www.matrix-machine.tw

Mazak Corporation
www.mazakusa.com

Meccanica Nova Corporation
www.novagrinders.com

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

Miller Broach
www.millerbroach.com

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

Mutschler Edge Technologies
mutschleredgetech.com

Nachi America Inc. SEE OUR AD P15,19
715 PUSHVILLE ROAD
GREENWOOD IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

Nagel Precision
www.nagelusa.com

Normac, Inc.
www.normac.com

ORT Italia
www.ortitalia.com

Ohio Broach & Machine Co.
www.ohiobroach.com

Okuma America Corporation
www.okuma.com

PITTLER T&S GmbH SEE OUR AD P3
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63128
GERMANY
Phone: +49-6074-4873-0
Fax: +49-6074-4873-291
christian.rhiel@pittler.de
www.pittler.de

PRAEWEMA Antriebstechnik GmbH SEE OUR AD P3
HESSENRING 4
ESCHWEGE HESSEN 37269
GERMANY
Phone: +49-5651-8008-0
Fax: +49-5651-12546
vertrieb@praewema.de
praewema.dvs-gruppe.com

PTG Holroyd
www.holroyd.com

Parker Industries Inc.
www.parkerind.com

Penta Gear Metrology LLC SEE OUR AD P18,32,51
6161 WEBSTER STREET
DAYTON OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com

Phoenix Inc.
www.phoenix-inc.com

Pioneer Broach Co.
www.pioneerbroach.com

PlasmaRoute CNC
www.cncplasmacutterinc.com

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
INDUSTRIESTRASSE 36
CH-8304 WALLISELLEN
SWITZERLAND
Phone: +(41) 44-832-22-11
Fax: +(41) 44-832-23-90
info@reishauer.com
www.reishauer.com
SEE OUR AD P27

Reishauer Corporation
1525 HOLMES ROAD
ELGIN IL 60123
Phone: (847) 888-3828
Fax: (847) 888-0343
usa@reishauer.com
www.reishauer.com
SEE OUR AD P27

Rotec Tools Ltd.
www.rotectools.com

Rotek Incorporated
www.rotek-inc.com

Russell Holbrook & Henderson
www.tru-volute.com

SETCO Precision Spindles
www.setcousa.com

SINTO AMERICA
www.sintoamerica.com

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

Saacke North America, LLC
saacke-pforzheim.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
SEE OUR AD INSIDE FRONT COVER,1,32

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
SEE OUR AD INSIDE FRONT COVER,1,32

Star SU LLC Star Cutter Co.
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,1,32

Steelmans Broaches Pvt. Ltd.
www.steelmans.com

Sunnen Products Company
www.sunnen.com

Surface Finishing Equipment Co.
www.sfecindia.net

Surplex GmbH
www.surplex.com

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

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

Toolink Engineering
www.toolink-eng.com

Ty Miles, Inc.
www.tymiles.com

U.S. Equipment
www.usequipment.com

Ultramatic Equipment Co.
ultramatic-equipment.com

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

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

WardJet
www.wardjet.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Wheelabrator
www.wheelabratorgroup.com

Willrich Precision Instrument Company
willrich.com

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

Yieh Chen Machinery
www.yiehchen.com

GRINDING WHEELS & ABRASIVE TOOLS

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

2L Inc.
www.2Linc.com

3M Abrasives
www.3m.com/Abrasives

Abtex Corp.
www.abtex.com

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

AccuBrass
accubrass.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.
POST BOX NO. 2272
TIROVOTTIYUR
CHENNAI - 600019 TAMIL NADU
INDIA
Phone: +(91) 44 3924 9000
Fax: +(91) 44 3924 9045
sales_abrasives@cumi.murugappa.com
www.cumiabrasives.com
SEE OUR AD P37

Cleveland Deburring Machine Co.
cdmcmachine.com

Comco Inc.
www.comcoinc.com

Continental Diamond Tool Corporation
www.cdtusa.net

DTR Corp. (formerly Dragon Precision Tools)
1865A HICKS ROAD
ROLLING MEADOWS IL 60008
Phone: (847) 375-8892
Fax: (224) 220-1311
alex@dragon.co.kr
www.dragon.co.kr
SEE OUR AD P20

DVS Technology America, Inc.
44099 PLYMOUTH OAKS BLVD.
PLYMOUTH MI 48170
UNITED STATES
Phone: (734) 656-2073
Fax: (734) 656-2091
ralf-georg.eitel@dvs-technology.com
www.dvs-technology.com
SEE OUR AD P3

DVS Tooling GmbH
BREDDESTR. 5A
HEMER NORDRHEIN-WESTFALEN 58675
GERMANY
Phone: +49-2372-55250-0
Fax: +49-2372-55250-11
info@dvs-tooling.de
www.dvs-tooling.de
SEE OUR AD P3

Diametal AG
www.diametal.ch

Diamond Abrasive Products
www.diamondabrasiveproducts.com

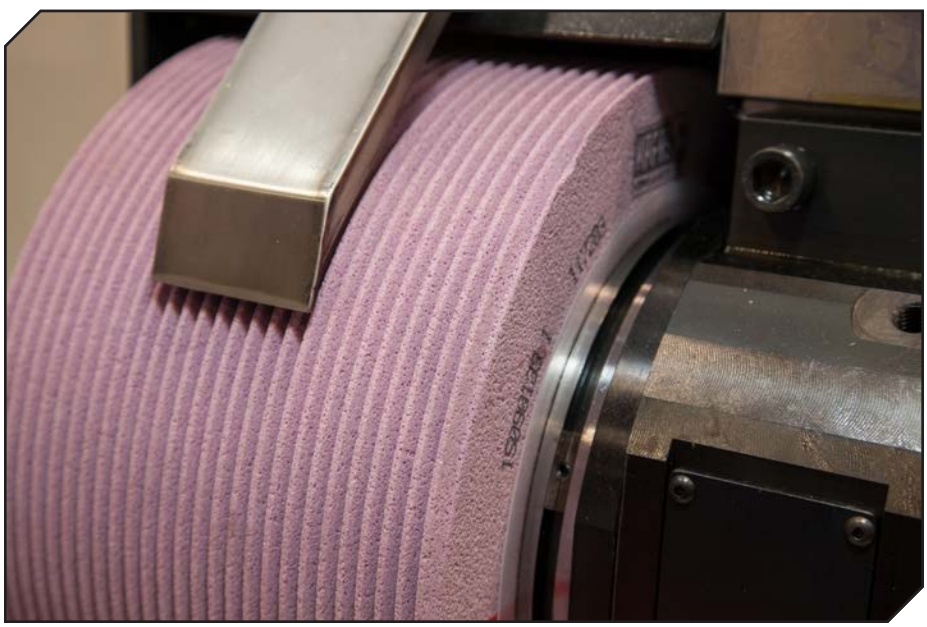
Dianamic Abrasive Products Inc.
www.dianamic.com

Dr. Kaiser Diamantwerkzeuge
www.drkaiser.de

ESGI Tools Pvt. Ltd.
esgitools.com

FFG - Modul
www.star-su.com

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 P13,30

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 P13,30

Gleason-Hurth Tooling GmbH
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com
SEE OUR AD P13,30

Graff Diamond Products
www.graffdiamond.com

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

Greg Allen Company
www.gallenco.com

GritSablare
gritsablare.ro

Helios Gear Products
635 SCHNEIDER DRIVE
SOUTH ELGIN IL 60177
Phone: (847) 931-4121
Fax: (847) 931-4192
sales@koepferamerica.com
heliosgearproducts.com
SEE OUR AD P4,41

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

JX Shot Blasting Machine Manufacturer Co., Ltd.
www.jxabrasives.com

Kapp Technologies
2870 WILDERNESS PLACE
BOULDER CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com
SEE OUR AD P11,18,32,51

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

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

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

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

Lambda Technologies
www.lambdatechs.com

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

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

Marposs Corporation
www.marposs.com

Matrix Precision Co. Ltd.
www.matrix-machine.tw

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

Modern Gearing
www.moderngearing.com

Mutschler Edge Technologies
mutschleredgetech.com

NAXOS-DISKUS Schleifmittelwerke GmbH
WERNER-VON-SIEMENS-STR. 1
BUTZBACH HESSEN 35510
GERMANY
Phone: +49-6033-899-0
Fax: +49-6033-899-300
info@naxos-diskus.de
www.naxos-diskus.de
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Nagel Precision
www.nagelusa.com

Norton | Saint-Gobain
www.nortonabrasives.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
INDUSTRIESTRASSE 36
CH-8304 WALLISELLEN
SWITZERLAND
Phone: +(41) 44-832-22-11
Fax: +(41) 44-832-23-90
info@reishauer.com
www.reishauer.com
SEE OUR AD P27

Reishauer Corporation
1525 HOLMES ROAD
ELGIN IL 60123
Phone: (847) 888-3828
Fax: (847) 888-0343
usa@reishauer.com
www.reishauer.com
SEE OUR AD P27

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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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
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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

Stella Keramik GmbH
www.stella-gruppe.de

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

Sunnen Products Company
www.sunnen.com

Toolink Engineering
www.toolink-eng.com

Ultramatic Equipment Co.
ultramatic-equipment.com

Vargus USA
www.vargususa.com

Weldon Solutions
www.weldonsolutions.com

Yash International
www.yashtools.com

HEAT TREATING EQUIPMENT & SUPPLIES

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

A&A Coatings
www.thermalspray.com

AFC-Holcroft
www.afc-holcroft.com

Abbott Furnace Company
www.abbottfurnace.com

Advanced Nitriding Solutions
www.ans-ion.net

Ajax Tocco Magnethermic
1745 OVERLAND AVE NE
WARREN OH 44483
Phone: 330-372-8511
Fax: 330-372-8608
sales@ajaxtocco.com
www.ajaxtocco.com
SEE OUR AD P38,47

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 Härtetechnik GmbH
www.stopoffpaints.com

DFC Tank Pressure Vessel Manufacturer Co., Ltd
www.dfctank.com

Davron Technologies
www.davrontech.com

Duffy Company, The
www.duffycompany.com

ECM USA
9505 72ND AVE. SUITE 400
PLEASANT PRAIRIE WI 53158
Phone: (262) 605-4810
info@ecm-usa.com
www.ecm-usa.com
SEE OUR AD P47

EFD Induction Inc.
www.efdinduction-usa.com

EMAG eldec Induction GmbH
www.eldec.net

East Coast Induction
www.eastcoastind.com

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

ElectroHeat Induction
www.electroheatinduction.com

Eltro Services, Inc.
www.eltroservices.com

Euclid Heat Treating
www.euclidheattreating.com

FPM Heat Treating
www.fpmht.com

Flame Treating Systems, Inc.
www.flametreatingsystems.com

Fredericks Company - Televac
www.frederickscompany.com

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

GH Induction Atmospheres
www.gh-ia.com

Gasbarre
www.gasbarre.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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Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Grieve Corporation, The
www.grievecorp.com

Heavy Carbon Co., LLC
www.heavycarbon.com

Houghton International
www.houghtonintl.com

IHI Ionbond Inc.
ionbond.com

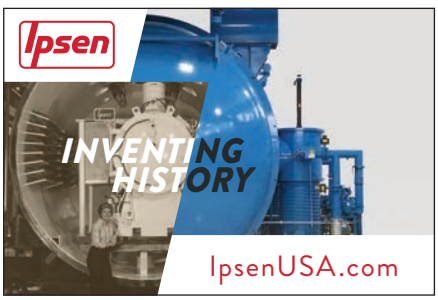
Induction Tooling, Inc.
www.inductiontooling.com

Inductoheat Inc.
inductoheat.com

Inductotherm Corp.
www.inductotherm.com

Infrared Heating Technologies
www.infraredheating.com

Ionitech Ltd.
www.ionitech.com



Ipsen, Inc.
984 IPSEN ROAD
CHERRY VALLEY IL 61016
Phone: (800) 727-7625
Fax: (815) 332-4549
sales@ipsenusa.com
www.USA.com
SEE OUR AD INSIDE BACK COVER,47

Khemka Broach & Spline Gauge
www.khemkabroach.com

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

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

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
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PhoenixTM
www.phoenixtm.com

Pillar Induction
www.pillar.com

Plus Furnace
www.plusfurnace.com

Preco Inc.
www.precoinc.com

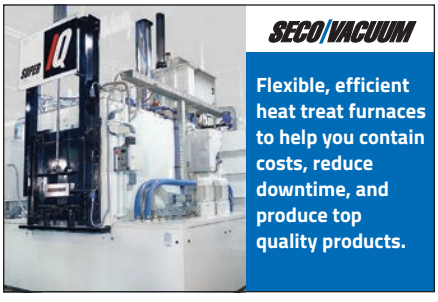
Premier Furnace Specialists Inc.
www.premierfurnace.com

Pro-Beam USA
www.pro-beam.com

Pyromaitre
www.pyromaitre.com

Radyne Corporation
www.radyne.com

Rubig US, Inc.
www.rubig.com



SECO/Vacuum Technologies LLC
180 MERCER STREET, STE. 100
MEADVILLE PA 16335
Phone: 814-332-8520
Fax: 814-724-1407
Mark.Hemsath@SecoVacUSA.com
www.secovacusa.com
SEE OUR AD P47

SINTO AMERICA
www.sintoamerica.com

SMS Elotherm North America
us.sms-elotherm.com/en/

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

Seco/Warwick Allied Pvt. Ltd.
www.secowarwick.com

Seco/Warwick Corp.
www.secowarwick.com

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

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

Solar Manufacturing SEE OUR AD P48
1983 CLEARVIEW ROAD
SOUDERTON PA 18964
Phone: (267) 384-5040
Fax: (267) 384-5060
info@solarmfg.com
www.solarmfg.com

Stack Metallurgical Services, Inc.
www.stackmet.com

Surface Combustion
www.surfacecombustion.com

TM Induction Heating
www.tminductionheating.com

Wickert USA
www.wickert-usa.com

ZRIME
www.zrime.com.cn

Zion Industries
www.zioninduction.com

HEAT TREATING SERVICES

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

300 Below, Inc.
www.300below.com

ALD Thermal Treatment, Inc.
www.heat-treatment-services.com

Accurate Steel Treating, Inc.
www.accuratesteeltreating.com

Advanced Heat Treat Corp.
www.ahtcorp.com

Advanced Nitriding Solutions
www.ans-ion.net

Ajax Tocco Magnethermic SEE OUR AD P38,47
1745 OVERLAND AVE NE
WARREN OH 44483
Phone: 330-372-8511
Fax: 330-372-8608
sales@ajaxtocco.com
www.ajaxtocco.com

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

Duffy Company, The
www.duffycompany.com

ECM USA SEE OUR AD P47
9505 72ND AVE. SUITE 400
PLEASANT PRAIRIE WI 53158
Phone: (262) 605-4810
info@ecm-usa.com
www.ecm-usa.com

EFD Induction Inc.
www.efdinduction-usa.com

ERS Engineering Corp.
www.ersengine.com

Eagle Tool Company Inc.
www.eaglebroach.com

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

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

ElectroHeat Induction
www.electroheatinduction.com

Eltro Services, Inc.
www.eltroservices.com

Engineered Heat Treat, Inc.
www.ehtinc.com

Erasteel Inc.
www.erasteel.com

Euclid Heat Treating
www.euclidheattreating.com

FPM Heat Treating
www.fpmht.com

Felsomat USA Inc.
www.felsomat.com

Flame Metals Processing Corporation
www.flamemetals.com

Flame Treating Systems, Inc.
www.flametreatingsystems.com

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

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

General Surface Hardening Inc.
www.gshinc.net

Gleason Corporation SEE OUR AD P13,30
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com

Härterei Reese Bochum GmbH
www.hardening.com

Heat Treating Services Corporation of America
www.htsmi.com

Hi TecMetal Group
www.htg.cc

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

Hudapack Metal Treating
www.hudapack.com

IHI Ionbond Inc.
ionbond.com

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

Induction Hardening Specialists
inductionhardeningspecialists.com

Induction Services, Inc.
www.inductionservicesinc.com

Induction Tooling, Inc.
www.inductiontooling.com

Inductoheat Inc.
inductoheat.com

Industrial Hard Carbon LLC
industrialhardcarbon.com

Industrial Metal Finishing, Inc.
www.indmetfin.com

Infrared Heating Technologies
www.infraredheating.com

Ionic Technologies Inc.
www.ionic-tech.com

Ionitech Ltd.
www.ionitech.com

Irwin Automation Inc.
www.irwinautomation.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

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

Klingelnberg GmbH
PETERSTRASSE 45
HUECKESWAGEN 42499
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
SEE OUR AD P15,19

National Heat Treat
nationalheattreat.com

Nisha Engineers (India)
www.nishagroup.com

Nitrex Inc. - Chicago Operations
www.nitrex.com

Nitrex Inc. - Indiana Operations
www.nitrex.com

Nitrex Inc. - Michigan Operations
www.nitrex.com

Nitrex Inc. - Nevada Operations
www.nitrex.com

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

Nitrex Metal Inc.
www.nitrex.com

Oerlikon Balzers - PPD Division
www.oerlikon.com

Ohio Vertical Heat Treat
www.ov-ht.com

Ovako AB
www.ovako.com

Paulo
www.paulo.com

Penna Flame Industries
www.pennaflame.com

Penticton Foundry Ltd.
www.pentictonfoundry.com

Peters Heat Treating
www.petersheattreat.com

Pillar Induction
www.pillar.com

Precision Finishing Inc.
www.precisionfinishinginc.com

Precision Heat Treating Co.
www.precisionheat.net

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

Preco Inc.
www.precoinc.com

Pro-Beam USA
www.pro-beam.com

Rex Heat Treat
www.rexht.com

Rockford Heat Treaters
www.rockfordheattreaters.com

Rotek Incorporated
www.rotek-inc.com

Rubig US, Inc.
www.rubig.com

SMS Elotherm North America
us.sms-elotherm.com/en/

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

SWD Inc.
www.swdinc.com

Sedlock Companies
www.sedlockcompanies.com

Solar Atmospheres
1969 CLEARVIEW ROAD
SOUDERTON PA 18964
Phone: 855-934-3284
Fax: (215) 723-6460
info@solaratm.com
www.solaratm.com
SEE OUR AD P29,49

Somers Forge
www.somersforge.com

Specialty Steel Treating Inc.
www.sst.net

Spectrum Thermal Processing
www.spectrumtp.com

Stack Metallurgical Services, Inc.
www.stackmet.com

Sun Steel Treating Inc.
www.sunsteeltreating.com

Super Systems Inc.
www.supersystems.com

Thermetco Inc.
www.thermetco.com

Thermex Metal Treating Ltd.
www.thermexmetal.com

Thermtech
www.thermtech.net

TimkenSteel Corporation
www.timkensteel.com

Titanium Coating Services Inc.
www.pvdamerica.com

Treat All Metals, Inc.
www.treatallmetals.com

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

VaporKote, Inc.
www.vaporkote.com

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

Wickert USA
www.wickert-usa.com

Willman Industries Inc.
www.willmanind.com

ZRIME
www.zrime.com.cn

Zion Industries
www.zioninduction.com

INSPECTION EQUIPMENT

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

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

AB Dynamics
www.abd.uk.com

ABTech Inc.
www.abtechmfg.com

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

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

Advico
www.advico.co.uk

Ajax Tool Supply
www.ajaxtoolsupply.com

Aksan Steel Forging
www.aksanforging.com

Alliance Broach & Tool
www.alliancebroach.com

American Stress Technologies, Inc.
www.astresstech.com

Andec Mfg. Ltd.
www.andec.ca

Ash Gear & Supply
www.ashgear.com

Avalon International Corporation
www.avalongateway.com

Becker GearMeisters, Inc.
www.maagmachines.com

Blackbox Technologies
www.blackboxtech.in

Borescopes-R-Us
www.borescopesrus.com

Bourn & Koch Inc. SEE OUR AD P33
2500 KISHWAUKEE STREET
ROCKFORD IL 61104
Phone: (815) 965-4013
Fax: (815) 965-0019
sales@bourn-koch.com
www.bourn-koch.com

Broach Masters / Universal Gear Co.
www.broachmasters.com

Buehler - An ITW Company
www.buehler.com

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

CNC Center
www.cnccenter.com

Capital Tool Industries
www.capital-tool.com

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

Celanese
www.celanese.com

Certified Comparator Products (CCP)
www.certifiedcomparator.com

Comtorgage Corporation
www.comtorgage.com

Dino-Lite
www.dinolite.us

Donner+Pfister AG
www.dpag.ch

Drewco Workholding
www.drewco.com

Dyer Company
dyergage.com

Emuge Corp.
www.emuge.com

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

Euro-Tech Corporation
www.eurotechcorp.com

FARO Technologies, Inc.
www.faro.com

FHUSA-TSA
www.fhusa-tsa.com

FPM Heat Treating
www.fpmht.com

Flexbar Machine Corporation
www.flexbar.com

Foerster Instruments Incorporated
foerstergroup.com

Fredericks Company - Televac
www.frederickscompany.com

Frenco GmbH
www.frenco.de

Fuji Machine America Corp.
www.fujimachine.com

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

Gage Assembly Company
www.gageassembly.com

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

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

Gleason Metrology Systems SEE OUR AD P13,30
300 PROGRESS ROAD
DAYTON OH 45449
Phone: (937) 859-8273
Fax: (937) 859-4452
gleason-metrology@gleason.com
www.gleason.com

Gleason Works (India) Private Ltd. SEE OUR AD P13,30
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

Gleason-Hurth Tooling GmbH SEE OUR AD P13,30
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com

Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

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

Greg Allen Company
www.gallenco.com

HITEC Sensor Developments
www.hitecorp.com

HVH Industrial Solutions
hvhindustrial.com

Hanik Corporation SEE OUR AD P30
201 E. OGDEN AVE., SUITE 34
HINSDALE IL 60521
Phone: (847) 364-4800
Fax: (847) 364-4840
info@hanikcorp.com
www.hanikcorp.com

Hansford Sensors
www.hansfordsensors.com/us/

Helios Gear Products SEE OUR AD P4,41
635 SCHNEIDER DRIVE
SOUTH ELGIN IL 60177
Phone: (847) 931-4121
Fax: (847) 931-4192
sales@koepferamerica.com
heliosgearproducts.com

Hexagon Metrology
www.hexagonmetrology.us

HobSource Inc. SEE OUR AD P37
834 E. RAND ROAD, SUITE 2
MOUNT PROSPECT IL 60056
Phone: (847) 398-8320
Fax: (847) 398-8326
sales@hobsource.com
www.hobsource.com

Hydra-Lock Corporation
www.hydralock.com

ITW Heartland SEE OUR AD P23
1205 36TH AVENUE WEST
ALEXANDRIA MN 56308
Phone: (320) 762-0138
Fax: (320) 762-5645
info@itwheartland.com
www.itwheartland.com

Innovative Analytical Solutions
www.steelanalyzer.com

Interstate Tool Corp.
itctoolcorp.com

Involute Gear & Machine Company
www.involutegearmachine.com

Kapp Technologies SEE OUR AD P11,18,32,51
2870 WILDERNESS PLACE
BOULDER CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

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

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

LDB Corporation
ldbcorp.com

Lambda Technologies
www.lambdatechs.com

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

MRO Electric and Supply
www.mroelectric.com

Magnetic Inspection Laboratory
www.milinc.com

Maheen Enterprises
www.maheenbroaches.com

Mahr Inc.
www.mahr.com

Marposs Corporation
www.marposs.com

Miller Broach
www.millerbroach.com

Mitutoyo America Corporation
www.mitutoyo.com

The Modal Shop
www.modalshop.com

Modern Gearing
www.moderngearing.com

Mutschler Edge Technologies
mutschleredgetech.com

Nachi America Inc. SEE OUR AD P15,19
715 PUSHVILLE ROAD
GREENWOOD IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

Newage Testing Instruments
www.hardnesstesters.com

Ono Sokki Technology, Inc.
www.onosokki.net

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

PCE Instruments
www.pce-instruments.com/english

Parker Industries Inc.
www.parkerind.com

Penta Gear Metrology LLC
SEE OUR AD P18,32,51
6161 WEBSTER STREET
DAYTON OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com

Phase II
www.phase2plus.com

Pinpoint Laser Systems
pinpointlaser.com

Pioneer Broach Co.
www.pioneerbroach.com

PlasmaRoute CNC
www.cncplasmacutterinc.com

Precision Devices, Inc.
www.predev.com

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

Prime Technologies
www.gear-testers.com

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

Promess Inc.
www.promessinc.com

Proto Manufacturing
SEE OUR AD P31
12350 UNIVERSAL DRIVE
TAYLOR MICHIGAN 48180
Phone: 1 (313) 965-2900
Fax: 1 (734) 946-0974
info@protoxrd.com
www.protoxrd.com

Quality Solutions
www.qs-hardnesstester.com

Quality Vision Services (QVS)
www.qvsi.com

RAM Optical Instrumentation, Inc.
www.ramoptical.com

Radix Technology Solutions
aistechgroup.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 Eletherm North America
us.sms-elotherm.com/en/

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
SEE OUR AD INSIDE FRONT COVER,1,32
sales@star-su.com
www.samputensili.com

Schnyder SA
SEE OUR AD P30
JAKOBSTRASSE 52
CH-2504 BIEL
SWITZERLAND
Phone: +(41)(32) 344-0406
Fax: +(41)(32) 344-0404
george.boon@schnyder.com
www.schnyder.com

Sensor Products Inc.
www.sensorprod.com

SerWeMa GmbH & Co. KG
www.serwema.de

Slone Gear International, Inc.
www.slonegear.com

Spline Gage Solutions
splinegagesolutions.com

Star Cutter Co.
23461 INDUSTRIAL PARK DRIVE
FARMINGTON HILLS MI 48335
Phone: (847) 649-1450
Fax: (847) 649-0112
SEE OUR AD INSIDE FRONT COVER,1,32
sales@starcutter.com
www.starcutter.com

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

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

Stotz Gaging Co.
www.stotz-usa.com

Stresstech Oy
www.stresstech.com

Sunnen Products Company
www.sunnen.com

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

Surplex GmbH
www.surplex.com

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

Techcellence
www.broachindia.com

TechnoMax Inc.
www.technomax-j.com

The L.S. Starrett Co.
www.starrett.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 Tool Supply
SEE OUR AD P38
851 OHIO PIKE
CINCINNATI OH 45245
Phone: (513) 752-6000
Fax: (513) 752-5599
info@united-tool.com
www.united-tool.com

View Micro-Metrology
www.viewmm.com

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

Wenzel America
www.wenzelamerica.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Westport Gage
www.westportcorp.com

Willrich Precision Instrument Company
willrich.com

Zoller Inc.
www.zoller-usa.com

LUBRICANTS

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

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

Aarna Lube Private Ltd.
www.aarnalube.com

Aerospace Lubricants, Inc.
www.aerospacelubricants.com

American Chemical Technologies, Inc.
www.americanchemtech.com

American Refining Group, Inc.
www.amref.com

Avalon International Corporation
www.avalongateway.com

BASF
www.basf.com/lubes

BFK Solutions LLC
bfksolutions.com

Blaser Swisslube Inc.
www.blaser.com

Bodycote Thermal Processing - Melrose Park
www.bodycote.com

Brighton Laboratories
www.brightonlabs.com

Byington Steel Treating
www.byingtonsteel.com

Carborundum Universal Ltd.
SEE OUR AD P37
POST BOX NO. 2272
TIROVOTTIYUR
CHENNAI - 600019 TAMIL NADU
INDIA
Phone: +(91) 44 3924 9000
Fax: +(91) 44 3924 9045
sales_abrasives@cumi.murugappa.com
www.cumiabrasives.com

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

Chemtool Inc.
www.chemtool.com

Cimcool Fluid Technology
www.cimcool.com

Cortec Corporation
www.cortecvci.com

Daubert Cromwell
www.daubertcromwell.com

Des-Case Corporation
descase.com

Dillon Chuck Jaws
SEE OUR AD P34,60
2115 PROGRESS DRIVE
SPRINGFIELD OH 45505
Phone: (800) 428-1133
Fax: (800) 634-6480
sales4@dillonmfg.com
www.dillonmfg.com

Etna Products, Inc.
www.etna.com

ExxonMobil Oil Corp.
www.mobilindustrial.com

Fuchs Lubricants Company
www.fuchs.com

General Magnaplate
www.magnaplate.com

HVH Industrial Solutions
hvhindustrial.com

Hangsterfer's Laboratories
www.hangsterfers.com

Hoffmann Filter Corporation
www.hoffmannfilter.com

Houghton International
www.houghtonintl.com

Hydrotex
www.hydrotexlube.com

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

Isel Inc.
www.iselinc.com

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

Lubegard / International Lubricants Inc.
www.lubegard.com

Lubrication Engineers
www.lelubricants.com

Lubriplate Lubricants Co. SEE OUR AD P67
129 LOCKWOOD STREET
NEWARK NJ 07105
Phone: (973) 589-4432
Fax: (800) 347-5329
www.lubriplate.com

ML Lubrication Inc.
www.ml-lubrication.com

Microsurface Corporation
www.ws2coating.com

Moncktons Machine Tools, LLC
www.mmtproductivity.com

Motultech
www.motul.com

Nye Lubricants
www.nyelubricants.com

Particular Technology, Inc.
www.particulartechnology.com

Petro Lubes Inc.
www.petrolubesinc.com

PetroChoice
www.PetroChoice.com

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

Productivity Inc.
www.productivity.com

RedLine Tools
www.redlinetools.com

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

SWD Inc.
www.swdinc.com

Shell Lubricants
www.shellus.com

Summit Industrial Products
www.klsummit.com

Sunnen Products Company
www.sunnen.com

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

Tecsia Lubricants USA
www.tecsialube.com

Texas Refinery Corp.
www.texasrefinery.com

TheLubricantStore.com
www.thelubricantstore.com

United Tool Supply Ltd.
www.unitedtoolsupply.com

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

Whitmore
whitmores.com

oelheld U.S., Inc. SEE OUR AD P34
1100 WESEMANN DRIVE
WEST DUNDEE IL 60118
Phone: (847) 531-8501
Fax: (847) 531-8511
hutec-us@oelheld.com
www.oelheld.com

MACHINE TOOLS

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

2L Inc.
www.2Linc.com

A&A Coatings
www.thermalspray.com

ADF Systems Ltd.
www.adfsys.com

ANCA, Inc.
www.anca.com

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

AccuBrass
accubrass.com

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

Acme Manufacturing Co.
www.acmemfg.com

Advico
www.advico.co.uk

Aksan Steel Forging
www.aksanforging.com

Alliance Broach & Tool
www.alliancebroach.com

Almco Finishing & Cleaning Systems
www.almco.com

American Broach & Machine Co.
www.americanbroach.com

Ampere Metal Finishing
www.amperemetal.com

Andec Mfg. Ltd.
www.andec.ca

Arbortech Corporation
www.arbortech.com

Asolutica LLC SEE OUR AD P34
12609 MONTE CASTILLO PARKWAY
AUSTIN TX 78732
www.asolutica.com

BFK Solutions LLC
bfksolutions.com

BTS Broaching Tools
www.brostakimsanayi.com.tr

BUDERUS Schleiftechnik GmbH
www.buderus-schleiftechnik.de

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

Blackbox Technologies
www.blackboxtech.in

Bohle Machine Tools, Inc.
www.bmtbohle.com

Bourn & Koch Inc. SEE OUR AD P33
2500 KISHWAUKEE STREET
ROCKFORD IL 61104
Phone: (815) 965-4013
Fax: (815) 965-0019
sales@bourn-koch.com
www.bourn-koch.com

Breton USA
www.bretonusa.com

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
www.capital-tool.com

Carborundum Universal Ltd. SEE OUR AD P37
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TIROVOTTIYUR
CHENNAI - 600019 TAMIL NADU
INDIA
Phone: +(91) 44 3924 9000
Fax: +(91) 44 3924 9045
sales_abrasives@cumi.murugappa.com
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

DFC Tank Pressure Vessel Manufacturer Co., Ltd
www.dfctank.com

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GERMANY
Phone: +49-6074-48402-0
Fax: +49-6074-48402-36
vertrieb@diskus-werke.de
www.diskus-werke.de

DMG MORI USA
www.dmgmori-usa.com

DVS Technology America, Inc. SEE OUR AD P3
44099 PLYMOUTH OAKS BLVD.
PLYMOUTH MI 48170
UNITED STATES
Phone: (734) 656-2073
Fax: (734) 656-2091
ralf-georg.eitel@dvs-technology.com
www.dvs-technology.com

DVS Universal Grinding GmbH SEE OUR AD P3
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63128
GERMANY
Phone: +49-6074-30406-81
Fax: +49-6074-30406-55
sabri.akdemir@dvs-universal-grinding.de
www.ugrind.de

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

Daubert Cromwell
www.daubertcromwell.com

Des-Case Corporation
descase.com

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

Duffy Company, The
www.duffycompany.com

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

Eagle PLC
www.eagleplc.com

ElectroHeat Induction
www.electroheatinduction.com

Eltro Services, Inc.
www.eltroservices.com

Engineered Abrasives
www.engineeredabrasives.com

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

Euro-Tech Corporation
www.eurotechcorp.com

FPM Heat Treating
www.fpmht.com

Felsomat USA Inc.
www.felsomat.com

Firbimatic Metal Cleaning Division
www.metalcleaning-firbimatic.com

Flexbar Machine Corporation
www.flexbar.com

Foerster Instruments Incorporated
foerstergroup.com

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

Fuji Machine America Corp.
www.fujimachine.com

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

GH Induction Atmospheres
www.gh-ia.com

GMN USA LLC
www.gmnusa.com

Galomb Inc.
www.injectionmolder.net

Gehring L.P.
www.gehring.de

General Broach Company
www.generalbroach.com

General Magnaplate
www.magnaplate.com

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www.gleason.com

GoHz Inc.
www.gohz.com

Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

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

Guardair Corporation
www.guardair.com

HARO Technologies
harotechnologies.com

HPI Processes, Inc.
www.hpipro.com

Haas Multigrind LLC
www.multigrind.com

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

Hardinge Inc.
www.hardinge.com

Havlik International Machinery Inc.
www.havlikinternational.com

Heiko Machine Tools
www.heikomachine.com

Heller Machine Tools
www.heller-machinetools.com

Hines Industries
www.hinesindustries.com

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

Hoffmann Filter Corporation
www.hoffmannfilter.com

Hy-Pro Filtration
www.hyprofiltration.com

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

IHI Ionbond Inc.
ionbond.com

IMPCO Microfinishng
www.impco.com

Index Corporation
us.index-traub.com

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

Industrial Hard Carbon LLC
industrialhardcarbon.com

Inovatec Machinery
www.inovatecmachinery.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
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CH-8050 ZURICH
SWITZERLAND
Phone: +(41) 44-2787979
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info@klingelnberg.com
www.klingelnberg.com

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

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www.klingelnberg.com

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

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

Kwikmark Inc.
www.kwikmark.com

Lafert North America
www.lafertna.com

Lambda Technologies
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Laser Tools Co.
www.lasertoolsco.com

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GERMANY
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Fax: +(49) 831-7861279
info.lvt@liebherr.com
www.liebherr.com

Longevity Coatings
www.longevitycoatings.com

MRO Electric and Supply
www.mroelectric.com

Machine Tool Builders
SEE OUR AD P21
7723 BURDEN ROAD
MACHESNEY PARK IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
KCWarren@MachineToolBuilders.com
www.machinetoolbuilders.com

Machine Tool Solutions, Inc.
machtoolinc.com

Matrix Precision Co. Ltd.
www.matrix-machine.tw

Mazak Corporation
www.mazakusa.com

Meccanica Nova Corporation
www.novagrinders.com

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

Metallurgical High Vacuum Corp.
www.methivac.com

Metallurgical Processing, Inc.
www.mpimetaltreating.com

Methods Machine Tools Inc.
www.methodsmachine.com

Miller Broach
www.millerbroach.com

Mitsubishi Heavy Industries America
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WIXOM MI 48393
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Fax: (248) 669-0614
brenda_motzell@mhiahq.com
www.mitsubishigearcenter.com

Modern Gearing
www.moderngearing.com

Moncktons Machine Tools, LLC
www.mmtproductivity.com

Mutschler Edge Technologies
mutschleredgetech.com

NTC America Corporation
www.ntcmc.com

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

National Heat Treat
nationalheattreat.com

Normac, Inc.
www.normac.com

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

Ohio Broach & Machine Co.
www.ohiobroach.com

Okuma America Corporation
www.okuma.com

PITTLER T&S GmbH
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Penna Flame Industries
www.pennaflame.com

Penta Gear Metrology LLC
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mnicholson@pentagear.com
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Permanent Steel Manufacturing Co.,Ltd
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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

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

Russell Holbrook & Henderson
www.tru-volute.com

SCHUNK
www.schunk.com

SETCO Precision Spindles
www.setcousa.com

SINTO AMERICA
www.sintoamerica.com

SMS Elotherm North America
us.sms-elotherm.com/en/

SWD Inc.
www.swdinc.com

Samputensili S.p.A.
STAR SU LLC
5200 PRAIRIE STONE PARKWAY
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Fax: (847) 649-0112
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SerWeMa GmbH & Co. KG
www.serwema.de

Slater Tools Inc.
www.slatertools.com

Slone Gear International, Inc.
www.slonegear.com

Solid Metalworking INC. Limited
www.atcarbide.com

Somers Forge
www.somersforge.com

Star Cutter Co.
23461 INDUSTRIAL PARK DRIVE
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Stotz Gaging Co.
www.stotz-usa.com

Sunnen Products Company
www.sunnen.com

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

Surplex GmbH
www.surplex.com

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

Titanium Coating Services Inc.
www.pvdamerica.com

Toolink Engineering
www.toolink-eng.com

Toolmex Corporation - Lathe group
www.toolmexlathes.com

Toshiba Machine Co.
www.toshiba-machine.com

Tribo Surface Engineering LLC
www.tribosurfaceengineering.com

Ty Miles, Inc.
www.tymiles.com

U.S. Equipment
www.usequipment.com

Ultramatic Equipment Co.
ultramatic-equipment.com

Ultrasonic LLC
www.ultrasonicllc.com

United Grinding
grinding.com

VaporKote, Inc.
www.vaporkote.com

Venture Mfg. Co.
www.venturemfgco.com

View Micro-Metrology
www.viewmm.com

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

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

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

WardJet
www.wardjet.com

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

Weldon Solutions
www.weldonsolutions.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Westfalia Technologies
www.westfaliausa.com

Wheelabrator
www.wheelabratorgroup.com

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

Yaskawa Motoman
www.motoman.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.com
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RESOURCES

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

AGMA - American Gear Manufacturers Association
www.agma.org

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

ASM International
www.asminternational.org

American Bearing Manufacturers Association
www.americanbearings.org

American Wind Energy Association
www.awea.org

BUDERUS Schleiftechnik GmbH
www.buderus-schleiftechnik.de

Balanstar Corp
www.balanstar.com

Banyan Global Technologies LLC
www.banyangt.com

CTI - Car Training Institute
cti.euroforum.de/en

DVS Technology America, Inc.
44099 PLYMOUTH OAKS BLVD.
PLYMOUTH MI 48170
UNITED STATES
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www.dvs-technology.com
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BREDDESTR. 5A
HEMER NORDRHEIN-WESTFALEN 58675
GERMANY
Phone: +49-2372-55250-0
Fax: +49-2372-55250-11
info@dvs-tooling.de
www.dvs-tooling.de
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Drive Systems Technology, Inc.
www.gear-doc.com

EES KISSsoft GmbH
www.ees-kisssoft.ch

FVA GmbH
www.fva-service.de

FZG
www.fzg.mw.tum.de

Forging Industry Association
www.forging.org

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

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P.O. BOX 22970
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Guardair Corporation
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sales@koepferamerica.com
heliosgearproducts.com
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The Herring Group Inc.
www.heat-treat-doctor.com

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Fax: 0041 (0)55 254 20 71
info@KISSsoft.ag
www.KISSsoft.ag
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BOULDER CO 80301
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Fax: (303) 447-1131
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Lubrication Engineers
www.lelubricants.com

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

Noria Corporation
www.noria.com

PITTLER T&S GmbH
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Fax: +49-6074-4873-291
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Fax: +49-5651-12546
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www.geartechnology.com

Thors, LLC
www.thors.com

VDI
www.vdi.de

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

West Michigan Spline, Inc.
www.westmichiganspline.com

SERVICES

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

2 Channel Transmission
PO BOX 1645
RENTON WA 98057
sixal@mindspring.com
www.2channeltransmission.com
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A&A Coatings
www.thermalspray.com

AB Dynamics
www.abd.uk.com

ATS - Advanced Technology Services
www.advancedtech.com

Acedes Gear Tools
www.acedes.co.uk

Advanced Coating Technologies
www.actechnol.com

Advanced Heat Treat Corp.
www.ahtcorp.com

Airflow Sciences Corporation
www.airflowsciences.com

Aksan Steel Forging
www.aksanforging.com

American Broach & Machine Co.
www.americanbroach.com

Ampere Metal Finishing
www.amperemetal.com

Andec Mfg. Ltd.
www.andec.ca

Apex Broaching Systems
www.apexbroach.com

Artemis Vision
artemisvision.com

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

BTS Broaching Tools
www.brostakimsanayi.com.tr

Balanstar Corp
www.balanstar.com

Banyan Global Technologies LLC
www.banyangt.com

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

Bates Technologies, LLC
www.batestech.com

Becker GearMeisters, Inc.
www.maagmachines.com

Best Technology Inc.
www.besttechnologyinc.com

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

Blackbox Technologies
www.blackboxtech.in

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
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Broach Masters / Universal Gear Co.
www.broachmasters.com

Broaching Technologies, LLC
keyway-spline-broaching.com

Bruce Cox Engineering Corporation
www.bcoxengineering.com

Buehler - An ITW Company
www.buehler.com

C & B Machinery
www.cbmachinery.com

CNC Center
www.cnccenter.com

CNC Design Pty Ltd
www.cncdesign.com

Capital Tool Industries
www.capital-tool.com

Carbide Tool Services, Inc.
www.carbidetool.com

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

Cincinnati Gearing Systems Inc. SEE OUR AD P16,56
5757 MARIEMONT AVE
CINCINNATI OH 45227
Phone: 5135278600
Fax: 5135278635
gearsales@cst-c.com
www.cincinnatigearingsystems.com

Curtiss-Wright Surface Technologies
www.cwst.com

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44099 PLYMOUTH OAKS BLVD.
PLYMOUTH MI 48170
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Daubert Cromwell
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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

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
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GWJ Technology GmbH
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Gehring L.P.
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General Magnaplate
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Fax: (815) 877-0264
gctc@gleason.com
www.gleason.com

Gleason Metrology Systems SEE OUR AD P13,30
300 PROGRESS ROAD
DAYTON OH 45449
Phone: (937) 859-8273
Fax: (937) 859-4452
gleason-metrology@gleason.com
www.gleason.com

Gleason Works (India) Private Ltd. SEE OUR AD P13,30
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WHITEFIELD ROAD, MAHADEVAPURA
BANGALORE 560 048
INDIA
Phone: 011-91-80-2850-4376/15/16/91
www.gleason.com

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Great Lakes Gear Technologies, Inc.
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Greg Allen Company
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Grindal Company
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Hansford Sensors
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www.heat-treat-doctor.com

HobSource Inc. SEE OUR AD P37
834 E. RAND ROAD, SUITE 2
MOUNT PROSPECT IL 60056
Phone: (847) 398-8320
Fax: (847) 398-8326
sales@hobsource.com
www.hobsource.com

Hydrotex
www.hydrotexlube.com

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

IHI Ionbond Inc.
ionbond.com

IMPCO Microfinishng
www.impco.com

Index Technologies Inc. SEE OUR AD P36
5755 CANAL ROAD
VALLEY VIEW OHIO 44125
Phone: 216 642 5900
Fax: 216 642 8837
galllen@gallenco.com
www.indextechnologiesinc.com

Industrial Hard Carbon LLC
industrialhardcarbon.com

Industrial Metal Finishing, Inc.
www.indmetfin.com

Innovative Analytical Solutions
www.steelanalyzer.com

Involute Gear & Machine Company
www.involutegearmachine.com

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

Jesse Garant Metrology Center
jgarantmc.com

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

Kapp Technologies SEE OUR AD P11,18,32,51
2870 WILDERNESS PLACE
BOULDER CO 80301
Phone: (303) 447-1130
Fax: (303) 447-1131
info-USA@kapp-niles.com
www.kapp-niles.com

Kinematics Manufacturing, Inc.
www.kinematicsmfg.com

Kingsford Broach & Tool Inc.
www.kingsfordbroach.com

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

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

Longevity Coatings
www.longevitycoatings.com

MATsolutions
www.matsolutions.com

MESYS AG
www.mesys.ag

MRO Electric and Supply
www.mroelectric.com

MTI Systems, Inc.
www.mtisystems.com

Machine Tool Builders SEE OUR AD P21
7723 BURDEN ROAD
MACHESNEY PARK IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
KCWarren@MachineToolBuilders.com
www.machinetoolbuilders.com

Machine Tool Solutions, Inc.
machtoolinc.com

Magnetic Inspection Laboratory
www.milinc.com

Maguire Technologies
www.maguiretech.com

Mahr Inc.
www.mahr.com

Masternet Ltd.
www.masternetltd.com

Matrix Precision Co. Ltd.
www.matrix-machine.tw

Metallized Carbon Corporation
www.metcar.com

Metallurgical Processing, Inc.
www.mpimetaltreating.com

Micro Surface Corp.
www.microsurfacecorp.com

MicroTek Finishing
mmptechnology.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
www.mmus.com

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

PITTLER T&S GmbH
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63128
GERMANY
Phone: +49-6074-4873-0
Fax: +49-6074-4873-291
christian.rhiel@pittler.de
www.pittler.de
SEE OUR AD P3

PRAEWEMA Antriebstechnik GmbH
HESSENRING 4
ESCHWEGE HESSEN 37269
GERMANY
Phone: +49-5651-8008-0
Fax: +49-5651-12546
vertrieb@praewema.de
praewema.dvs-gruppe.com
SEE OUR AD P3

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 MICHIGAN 48180
Phone: 1 (313) 965-2900
Fax: 1 (734) 946-0974
info@protoxrd.com
www.protoxrd.com
SEE OUR AD P31

Quality Reducer Service, Inc
www.qualityreducer.com

REM Surface Engineering
www.remchem.com

Rewitec GmbH
www.rewitec.com

Riley Gear Corporation
www.rileygear.com

Riverside Spline & Gear
www.splineandgear.com

Romax Technology
www.romaxtech.com

SMT
www.smartmt.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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Sandvik Coromant
www.sandvik.coromant.com

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

Sedlock Companies
www.sedlockcompanies.com

Shenzhen Gearshine Precision Machine Co. Ltd.
www.gearshine.com

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

Six Star
www.sixstar.com.tw

Slone Gear International, Inc.
www.slonegear.com

Somers Forge
www.somersforge.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,1,32

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
www.stresstech.com

Surface Finishing Equipment Co.
www.sfecindia.net

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
851 OHIO PIKE
CINCINNATI OH 45245
Phone: (513) 752-6000
Fax: (513) 752-5599
info@united-tool.com
www.united-tool.com
SEE OUR AD P38

United Tool Supply Ltd.
www.unitedtoolsupply.com

VFA Engineering Group
failure-analysis-durability.com

VaporKote, Inc.
www.vaporkote.com

Victrex Gear Solutions
www.victrex.com/en/gears

Viking Equipment Finance
www.vikingequipmentfinance.com/manufacturing/

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

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

Work Out Ind. Com. Imp. e Exp. de Maq. ltda
www.workout.com.br/index-en

SOFTWARE

All of the suppliers listed here are broken down by category (custom software, gear design software, shop management software, etc.) at *www.geartechnology.com*.

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

AB Dynamics
www.abd.uk.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

Artis Division of Marposs
www.artis.de

Ash Gear & Supply
www.ashgear.com

Blackbox Technologies
www.blackboxtech.in

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 P33

Broach Masters / Universal Gear Co.
www.broachmasters.com

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
SEE OUR AD P59
ROTTERDAM HOUSE
116 QUAYSIDE
NEWCASTLE-UPON-TYNE NE1 3DY
ENGLAND
Phone: +(44) 191-206-4021
Fax: +(44) 191-206-4001
namerica@dontynesystems.com
www.dontynesystems.com

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

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

EES KISSsoft GmbH
www.ees-kisssoft.ch

ESI ITI GmbH
www.simulationx.com

Eltro Services, Inc.
www.eltroservices.com

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

Estudio Piña
www.estudiopina.com

Euklid CAD/CAM AG
www.euklid-cadcam.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
www.gwj.de

Gleason Corporation
SEE OUR AD P13,30
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com

Gleason Metrology Systems
SEE OUR AD P13,30
300 PROGRESS ROAD
DAYTON OH 45449
Phone: (937) 859-8273
Fax: (937) 859-4452
gleason-metrology@gleason.com
www.gleason.com

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
SEE OUR AD P30
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

KISSsoft/Gleason
SEE OUR AD P30
2167 US HIGHWAY 45 NORTH
EAGLE RIVER WI 54521
Phone: (715) 477-0828
Fax: (866) 623-7269
info@KISSsoft.com
www.kisssoft.com

Khemka Broach & Spline Gauge
www.khemkabroach.com

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

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

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

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

MESYS AG
www.mesys.ag

MSC Software Corp.
www.mscsoftware.com

MTI Systems, Inc.
www.mtisystems.com

Machine Tool Builders
SEE OUR AD P21
7723 BURDEN ROAD
MACHESNEY PARK IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
KCWarren@MachineToolBuilders.com
www.machinetoolbuilders.com

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
SEE OUR AD P18,32,51
6161 WEBSTER STREET
DAYTON OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com

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
www.smartmt.com

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

SerWeMa GmbH & Co. KG
www.serwema.de

Slone Gear International, Inc.
www.slonegear.com

Stotz Gaging Co.
www.stotz-usa.com

Stresstech Oy
www.stresstech.com

Super Systems Inc.
www.supersystems.com

Techcellence
www.broachindia.com

Thermo-Calc Software Inc.
www.thermocalc.com

Universal Technical Systems, Inc.
www.uts.com

WardJet
www.wardjet.com

Waterloo Manufacturing Software
www.waterloo-software.com

Web Gear Services Ltd.
www.webgearservices.com

Wenzel America
www.wenzelamerica.com

Yash International
www.yashtools.com

Zontec
www.zontec-spc.com

USED MACHINERY

All of the suppliers listed here are broken down by category (auctioneers, used machiner dealers, etc.) at *www.geartechnology.com.*

Advico
www.advico.co.uk

Ajax Tocco Magnethermic
SEE OUR AD P38,47
1745 OVERLAND AVE NE
WARREN OH 44483
Phone: 330-372-8511
Fax: 330-372-8608
sales@ajaxtocco.com
www.ajaxtocco.com

Apex Auctions Inc.
www.apexauctions.com

Blackbox Technologies
www.blackboxtech.in

CBI Industrial Asset Management bv
www.cbiworld.com

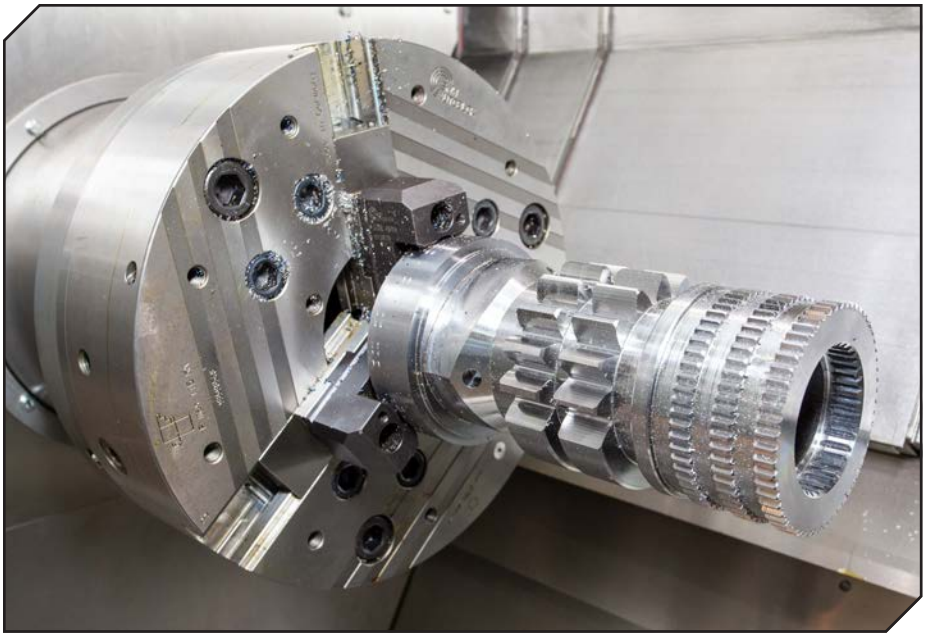
Cincinnati Industrial Auctioneers
www.cia-auction.com

Corporate Assets Inc.
www.corpassets.com

Dixitech CNC
www.dixitechcnc.com

Fairfield Auctions
www.lotsurf.com

Gear Machinery Exchange
www.gearmachineryexchange.com



Gibbs Machinery Company
www.gibbsmachinery.com

GoIndustry DoveBid
www.go-dove.com

Goldstein Gear Machinery LLC
www.goldsteingearmachinery.com

Gray Machinery Company
www.graymachinery.com

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

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

Hilco Industrial
www.hilcoind.com

Koster Industries
kosterindustries.com

MATsolutions
www.matsolutions.com

Mohawk Machinery Inc.
www.mohawkmachinery.com

PPL Group
www.pplauction.com

Prestige Equipment
www.prestigeequipment.com

U.S. Equipment
www.usequipment.com

Used Machinery Sales LLC
www.cnctool.com

West Michigan Spline, Inc.
www.westmichiganspline.com

WORKHOLDING & TOOLHOLDING

All of the suppliers listed here are broken down by category (arbors, chucks, mandrels, modular fixtures, etc.) at *www.geartechnology.com.*

2L Inc.
www.2Linc.com

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

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

Acme Manufacturing Co.
www.acmemfg.com

Acme Wire Products
www.acmewire.com

American Broach & Machine Co.
www.americanbroach.com

Andec Mfg. Ltd.
www.andec.ca

Apex Broaching Systems
www.apexbroach.com

Ash Gear & Supply
www.ashgear.com

Balanstar Corp
www.balanstar.com

Banyan Global Technologies LLC
www.banyangt.com

Blackbox Technologies
www.blackboxtech.in

Bourn & Koch Inc. SEE OUR AD P33
2500 KISHWAUKEE STREET
ROCKFORD IL 61104
Phone: (815) 965-4013
Fax: (815) 965-0019
sales@bourn-koch.com
www.bourn-koch.com

Broach Masters / Universal Gear Co.
www.broachmasters.com

Chevin Tools Inc.
www.chevintools.com

Cleveland Deburring Machine Co.
cdmcmachine.com

Dillon Chuck Jaws SEE OUR AD P34,60
2115 PROGRESS DRIVE
SPRINGFIELD OH 45505
Phone: (800) 428-1133
Fax: (800) 634-6480
sales4@dillonmfg.com
www.dillonmfg.com

Dinanath
www.dinanathengineering.com

Dr. Kaiser Diamantwerkzeuge
www.drkaiser.de

Drewco Workholding
www.drewco.com

Eagle Tool Company Inc.
www.eaglebroach.com

Emuge Corp.
www.emuge.com

Engineered Tools Corp.
www.engineeredtools.com

Euro-Tech Corporation
www.eurotechcorp.com

Fixtureworks
www.fixtureworks.net

Forkardt
www.forkardt.com

Frenco GmbH
www.frenco.de

Fuji Machine America Corp.
www.fujimachine.com

GMI Group
www.gmigroup.com

Galaxy Sourcing Inc.
www.galaxysourcing.com

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

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

Gleason Corporation SEE OUR AD P13,30
1000 UNIVERSITY AVENUE
P.O. BOX 22970
ROCHESTER NY 14692-2970
Phone: (585) 473-1000
Fax: (585) 461-4348
sales@gleason.com
www.gleason.com

Gleason Metrology Systems SEE OUR AD P13,30
300 PROGRESS ROAD
DAYTON OH 45449
Phone: (937) 859-8273
Fax: (937) 859-4452
gleason-metrology@gleason.com
www.gleason.com

Gleason Works (India) Private Ltd. SEE OUR AD P13,30
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

Gleason-Hurth Tooling GmbH SEE OUR AD P13,30
MOOSACHER STR. 42-46
D-80809 MUENCHEN
GERMANY
Phone: 011-49-89-35401-0
www.gleason.com

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

Greg Allen Company
www.gallenco.com

Guardair Corporation
www.guardair.com

Hainbuch America SEE OUR AD P25
W129 N10980 WASHINGTON DRIVE
GERMANTOWN WI 53022
Phone: (414) 358-9550
Fax: (414) 358-9560
sales@hainbuchamerica.com
www.hainbuchamerica.com

Hardinge Inc.
www.hardinge.com

HobSource Inc. SEE OUR AD P37
834 E. RAND ROAD, SUITE 2
MOUNT PROSPECT IL 60056
Phone: (847) 398-8320
Fax: (847) 398-8326
sales@hobsource.com
www.hobsource.com

Hydra-Lock Corporation
www.hydralock.com

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

Industrial Tools Corporation
www.industrialtoolscorp.com

Interstate Tool Corp.
itctoolcorp.com

Involute Gear & Machine Company
www.involutegearmachine.com

JRM International, Inc
www.jrminternational.com

Kennametal Inc.
www.kennametal.com

Kitagawa - NorthTech Workholding
www.kitagawa.com

Kitagawa Europe
www.kitagawa.global

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

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

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

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

LMC Workholding
www.lmcworkholding.com

Lyndex-Nikken
www.lyndexnikken.com

Machine Tool Builders SEE OUR AD P21
7723 BURDEN ROAD
MACHESNEY PARK IL 61115
Phone: (815) 636-7502
Fax: (815) 636-5912
KCWarren@MachineToolBuilders.com
www.machinetoolbuilders.com

Machine Tool Solutions, Inc.
machtoolinc.com

Maprox
www.rotectools.com

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

Miller Broach
www.millerbroach.com

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

Moncktons Machine Tools, LLC
www.mmtproductivity.com

Nachi America Inc. SEE OUR AD P15,19
715 PUSHVILLE ROAD
GREENWOOD IN 46143
Phone: (317) 530-1001
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

Northfield Precision Instrument Corp.
www.northfield.com

Ohio Broach & Machine Co.
www.ohiobroach.com

P.G. Engineers
www.pgcollets.info

Parker Industries Inc.
www.parkerind.com

Penta Gear Metrology LLC SEE OUR AD P18,32,51
6161 WEBSTER STREET
DAYTON OH 45414
Phone: (937) 660-8182
mnicholson@pentagear.com
www.gearinspection.com

Permanent Steel Manufacturing Co.,Ltd
www.permanentsteel.com

Phase II
www.phase2plus.com

Pinpoint Laser Systems
pinpointlaser.com

Pioneer Broach Co.
www.pioneerbroach.com

Polygon Solutions
www.polygonsolutions.com

Positrol
www.positrol.com

Precision Devices, Inc.
www.predev.com

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

Precision Spindle & Accessories Inc.
www.precisionspindleinc.com

Pro-Beam USA
www.pro-beam.com

Productivity Inc.
www.productivity.com

QC American
www.qcamerican.com

RedLine Tools
www.redlinetools.com

Renishaw Inc.
www.renishaw.com

Reska Spline Products Co.
www.reskasplinegauge.com

Riten Industries, Inc.
www.riten.com

Royal Products
www.royalprod.com

SCHUNK
www.schunk.com

Samchully Machinery Co., Ltd.
www.samchully.com

Slater Tools Inc.
www.slatertools.com

Slone Gear International, Inc.
www.slonegear.com

Speedgrip Chuck
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Reverse Cutter Hand for Face Milling and Face Hobbing: Is a Left-Hand Cutter Required for a Left-Hand Face Mill Part?

Dr. Hermann J. Stadtfeld

(*The following is another chapter from Dr. Hermann J. Stadtfeld's new book, Practical Gear Technology, part of an ongoing series of installments excerpted from the book. Designed for easy understanding and supported with helpful illustrations and graphic material, the e-book can be accessed for free at Gleason.com.*)

Introduction

Bevel and hypoid gear cutting in a single indexing face milling process is preferably conducted with a cutter hand (left-hand cutter vs. right-hand cutter) that matches the spiral direction of the part. For example, a right-hand gear is commonly cut with a right-hand cutter head. The reason is that the cutter head should rotate from toe to heel, which directs the axial cutting force component at the workholding, as shown (Fig. 1, red → axial cutting force component). In other words, if the cutter hand matches the hand of the bevel gear it cuts, then the cutting forces press the part against the workholding, thus securing its correct seating and its firm clamping.

If a manufacturer likes to limit the investment in cutter heads, because the batch sizes are low and pinion and gear cutting is conducted at different times on the same machine, then the cutter hand (of the single cutter which is purchased) should be chosen so that it matches the spiral direction of the ring gear. This decision is especially critical in the case of large-size Formate ring gears. In Formate cutting, the cutting forces are the highest compared to any other process because the blades cut the entire profile as well as the entire face width while they are moving through the slot. For the pinion, which is then cut with the opposite hand cutter, it has to be assured that the clamping is very secure. In addition, the plunge feed rates and the roll rates should be reduced to account for this less-than-optimal condition.

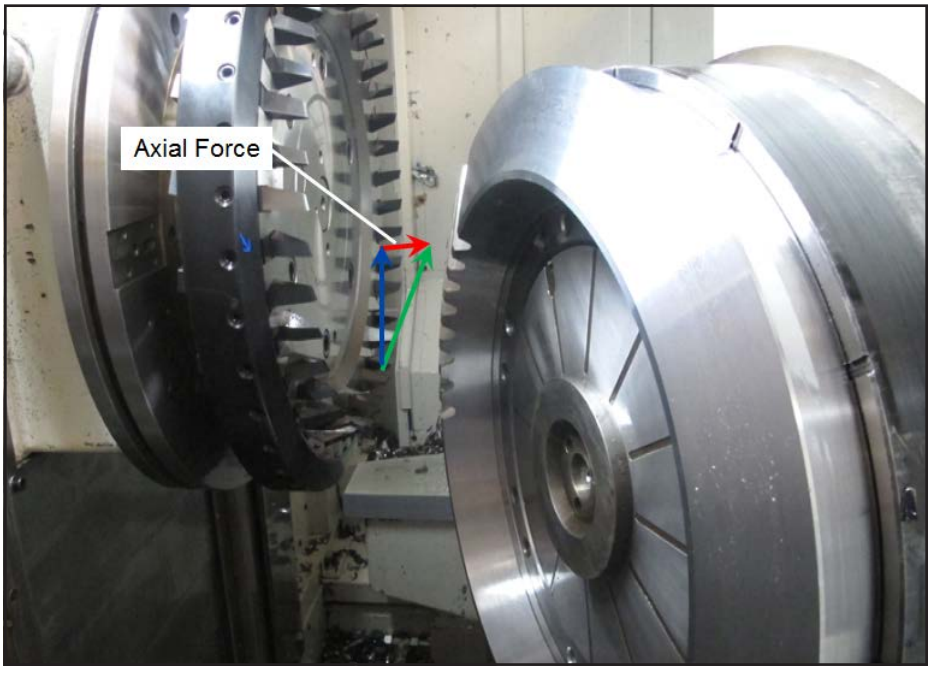

Figure 1 Right-hand gear cut with right-hand cutter.

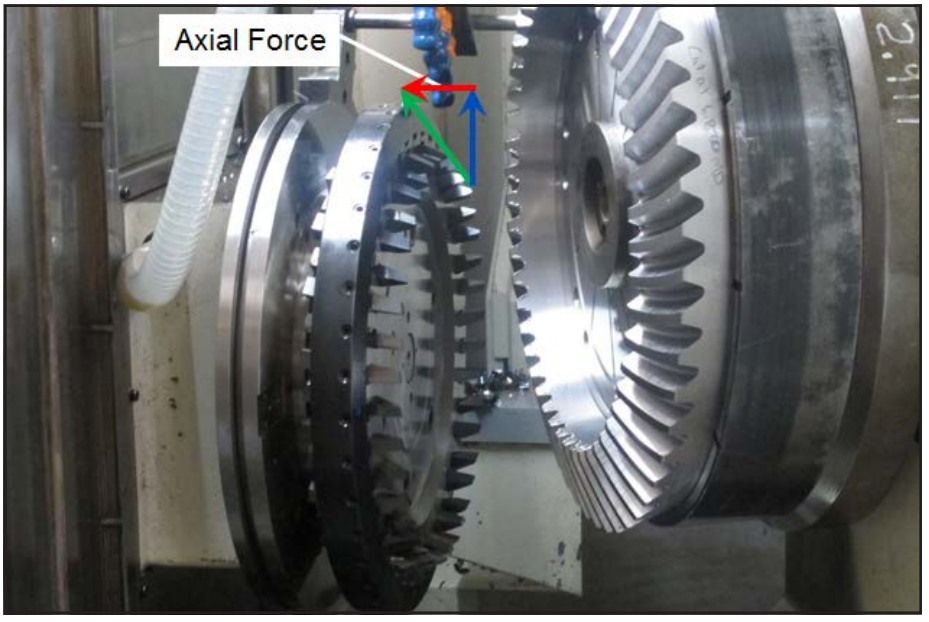

Figure 2 Left-hand gear cut with right-hand cutter.

Ring gears (Figs. 1 and 2) are centered radially by the expander dish spring and axially by the arbor face. The distance between the axial force application point of the expander spring and the outside of the ring gear is generally too great to assure a firm axial seating. In other words, the contact force on the outside of large ring gears diminishes to zero. In order to achieve good axial clamp forces on the outside, all gear arbor face plates are manufactured with a dish angle of, for example, 7 minutes; the dish angle will assure that the first contact is on the outside of the ring gear. While the draw rod pulls the expander disk and the gear back, the contact area on the back seating surface of the ring gear spreads from the outside in.

The arbor dish angle provides a more uniform axial seating, but it should not be underestimated that the distances from the clamping bore surface to the outside of the ring gear can be more than a third of the gear's radius. In particular, the inside flange with holes for the connection of the ring gear to the transmission shaft presents a severe drop of stiffness when compared to the outside ring. This drop of stiffness reduces the contact forces on the outside diameter of the ring gear in some cases to zero — even if the arbor plate has the correct dish angle.

The problem described above is eliminated if the cutter hand and the hand of the ring gear spiral angle match. The red cutting force component in Figure 1 has a significant component that presses the ring gear back, against the arbor plate. This not only creates axial contacting forces, it also generates sufficient friction that will prevent the gear ring from vibrating during the slot cutting; the opposite scenario is shown in Figure 2. The already-critical condition of axial seating contact — particularly in the case of ring gears with an ID connecting flange — now becomes more problematic because the axial cutting force component (red vector in Fig. 2) even pulls the ring away from the arbor plate. The result is a chatter sound during the plunge, which causes shadows and waves along the face width of the teeth.

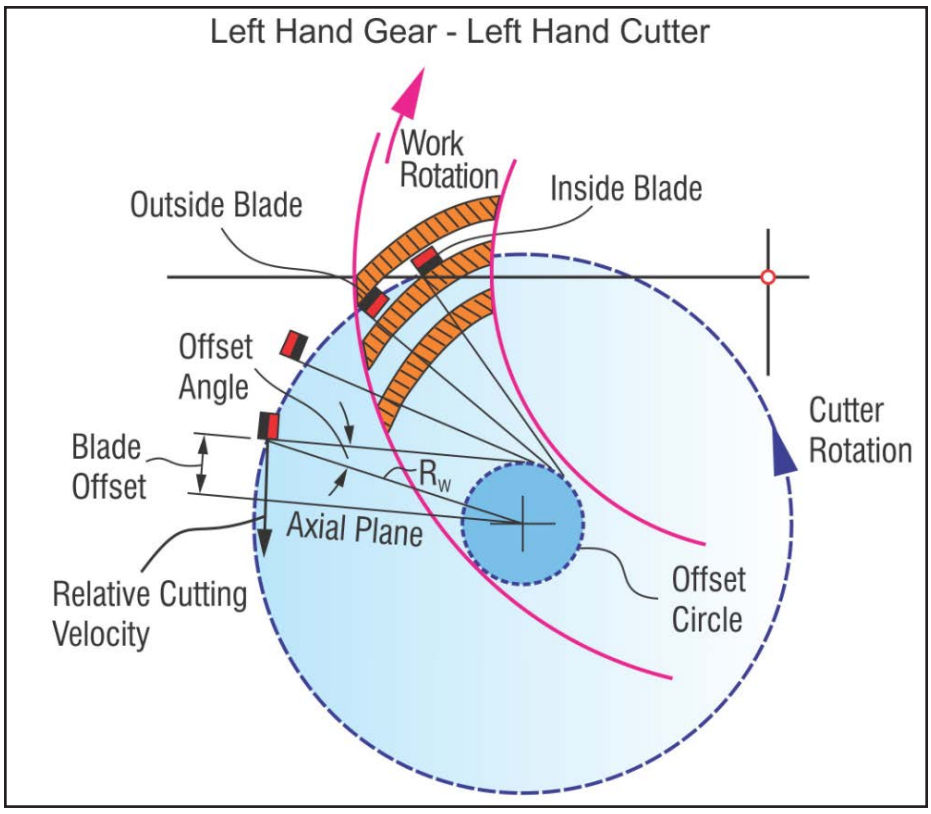

Figure 3 Face hobbing, left-hand gear with left-hand cutter head.

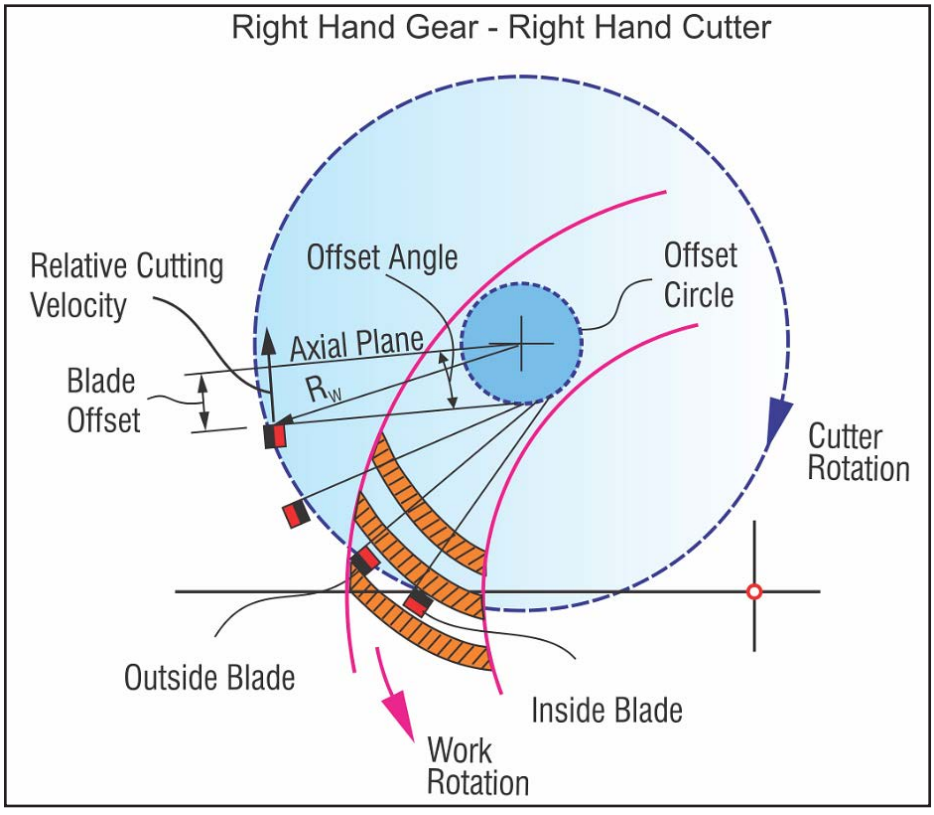

Figure 4 Face hobbing, right-hand gear with right-hand cutter head.

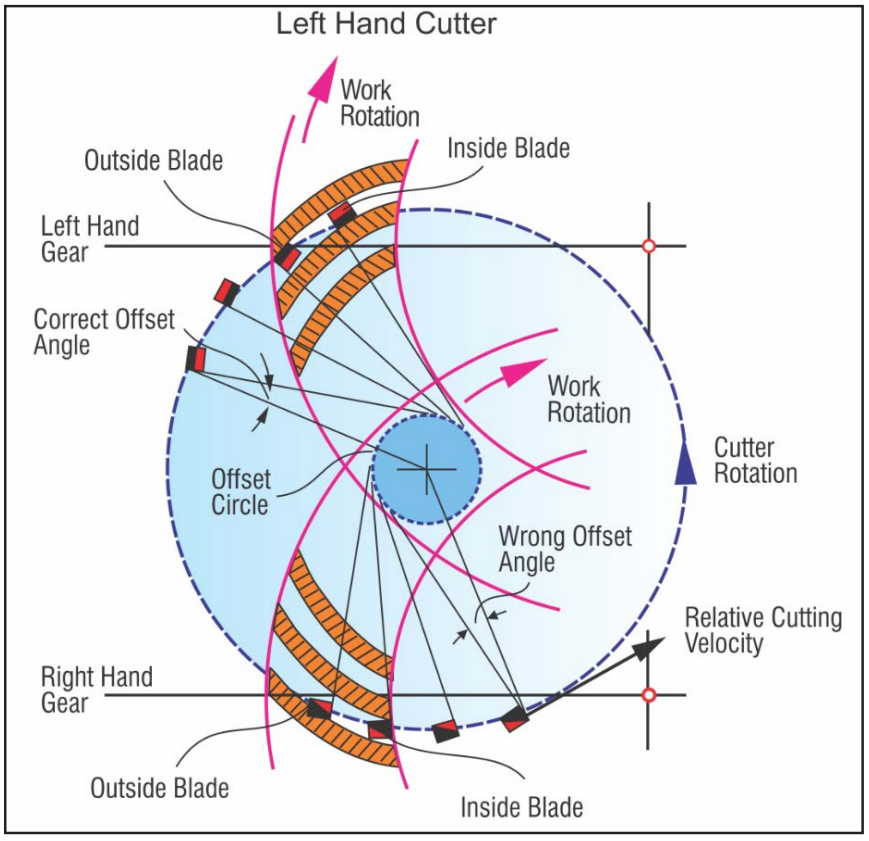

Figure 5 Left-hand cutter with left-hand gear (top) and right-hand gear (bottom).

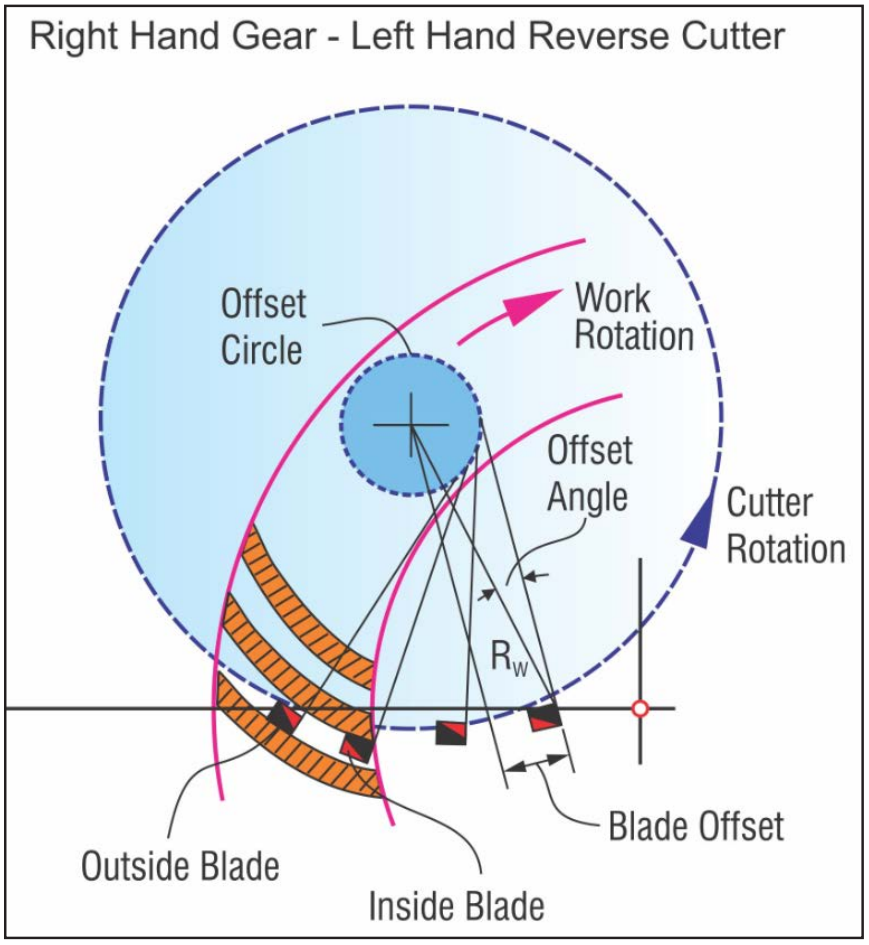

Figure 6 Face hobbing, right-hand gear with left-hand reverse cutter head.

Is a Left-Hand Cutter Required for a Left-Hand Face Hob Part?

In face hobbing, the face width function of the flanks is the result of the cutter radius and the simultaneous rotation of cutter and work. One blade group moves through one slot, while the preceding blade group moves through the following slot. Figure 3 shows the outside blade cuts the slot first, followed by the inside blade. The rotation between outside and inside blade (when passing the same face width position), rotates the work exactly by one half pitch (equally spaced blades). This work rotation, which is connected to the cutter rotation, created the correct slot width.

The case of cutting a right-hand pinion would also require a right-hand cutter. The right-hand cutter shown (Fig. 4) is a mirror image of the cutter in Figure 3. Because the directions of work and cutter rotation change versus Figure 3, also the right-hand pinion is cut from toe to heel with the outside blade cutting the slot first and the inside blade following by 360°/(2.Number of Blade Groups). As can be seen (Figs. 3 and 4), the front of the cutting blades is oriented in the direction of the tangent line to the offset circle; the radius of the offset circle is equal to the blade offset.

The blade offset defines the linear displacement of the cutter head slot front, perpendicular to an axial plane (Fig. 4). If the offset angle δ_w is known, then the blade offset can be calculated with the following relationship:

$$\text{Blade Offset} = \tan(\delta_w) * R_w \quad (1)$$

The offset angle of a cutter head is defined during the cutter head design in order to orient the tangent line (Figs. 3 and 4) perpendicular to the relative cutting velocity direction in face hobbing. The formula for the offset angle in order for a particular job to fulfil this requirement is:

$$\delta_w = arcsin[(z_w * m_n)/(2 * R_w)] \quad (2)$$

Where:

δ_w Off-set angle
z_w Number of blade groups
m_n Normal module
R_w Nominal cutter radius

Relatedly, it should be mentioned here that the offset angle is calculated for a certain average bevel gear design. Because every cutter head has to cover an entire range of job designs, the offset

or offset angle of the cutter head will in most cases deviate from the ideal value of a particular job. For 2-face ground blades, a deviation of 3° is permissible and will not influence the cutting condition too significantly. In the case of 3-face ground blades, the offset angle discrepancy is completely eliminated by the direction of the ground front face (Ref. 1).

It is possible in the face milling process to break the rule cited above and to use a cutter that has the opposite hand than the part; this is often done if a cutter of the same*d* hand as the part is not available. Another process-related reason is in the case of a generated part where the cutting starts at the heel roll position and then rolls to the toe. If this described process uses a cutter head hand that matches the hand of the part, then the process is conventional cutting. If the opposite-hand cutter is used, then the cutter spindle rotation has to be reversed, resulting in a climb cutting process. Some bevel gear manufacturers prefer the climb cutting process for pinions because of an improvement in surface finish. However, it has to be noted that the chip removal from heel to toe (reverse cutter hand) will pull the part away from the workholding, which could lead to flank geometry errors or, in severe cases, to a crash. A crash can happen when the part is pulled out of the workholding by one millimeter or more — which leads to blade breakages.

Another collateral effect of an opposite cutter hand and work spiral direction is the burr, which in this case is not on the heel, but on the toe. If a manufacturer either likes to apply a climb cutting process or prefers the burr to be created on the toe side of the teeth, then the opposite cutter hand can be considered in connection with reduced roll rates.

Is a Different Cutter Hand Possible in Face Hobbing?

In the continuous indexing face hobbing process, in addition to the facts explained in the last section, the blades are arranged in blade groups that adjust the outside blade radius and the following inside blade radius to the indexing rotation of the bevel gear and to the resulting epicyclical flank lead function. Some tricks could be applied to utilize, for example, a left-hand cutter to cut a right-hand bevel gear. Figure 5 shows the change from a left-hand cutter, cutting a left-hand gear (upper half of the graphic) to the same left-hand cutter cutting a right-hand gear (lower half of the graphic). The cutter spindle has to rotate in the opposite direction from that shown in Figure 4, and subsequently the work indexing rotation has to be reversed, versus Figure 4. That's because now that the cutting motion is directed from heel to toe, the inside blade has to cut the slot first, followed by the outside blade; this is solved automatically. The inside blade from one blade group and the outside blade from the following blade group now form one new blade group of the heel-to-toe cutting process (Fig. 5, bottom).

The major problem with this arrangement is the wrong blade offset or offset angle. In order to cut a right-hand gear with an epicyclical flank lead function, the blade offset needs to be in the opposite direction of the cutting motion. As Figure 5 shows, the left-hand cutter cutting a left-hand gear on top (from toe to heel) has a blade offset in the opposite direction from the cutter rotation. The left-hand cutter cutting a right-hand gear at the bottom (from heel to toe) would require a blade offset in cutting direction in order to align the blade with the slot. The inside and outside blade in the slot of the right-hand gear demonstrate very well a severe misalignment between the blade sides and the slot "walls." This misalignment is in the range of 15° to 40°, which only leads to a very exotic blade front face and relief surface appearance. In the case of 2-face ground blades, the inside blade has a side rake angle that could be up to 60°, and the outside blade has an up to 50° negative side rake angle, and therefore cannot remove chips. Although 3-face blade grinding can correct for the side rake angle, the exotic blade appearance with very small cross-sections in the cutting area of the blade makes this a poor-performing cutting tool.

The Reverse Cutter Head

If the offset angles of the blades in the lower section of Figure 5 are reversed, then the cutter from Figure 5 becomes a left-hand reverse cutter that can cut from heel to toe with good performance characteristics. In this case the blades will look like the blades in a regular left-hand cutter and the changed slot offsets make up for the changed cutting conditions. The example of a left-hand reverse cutter head in Figure 6 shows the differences from the standard left-hand cutter in Figure 5.

Left-hand or right-hand reverse cutter heads do not exist for completing stick blade cutters. The older Cyclo-Palloid system from Klingelnberg used left-hand cutter heads for cutting right-hand bevel gears, and vice versa (Ref. 2). When a manufacturer of Cyclo-Palliod gears was asked why Cyclo-Palloid is the only bevel cutting system in the world cutting from heel to toe, he answered: "You wouldn't sharpen a pencil with a knife from the tip to the stem of the pen," Regarding the pencil, this is a good point which might, however, not be applicable to bevel gear cutting. The Cyclo-Palloid system uses a two-part interlocking cutter head that achieves only low chip removal volume per time unit. The fact that the cutting forces try to pull the work away from the workholding might not be too significant for the low cutting forces of the Cyclo-Palloid cutting process. Today, Klingelnberg has also adopted, with their modern processes (like Oerlikon in 1945 with their SKM2 machine), the Gleason method of cutting from toe to heel.

Summary

In short, a left-hand cutter (Fig. 5) can be theoretically used to cut a right-hand pinion or gear if 3-face ground blades are used. In order to realize such a scenario, and generate a correct blade grinding summary with existing software, a number of steps have to be followed. First, the blade offsets in the *SPA* file or in the cutter section of the *UNICAL* file have to be increased so that the offset angle is tripled, versus the original cutter head offset angle (twice the value of offset angle has to be added to the standard left-hand cutter offset angle). While this is done, attention has to be paid to $R_W = [(\text{normal cutter radius})^2 + \text{offset}^2]^{½} = \text{constant}$, because a sole offset value change, would increase R_W. The comparison between the upper and lower part of Figure 5 provides some explanation to the statements in the last sentences.

After the preparation of the basic data files and cutter table data, a 3-face blade

summary is calculated and the blades are ground and built in the left-hand cutter. In many cases this will not be possible, because the blade distance is either close to zero or larger than the blade width. Even if the blade profile still fits on the blade shank, the blades will look very exotic, with strange angles and less-than-optimal cross-sections in any cases using the opposite cutter hand.

On the cutting machine, in order to use existing *MMC* software the basic settings are entered from the standard right-hand part summary, but the hand of the part is entered as "LH" and the signs of all roll positions have to be reversed. In the case of a Formate ring gear, not the roll positions but the "vertical-setting" that has to be entered with a negative sign. The cutting will now take place from heel to toe, with a left-hand cutter cutting a right-hand part with the correct flank geometry.

The photo in Figure 7 shows a left-hand face hobbing cutter head with one blade group with standard blades for cutting a left-hand gear in slots 35 and 36 (outside blade in slot 35). The green arrow points in the velocity direction of the two blades relative to the work gear. Two blades for the opposite-hand work gear cutting have been inserted in slots 32 and 33. In this blade group, the inside blade in slot 32 cuts first, followed by the outside blade in slot 33. The red arrow points in velocity direction of the two blades relative to the work gear.

The velocity directions of the two blade groups differ by about 40°. In order to make this experiment work, the nominal cutter radii had to be reduced in order to fit the blade profiles within the cross-section of the stick blade. This experiment is only of an academic nature because standard software does not support the blade alterations, and the change in cutter radii would not produce the originally intended flank geometry.

The solution for a left-hand face hobbing cutter to the manufacture of a right-hand gear (or vice versa) would require, as mentioned in connection with Figure 6, a specially designed cutter head with the reverse hand.

For more information. Questions or comments regarding this paper? Contact Dr. Stadtfeld at *hstadtfeld@gleason.com.*

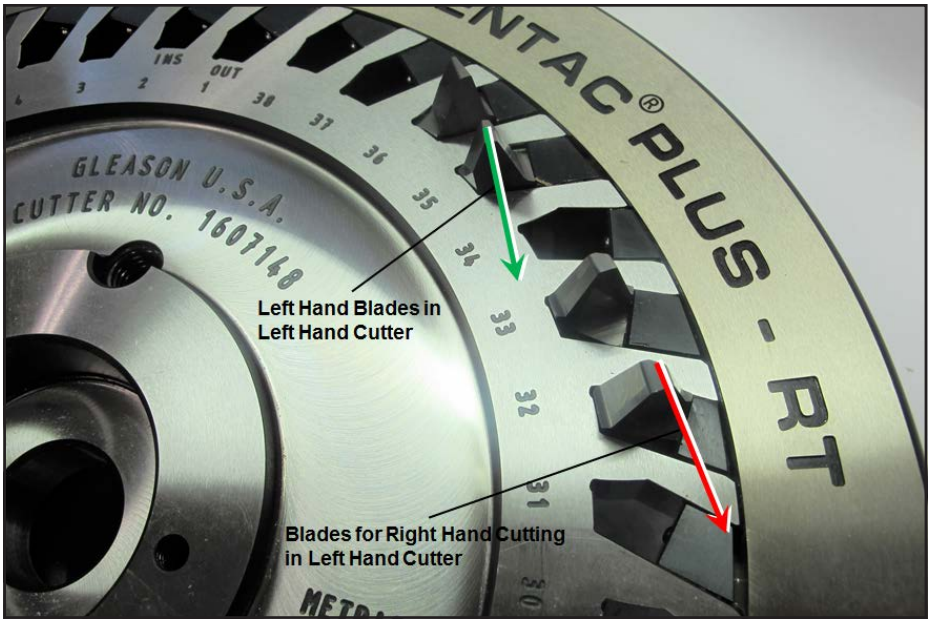

Figure 7 Standard blades for LH cutter and special blades for RH gear.

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Dr. Hermann J. Stadtfeld is the Vice President of Bevel Gear Technology and R&D at the Gleason Corporation and Professor of the Technical University of Ilmenau, Germany. As one of the world's most respected experts in bevel gear technology, he has published more than 300 technical papers and 10 books in this field. Likewise, he has filed international patent applications for more than 60 inventions based upon new gearing systems and gear manufacturing methods, as well as cutting tools and gear manufacturing machines. Under his leadership the world of bevel gear cutting has converted to environmentally friendly, dry machining of gears with significantly increased power density due to non-linear machine motions and new processes. Those developments also lower noise emission level and reduce energy consumption.

For 35 years, Dr. Stadtfeld has had a remarkable career within the field of bevel gear technology. Having received his Ph.D. with summa cum laude in 1987 at the Technical University in Aachen, Germany, he became the Head of Development & Engineering at Oerlikon-Bührle in Switzerland. He held a professor position at the Rochester Institute of Technology in Rochester, New York From 1992 to 1994. In 2000 as Vice President R&D he received in the name of The Gleason Works two Automotive Pace Awards — one for his high-speed dry cutting development and one for the successful development and implementation of the Universal Motion Concept (UMC). The UMC brought the conventional bevel gear geometry and its physical properties to a new level. In 2015, the Rochester Intellectual property Law Association elected Dr. Stadtfeld the "Distinguished Inventor of the Year." Between 2015–2016 CNN featured him as "Tech Hero" on a Website dedicated to technical innovators for his accomplishments regarding environmentally friendly gear manufacturing and technical advancements in gear efficiency.

Stadtfeld continues, along with his senior management position at Gleason Corporation, to mentor and advise graduate level Gleason employees, and he supervises Gleason-sponsored Master Thesis programs as professor of the Technical University of Ilmenau — thus helping to shape and ensure the future of gear technology.

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A Comparative Study of Polymer Gears Made of Five Materials

K. Mao, P. Langlois, N. Madhav, D. Greenwood and M. Millson

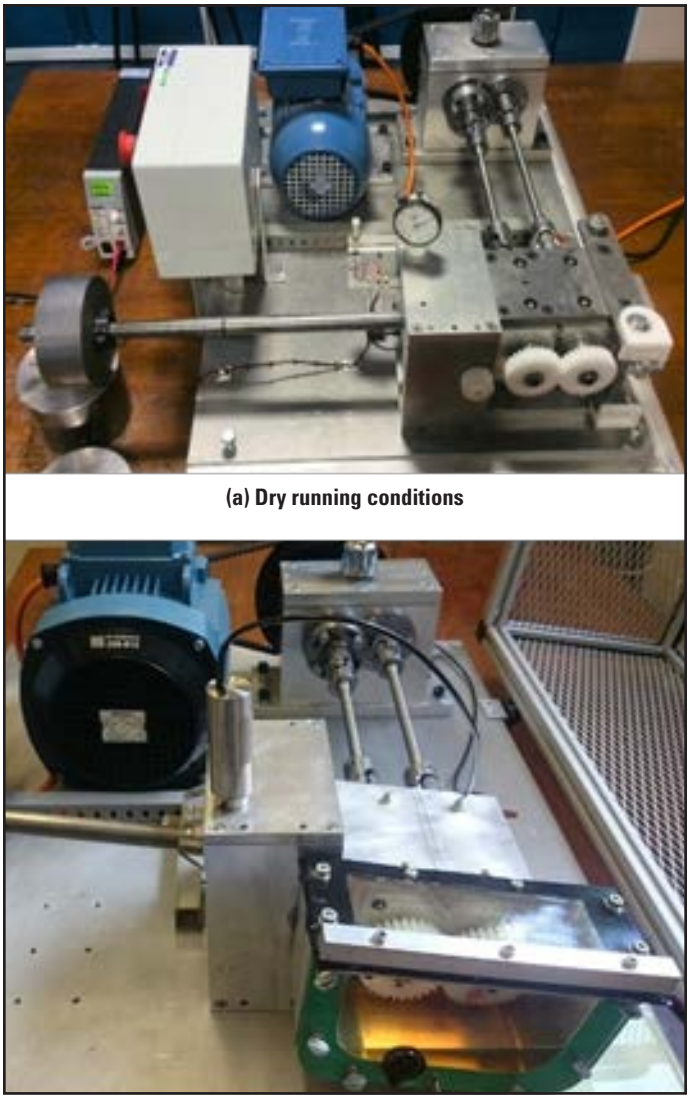
Introduction

Polymer materials have been used for many gear applications due to several advantages over metal gears, including their light weight, good damping resistance and low cost. Polymer gears are currently being designed for applications, from traditional low-power motion transmission to middle- and even high-power transmission — especially within automotive engineering. Currently, there are a few design standards for polymer gear applications (Refs. 1–2) which have been mainly developed by modifying the existing metal gear design methods. However, it may be noted that the design guidance is only available in detail for POM and PA materials. This is a major limitation of the existing design methods, as new polymer materials are becoming available continuously. Furthermore, there is little evidence in the literature showing the validity of the methods, and in some cases poor correlation has been shown between the standards and test results (Refs. 3–4). As a result, the use of polymer gears in higher-power applications is not widely accepted due to the lack of understanding of their performance.

Polymer materials — especially their elasticity and strength — are very sensitive to temperature variations, and one of the main challenges for polymer gear applications is to understand the gear thermo-mechanical contact performance. It has been known that the available design methods for polymer gear performance prediction are still limited with regards to the effects of temperature and that the existing polymer gear surface temperature predictions require much further study regarding their practical applicability. For instance, most of the polymer gear surface temperature estimation methods are based on the approach of Hachman and Strickle (Ref. 5), assuming that polymer gear tooth heat transfer is not significantly affected by lubrication. However, it has also been reported that polymer gear performance has been significantly improved under lubrication conditions (Ref. 6).

Although the typical failure modes in polymer gears (wear, pitting, root and pitch cracks) can also occur in metal gears, the failure mechanisms of polymer gears are much more dominated by the gear temperature. Yousef (Ref. 7) has reported that methods for measuring gear surface temperature after stopping the tests are inaccurate because the gear body temperature drops very rapidly soon after the gears stop running. Letzelter et al (Ref. 8) have reported a non-stop gear temperature measurement approach using an infrared camera with the measurements carried out on PA 6/6 gears. To use the steel's relatively good thermal conductivity, some experimental work has concentrated on meshing polymer gears with steel pinions (Refs. 9–11). Recently, it has also been shown experimentally that the load capacity of carbon fiber-reinforced PEEK gears under high running temperature is much improved to that of PA gears (Refs. 11–14).

As the injection molding techniques for polymer gears have rapidly developed, it is necessary to learn more about the performance of injection-molded gears under different operating conditions. The study of injection-molded polymer gear performance is important due to the significantly lower cost of injection-molded gears when compared to machined gears.



(a) Dry running conditions

(b) Oil lubricated conditions

Figure 1 Two gear test rigs.

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Experimental Test Rig and Gear Specifications

A unique test rig suitable for dry running conditions — with a fixed speed ratio of 1:1 and a center distance of 60 mm — has been employed in this study (Fig. 1a). A similar rig suitable for oil-lubricated conditions is also available at the authors' lab but was not employed here (Fig. 1b). All the tests described in this paper are under dry running conditions. The effect of lubrication is the subject of further, ongoing investigation. The unique capabilities of the rig have been introduced in the authors' previous research (Ref. 15); these include the capability to misalign the gear engagement and to record the gear surface wear continuously with constant load without the requirement to stop the test. A weighted block is used to apply the continuous torque, with the wear rate measured indirectly by recording the linear movement of the weighted block. It is worth noting that a limitation to this set up is that the results from the rig cannot separate the tooth deflections from wear. However, the wear rate obtained has been successfully used to understand and predict the polymer gear load capacity, as described in the authors' previous research (Ref. 15).

Injection molding using five polymer materials has been used to manufacture the gears for this study: PC (polycarbonate); POM (Polyoxymethylene); HDPE (high-density polyethylene); PA (Polyamide, nylon 46); and PEEK (Polyether ether ketone, or PEEK650). The gear center distance has been adjusted to account for the effects of polymer gear shrinkage following injection molding. Measurements were carried out to assess the amount of shrinkage. For the gears having a nominal outside diameter of 64 mm, the following average outside diameters were observed — 63.45 mm for PA; 64.91 mm for PC; 63.70 mm for HDPE; 64.11 mm for PEEK; and 63.52 mm for POM. The material properties of the polymer gears are shown in Table 1 and the nominal geometry of the tested gears is summarized in Table 2.

Table 1 The five material properties

	HDPE	PC	POM	PA46	PEEK650
Specific gravity (g/cm^3)	0.96	1.20	1.42	1.18	1.30
Tensile strength (MPa)	23	66	70	105	155
Flexural modulus (MPa)	900	2400	2900	3300	3600
Coefficient of friction	0.1	0.31	0.21	0.28	0.21
Melting temperature (°C)	131	155	178	295	343

Table 2 Nominal geometry for all gears

Module (mm)	2
Tooth Number	30
Pressure angle	20°
Face width (mm)	17
Thickness (mm)	3.14
Contact ratio	1.67

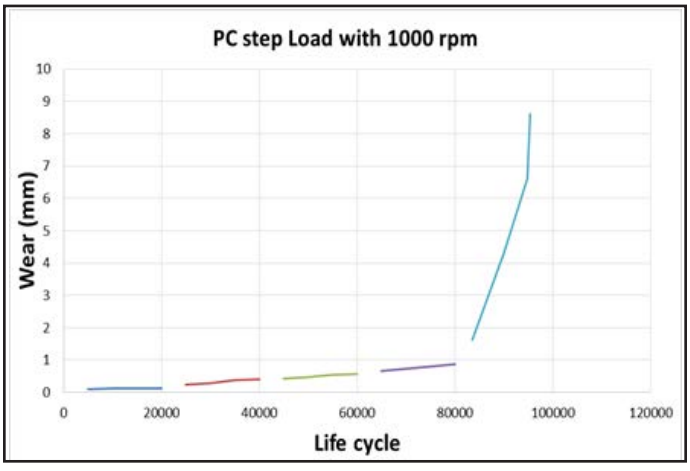


Figure 2 Experimental results for polycarbonate gears.

Test Results and Discussion

Gear engagements of same materials. The incremental step loading test method (Ref. 4) has been employed for the tests. During the incremental test, only one single-polymer gear pair is tested. The tested gears are loaded at a designed constant load for a certain period (e.g., 1 hour), after which the load is incrementally increased to a designed value for another certain period. This process of incremental load increase continues until a rapid wear rate increase is observed and the experimental test is completed. This method has previously been compared to normal endurance tests, where different gear pairs are run at each load until failure. It has been shown that the incremental test method is a very effective way to achieve the performance evaluation for new gears (Ref. 3). From the experiments, it can be seen that with a properly designed run time for each load, an adequate wear rate value will be obtained, as can an adequate result for the transition torque at which the wear rate accelerates rapidly. The main benefit of using the incremental loading method is that an overview of a new gear pair's performance can be obtained within one day, compared with the several weeks required to perform full endurance

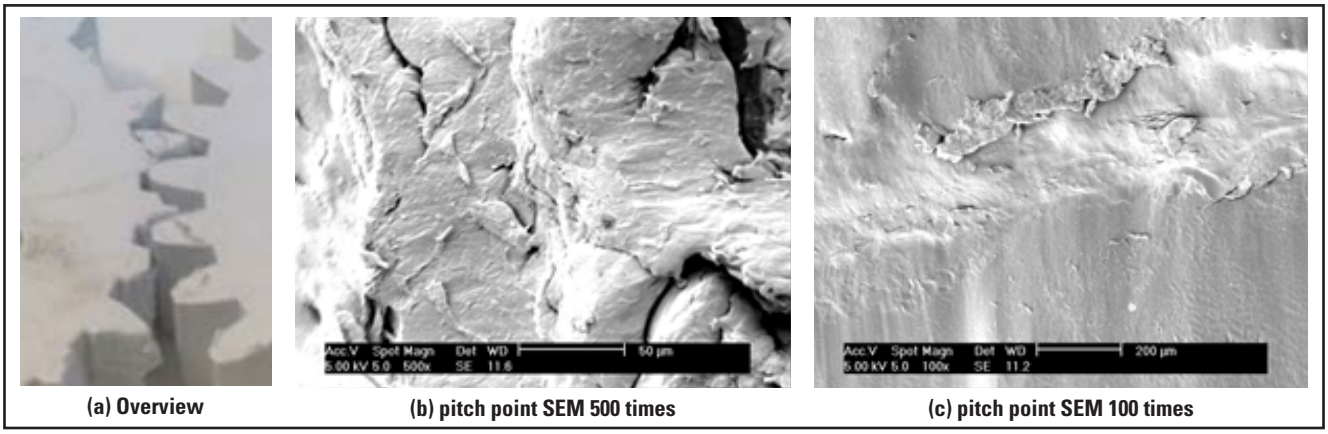


Figure 3 Experimental results for polycarbonate gears.

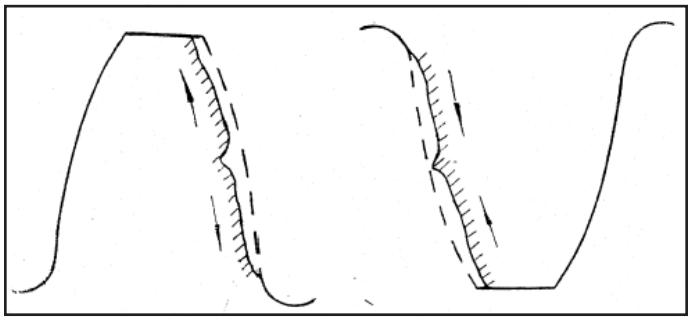


Figure 4 Gear surface wear (Ref. 2).

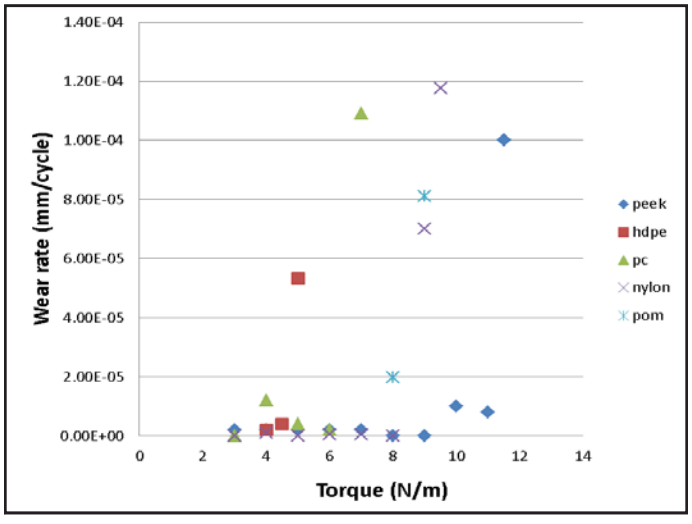
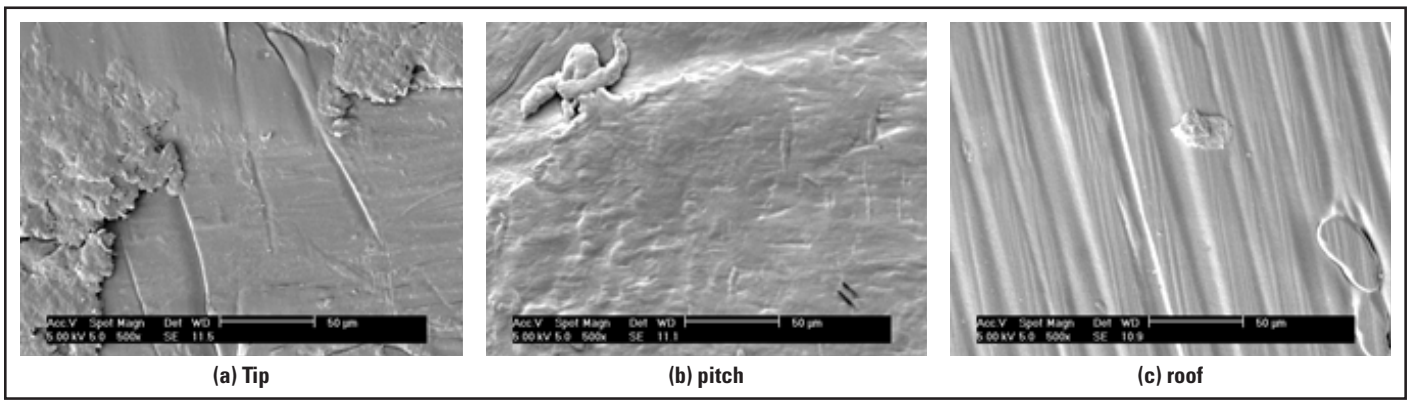


Figure 5 Wear rate against load for the same five polymer gear pairs.

testing on multiple gear pairs at multiple torques. Figure 2 shows the experimental results for an incremental load test of a polycarbonate gear pair running at 1,000 rpm. The gears were loaded at 3 Nm for one hour, after which the load was increased to 4, 5, 6 and 7 Nm for one hour running under each load. Under 7 Nm the polycarbonate gears failed due to pitch fracture.

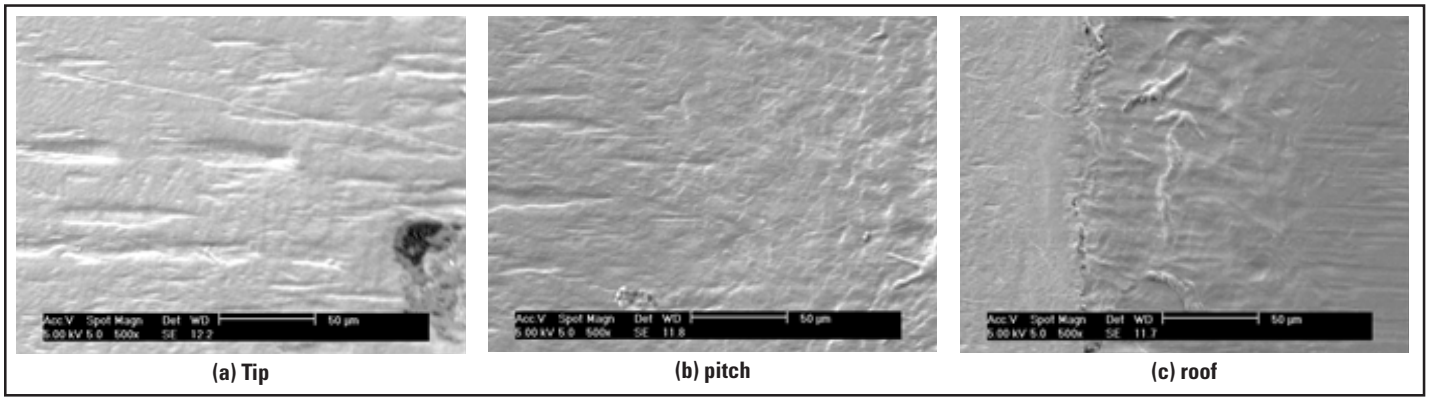
The polycarbonate gears fractured only on the driver (Fig. 3). A possible reason for this may be linked to the difference in wear patterns between the driver and the driven gears as shown (Fig. 4). The driving gear's tooth root wear is higher due to a higher friction force at approach than the recess friction force. The reason for the difference in friction force is that during tooth meshing, the rolling action of the teeth on the two engaged gears in approach is towards each other, whereas in recess the teeth rolling action is away from each other. The pitch point fracture for the driver is likely related to the tooth wear pattern, combined with the high temperature at the tooth surface around the pitch point.

Figure 5 shows wear rate against torque for gear pairs manufactured using the 5 different polymer gear materials. The wear rate considered here is the material depth removed per cycle, given by the linear wear period slope as shown (Fig. 2). All tests were run at a constant speed of 1,000 rpm. The experimental results show that, for all polymer gear pairs tested, below a certain load the gear surfaces wear slowly and a relatively long life for the gears will be achieved (nearly 10^7 cycles), while above a critical torque wear rate accelerates rapidly and leads to rapid failure. The observed critical torques for each gear pair are about 6 Nm for polycarbonate (PC); 8 Nm for POM; 8.5 Nm for PA; 11 Nm for PEEK; and 4.7 Nm for high-density polyethylene



(a) Tip (b) pitch (c) roof

Figure 6 PEEK gear tooth SEM results.



(a) Tip (b) pitch (c) roof

Figure 7 PA gear tooth SEM results.

(HDPE). Above the critical torques, the polycarbonate gears failed due to pitch fracture; the POM gears failed due to thermal wear (the tooth surface maximum temperature reaching the POM material melting temperature (Ref. 15); the PA and PEEK gears failed due to excessive surface wear; and the HDPE gears failed due to large deformation. The large deformation failure of the HDPE gears was expected, given its low modulus of elasticity (approximately one-third of the other polymers considered (Table 1)). HDPE has been considered in this study and is of interest to polymer gear applications — particularly low-load, high number of cycle applications — due to its very low co-efficient of friction.

As the wear performance for both injection-molded and machine-cut POM gears has been discussed extensively in the previous literature (Refs. 3–4, 15), more focus in this study has been placed on investigating the PEEK and PA gear performance. Figure 6 shows SEM results for the PEEK gears, while Figure 7 shows SEM results for the PA gears. Although the sudden wear rate increase mechanisms for PEEK and PA are not clear at the moment, the high tip wear for both gears are expected due to high friction load in tooth tip region (Ref. 3).

Gear engagements of dissimilar materials. Incremental load tests were also performed running paired gears of different materials — again at a constant speed of 1,000 rpm. Figure 8 shows torque against wear rate for different combinations of running POM and PEEK gears; POM against POM; PEEK against PEEK; PEEK (driver) against POM; and POM (driver) against PEEK. It is very interesting to note the significant performance variation for dissimilar material engagement. The best performance was observed in the test with POM as the driver and PEEK as the driven gear, showing a transition torque of about 13 Nm. Next in terms of performance came PEEK against PEEK (11 Nm), PEEK against POM (10 Nm) and then POM against POM (8 Nm). Similar results have previously been reported by one of the authors for POM paired with PA (Ref. 4). The mechanism for good performance of POM as the driver is discussed as follows.

It has previously been shown that the main failure mode for POM gears is wear due to thermal effects (Refs. 4, 15). It has been argued that the tooth pressure angle will be increased with the tooth surface wear and the increase in tooth pressure angle will make the tooth wear even more quickly (Ref. 15). The typical wear form for POM is schematically shown (Fig. 9). The reason for the acceleration in wear as the pressure angle increases is because the torque T applied to the test gears is constant, i.e. — $T = F_n r$. When the gear tooth wears, the pressure angle increase causes the arm r of the normal contact force F_n about the gear center to reduce. However, the torque is constant, hence the normal contact force F_n' must increase, resulting in higher friction force. The friction force is the dominant factor causing POM tooth thermal wear and wear rate acceleration.

Further, it has been confirmed that the friction force is higher in the tooth tip area than the root area for the driven gear (Ref. 4), but higher in the tooth root area than the tip for the driving gear. This was discussed with regards to the polycarbonate gear tests earlier. As a result, more wear occurs at the root than the tip when POM is the driver, whereas more wear occurs at the tip than the root for the driven POM gear. Tip wear accelerates the gear wear much quicker than root wear and thus POM gears perform worse as the driven gear and better as the driver.

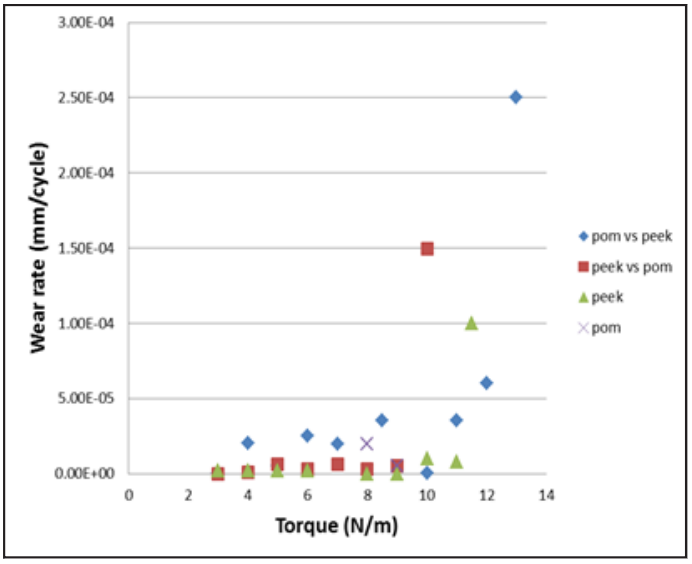


Figure 8 Wear rate against load for POM and PEEK gears.

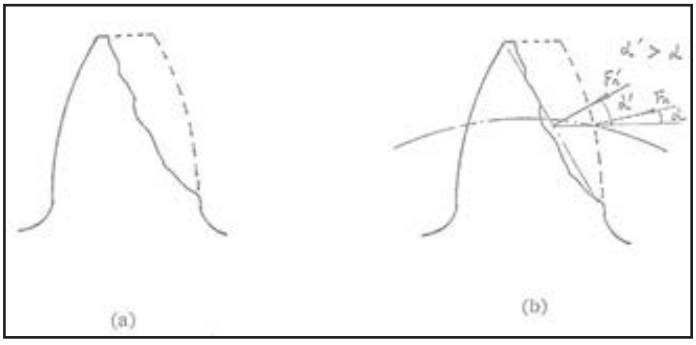


Figure 9 Typical wear form for POM gears (Ref. 2).

Conclusions

The wear behavior of polymer gears made of five different materials has been investigated using an existing polymer gear test rig. Step loading tests at a constant speed of 1,000 rpm were performed.

Significant differences in failure modes and performance have been observed for the five polymer gear materials for gear engagements of gears, with the same material as each other. The observed critical torques for each gear pair are about 4.7 Nm for HDPE; 6 Nm for PC; 8 Nm for POM; 8.5 Nm for PA; and 11 Nm for PEEK. The polycarbonate gears showed pitch point fracture failure related to the gear surface wear pattern, while the POM gears tested failed due to thermal wear. For POM the gears' surface will wear slowly, with a low, constant wear rate if the gear pair load is below a transition value. The wear rate increases rapidly when the gear load is equal or higher than the transition torque value. The transition torque has previously been shown to relate to the point where the gear tooth maximum surface temperature is equal or above the POM melting temperature. For the PA and PEEK gears, progressive wear was the main failure mode observed. Further endurance tests are needed to understand their wear mechanisms. The high-density polyethylene gears' performance was poor — as expected — and large deformation failure was observed due to the material's low

modulus of elasticity.

For dissimilar material gear engagement between POM and PEEK, it is interesting to note that the best performance was achieved with POM as the driver and PEEK as the driven gear, when compared to POM against POM, PEEK against PEEK and PEEK against POM.

It may be noted that only dry running condition test results have been reported in this paper, and that lubrication effects are under further investigation. Preliminary results of the current research show an increase of over 40% for the load capacity of lubricated PEEK against PEEK as compared to dry running gears.

Injection molding process capabilities (including mold design and manufacture) have been established at Warwick University and research is ongoing with regards to the performance of reinforced polymer gears. Initial research results showed significant performance improvement for 28% glass fiber-reinforced POM gears when compared with the performance of unreinforced POM gears (Refs. 16–17).

For more information. Questions or comments regarding this paper? Contact Ken Mao at *K.Mao@warwick.ac.uk.*

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The Application of Geometrical Product Specification (GPS) — Compatible Strategies for Measurement of Involute Gears

R.C. Frazer, G. Koulin, T. Reavie, S.J. Wilson, J. Zhang and B.A. Shaw

Introduction

During the revision of ISO 1328-1:2013 Cylindrical gears — ISO system of flank tolerance classification, ISO Technical Committee TC 60 WG2 delegates discussed proposals that the standard should be modified to ensure that it is compatible with the ISO Geometrical Product Specification (GPS) series of standards (Refs. 1-3). This seems sensible because the gears are geometrical components, but after reviewing the implications, it was rejected because ISO TC 60 WG2 did not think the gear manufacturing industry was ready for such a radical change in measurement strategy. GPS standards are numerous: a search on the British Standards website delivered 203 documents (Ref. 4) and it is probably not surprising that few companies have adopted the guidance within the documents.

An EMRP EURAMET-funded project (ENG56-DriveTrain), which is jointly funded by the EU and participating national states, completed a significant research project to improve the 'Traceable measurement of drivetrain components for renewable energy systems.' Part of this project investigated the feasibility of implementing GPS-compatible measurements to gears. The work concluded that there would be significant benefit in applying GPS strategies to gears, but there are also some significant problems. The need to specify functional, performance-based characterization parameters is very challenging, but the work summarized in this paper provides a framework to develop GPS-compatible measurement strategies for gears.

GPS Methodology

GPS was introduced in 1992 when it was realized that digital definitions of products or workpieces were changing how the design, stress analysis and modeling, as well as CNC machine tool manufacture, and measurement processes were used. There is a need to define inputs mathematically for these tools and to define a structured way of processing the data.

The process assumes that we specify allowable deviations or tolerances to the ideal or theoretically shaped component. We specify functional, performance-based characterization parameters or 'features' for each of these geometry elements. These geometry features have a functional effect on the component performance and require controlling. For example, we specify the effect that eccentricity (µm) will have on out-of-balance forces (*N*) when a shaft is rotating. We calculate these effects reasonably accurately, but the geometry specification parameter may not exactly control or influence the function requirements, so there is residual uncertainty with the specification parameter — although it may be small. For gears, functional performance or key performance indicators (KPIs) may include noise and vibration limits at a range of torque values and operating speeds, contact stress resulting in macro- and micropitting damage, bending fatigue failure and scuffing risk. The correlation between the geometrical component specification and each KPI needs to be quantified to specify tolerance limits. These will be different for each application, but it is likely that common processes and strategies could be adopted. All stages of the process include unavoidable uncertainties, as no process is perfect and these need to be quantified.

The key GPS process stages are:

- A measurement strategy (extraction) is needed to extract points from the selected collection of surfaces on the manufactured workpiece. If we can't measure 100% of the surfaces, there is potential that our measurement data density was not sufficient to capture the manufactured characteristics and uncertainty in characterization of each measured element from the measurement strategy.
- The geometrical extracted feature will include 'noise' from the extraction process (equipment) and include high- or low-frequency workpiece deviations which may not be required for the evaluated functional parameter. Thus, appropriate filters are specified.
- We need to use the extracted data and evaluate functional characterization features. This process is called 'association,' which fits the imperfect extracted feature with an ideal feature (such as a circle or involute profile — both of which are mathematically defined). Each characteristic of the feature is independent of other characteristics (the so-called independency principle).
- Evaluation of the functional characteristics introduces further potential uncertainty.
- The final stage is to establish compliance (or otherwise) with the component's GPS.
- The choice of measuring equipment, environment, calibration strategy and traceability of the evaluated parameters can potentially contribute significant uncertainty to the overall process. For example, if old or poor-performing measuring equipment is used for measuring precise components, such as gears.
- Compliance uncertainty. The uncertainty contributions outlined above will affect the decision process when results are compared to the tolerance limits. To

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minimize the risk of accepting components outside tolerance or of rejecting components within tolerance, uncertainty of each process should be used to define working tolerance limits that can be used by the shop floor during manufacture.

In summary, we specify functional, performance-based characterization features which are measured, filtered and evaluated with equipment of known measurement uncertainty; this uncertainty is considered when reporting compliance or otherwise with a functional specification.

Classical Gear Metrology Methods

Since the development of early gear tolerance specifications (Ref. 5), conventional inspection involved the measurement of individual gear parameters such as single and cumulative pitch, involute profile and helix deviations. Generally, a single profile and helix trace (2-D line) at mid-facewidth or tooth depth on 3 or 4 teeth spaced at 120° or 90° intervals, and single pitch and cumulative pitch on all teeth is measured. 2-D line methods were adopted because they provided information that can be used to modify the machine tool set-up and reduce the deviations. Tolerance values were primarily defined based on machine tool manufacturing capability, rather than gear performance. ISO17485:2003 tolerance grades for bevel gears (Ref. 6) were identical to ISO1328-1995 (Ref. 7) tolerance standard values for cylindrical gears, except that the bevel gear tolerance grades were 1 grade larger to reflect the additional difficulty involved with manufacturing bevel gears.

These measurement methods are sometimes extended to include additional profile and helix 2-D line scans on a single tooth (Fig. 1) to quantify variation in profile and helix deviation caused by the machine tool manufacturing characteristic. Tolerances of evaluated parameters are usually applied uniformly to all profile and helix measurements over the tooth surface.

The helix and profile 2-D line deviations are both evaluated by 3 parameters, which for profile are evaluated between the profile control diameter and tip form diameter, and include the total deviation F_{α}, the profile slope deviation $f_{H\alpha}$, and profile form deviation $f_{f\alpha}$. The parameters control the manufacturing processes and affect the performance of gears, although the correlation between gear performance and these tolerance values in the ISO 6336 stress analysis standard (Ref. 8) is not so clear. ISO 6336 uses the ISO 1328-1 single-pitch tolerance to contribute to the estimation of the dynamic load modification factor K_{v}, which estimates the increase in load caused by self-excited dynamic effects. The effect of misalignment caused by manufacturing deviations is also considered, but the implementation is determined by the user.

Another method, commonly known as topography measurement, is illustrated (Fig. 2). Multiple 2-D profile measurements and single-helix line scans fully characterize a single tooth flank surface topography. Such results are usually only examined visually for damage and manufacturing trends, because evaluation parameters have not been developed for this type of measurement.

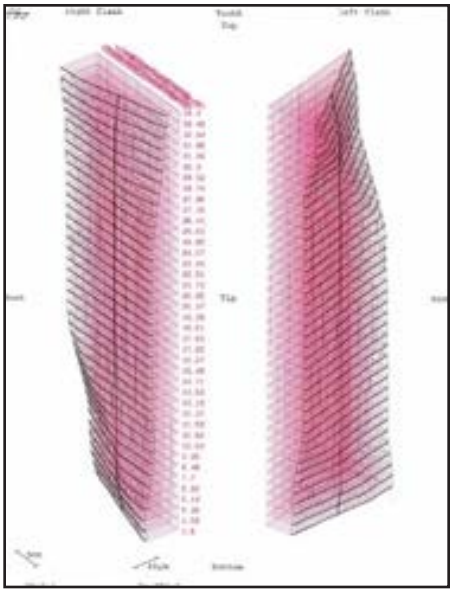

Figure 2 Topography measured on a single tooth combining a single helix 2-D line scan on each flank with multiple profile 2-D line scans.

In summary, the parameters evaluated in both previous and current versions of the ISO 1328-1 tolerance standard are at best weakly correlated to gear performance, and the link to KPIs such as contact stress, scuffing risk and noise are not properly established. Deviations in involute gear flank form from design intent contributes to a number of potential failure mechanisms which can be considered as KPIs for gears. These include:

Peak load intensity increase leading to premature gear failure by tooth root bending fatigue, flank contact fatigue by macropitting or micropitting, and scuffing failure.

Excessive noise and vibration resulting from high dynamic loads (potentially causing premature fatigue failure of the gears).

Reduced reliability, efficiency and variability in product performance.

It can be imagined that the classical 3-form characterization parameters, which include microgeometry corrections such as tip relief and helix crowning, applied to a tooth surface that is misaligned and deflects elastically when loaded, is unlikely to fully characterize gear performance.

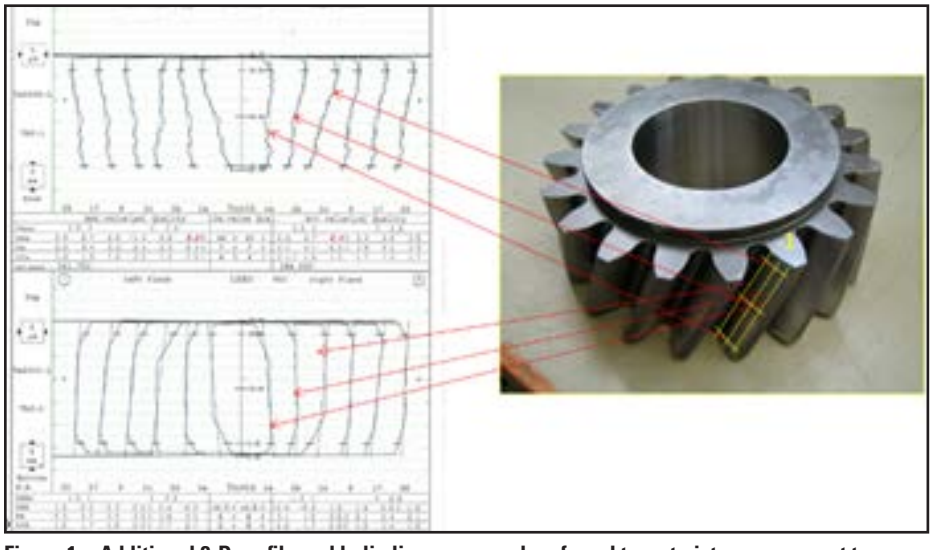

Figure 1 Additional 2-D profile and helix lines commonly referred to as twist measurement to quantify common machine tool manufacturing characteristics.

GPS-Compatible Revisions to ISO 1328-1:2013

General. Although GPS strategies were not adopted during the revision, a number of changes were introduced that are compatible with GPS:

- Involute profile measurement requires a minimum of 150 points equally spaced along the profile length of roll.
- Helix measurement requires a minimum of 150 points (expressed as 5.b/λ_β).
- If waviness is to be checked, a minimum of 300 points or 5/mm is required.
- A profile filter cut-off is defined as $\lambda_\alpha = L_\alpha/30$, where L_α is the profile length of roll [mm] and the helix filter cut-off is $\lambda_\beta = b/30$ where b is the face width [mm].
- The filter is a Gaussian 50%, defined in accordance with ISO/TS 16610-1 and ISO 16610-21 — both of which are GPS standards.
- Evaluation methods to assess deliberate microgeometry corrections to improve functional gear performance.

These changes minimize the measurement uncertainty caused by different sampling strategies, which is particularly sensitive where larger deviations from involute form exist (Refs. 8-9). The results in Figure 3 with significant deviations resulted in $f_{H\alpha}$ values of 14.0 µm and 16.2 µm for length of roll and radially spaced data; deviation in form parameters $f_{f\alpha}$ varies between 20.4 to 19.7 µm, and total form F_α of 27.1 and 27.0 µm. These are significant differences in values compared to the tolerance.

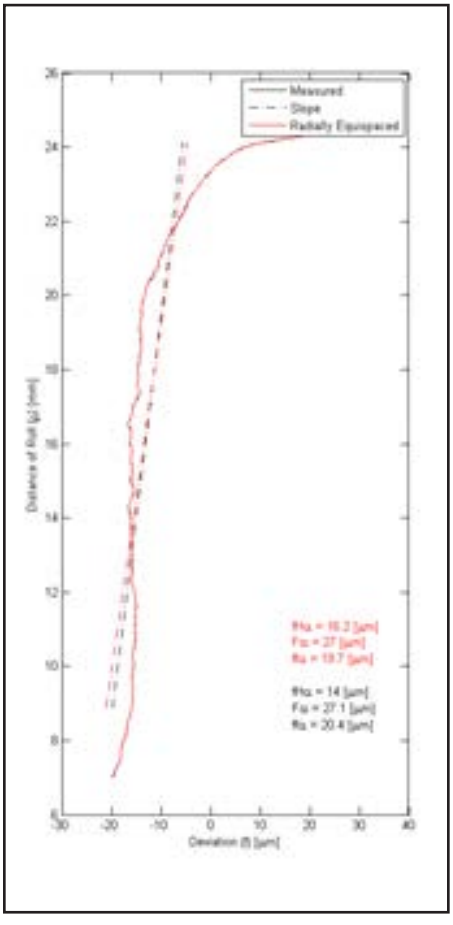

Figure 3 Change in profile parameters with data spacing strategy for large deviations with 480 data points.

A comparison of 2-D profile data requirements for wind turbine gears. The EMRP ENG56 project considered the requirements of wind turbine gearboxes and reviewed the ISO 1328-1:2013 recommendations for filter and data spacing, compared to the functional impact on gear noise/vibration and contact fatigue. Large wind turbine gearbox drives commonly have 3 stages, i.e. — low-speed 1st and 2nd stage are often epicyclic gear arrangements and the 3rd high-speed stage is a parallel axis gear pair. The typical gear size (module) depends on the detailed design, but it is common to use around 18 mm, 16 mm and 8 mm module gears for 1st, 2nd and 3rd stages, respectively. The length of path of contact (L_α) — that defines the length of profile measurement for each of these stages — again varies, but is usually around 80 mm for the 1st and 2nd stages, and 45 mm for the 3rd stage. Face widths are usually around 400 mm (1st and 2nd stage) and 200 mm (3rd stage) gears.

Noise and Vibration Frequencies and Measurement Data Requirements

Noise and vibration caused by gears during operation is at tooth passing frequency and its higher harmonics. 10× tooth passing frequency ($f_{max} = \times 10$) are not likely to cause significant problems, and generally ×5 or ×6 tooth passing frequency are common limits. Thus we need to properly capture flank features that cause deviations at or below these frequencies. Assuming a minimum of 5 *(n)* data points to model each harmonic of tooth passing frequency (for an FFT analysis for example) the minimum data spacing requirements in the transverse profile are given in Equation 1.

$$\text{data spacing [mm]} = \frac{L_\alpha}{f_{max} \cdot n \cdot \varepsilon_\alpha} \quad (1)$$

Where:

L_α profile length of roll [mm]
f_{max} tooth passing harmonic (relative frequency)
n number of data points per frequency
ε_α gear transverse contact ratio

The required number of data points in Table 1 for the wind turbine gears is significantly less than the minimum of 150 specified by ISO 1328-1:2013. The data density for 2-D helix measurement on helical gears is not so critical for noise and vibration because the line of contact is inclined at an angle over the face width.

Contact Stress Modeling and Measurement Data Requirements

The data spacing requirements for contact stress can be estimated from the Hertzian contact half-width (a). Under normal nominal load conditions in wind turbine gears, the Hertzian contact half-width (a) varies between 0.35 mm and 0.7 mm — assuming aligned and perfect surfaces. Geometry features with a wavelength of around the Hertzian contact length will have a significant effect on the actual contact stress.

Assuming the same minimum of 5 data points are required for modeling involute profile shape over the Hertzian contact length, the data density and number of measurement point requirements are summarized (Table 2). The results suggest we need approximately twice the minimum requirement of 150 specified

Table 1 Profile data density requirements for noise and vibration

Stage	Module mn [mm]	Profile length L_α [mm]	Transverse contact ratio ξ_α	Data spacing [mm]	Points per profile length
1st (epicyclic)	18	85	1.6	1.06	80
2nd (epicyclic)	16	80	1.6	1.00	80
3rd (gear pair)	8	45	1.8	0.50	90

Table 2 Data spacing and number of points based on contact stress modeling

Stage	Module m_n [mm]	Profile length L_α [mm]	Hertzian length [mm]	Data spacing [mm]	Points per profile length
1st (epicyclic)	18	85	0.7×2	0.28	304
2nd (epicyclic)	16	80	0.7×2	0.28	285
3rd (gear pair)	8	45	0.35×2	0.14	321

in ISO 1328-1:2013. This is consistent with the recommendations for waviness measurement where a minimum of 300 points is recommended by ISO 1328-1.

Local contact stress is significantly affected by smaller deviations at the surface roughness and waviness level. It could be argued that the profile form measurement does not need to measure features around the Hertzian contact length, and that waviness and roughness measurement methods using small 2 or 5 µm radius stylus or optical methods are more appropriate. This depends on the CMM and GMM probe system performance, which is generally not verified by CMM or GMM users. If CMMs and GMMs can detect waviness parameters which will characterize features that affect micro-pitting, macro-pitting and scuffing performance acceptably, then waviness can be measured independently of roughness.

2-D Helix Line Data Density

The inclined line of contact at the base helix angle on helical gears is influenced by both profile and helix form deviations. ISO 1328-1:2013 recommends a minimum of 150 points for helix measurement and a minimum 300 points or 5 points/mm of facewidth, if waviness is required. Table 3 shows that meeting the minimum number of points for waviness measurement requires significantly more than 300 points. The helix data density at 5 points/mm gives a similar density to the requirements for involute profile measurement, and this is appropriate for contact stress analysis with CAD models. The data density resulting from the 150 minimum points provides sufficient information to define load distribution for bending stress analysis with CAD models.

ISO 1328-1 Filter Specification

The cut-off lengths for involute profile and helix measurement, λ_α and λ_β, respectively, are low-pass cut-offs that exclude high-frequency deviations. The cut-off lengths are specified as $L_\alpha/30$ and $b/30$ and examples for typical wind turbine gear applications are illustrated (Table 4).

Other Considerations

A line of contact on a helical gear is inclined at the base helix angle (β_b) and thus the effect of the attenuation of measured features used to model a tooth surface is influenced by both profile and helix deviations.

If the base helix angle (β_b) is greater than the Tan^{-1} ($\lambda_\alpha/\lambda_\beta$) from Table 4, the highest frequency that influences geometry modeling is limited by the profile filter selection; conversely, if it is smaller, the helix filter limits the geometry frequency.

Example: ISO 1328-1: Filter Test Results and Analysis

The sample measurement results are from a ground gear artifact with geometry summarized in Table 5; a 5 mm-diameter probe was used for these tests. Each profile and helix evaluation used 480 data points, which is greater than the minimum of 150 points specified in ISO 1328-1 and consistent with the requirements for the measurement of features that will influence noise, vibration and contact stress. Selected flanks were measured on a Klingelnberg P65 at the UK's National Gear Metrology Laboratory. Three conditions were tested:

- No filter, except a morphological filter (5 mm probe diameter) and mechanical filtering from the P65 probe system (unquantified).
- ISO 1328-1:2013 Gaussian filter defined in accordance with ISO/TS 16610-1 and ISO 16610-21.
- A Klingelnberg 2CR filter. This is the standard filter offered by Klingelnberg — with a cut-off wavelength λ_α of $L_\alpha/15$ and λ_β of $L_\beta/15$ — and thus removes higher frequencies than the ISO filter. It provides an example of an existing filter and illustrates the

Table 5 Test gear geometry

Module m_n	8 mm
Profile length L_α	32.33 mm
Helix β_b	0°
Face with (b)	155 mm
Involute profile λ_α	1.077 mm
Helix λ_β	5.166 mm
Profile data (n)	480
Helix data (n)	480
Tan^{-1} ($\lambda_\alpha/\lambda_\beta$)	11.78°

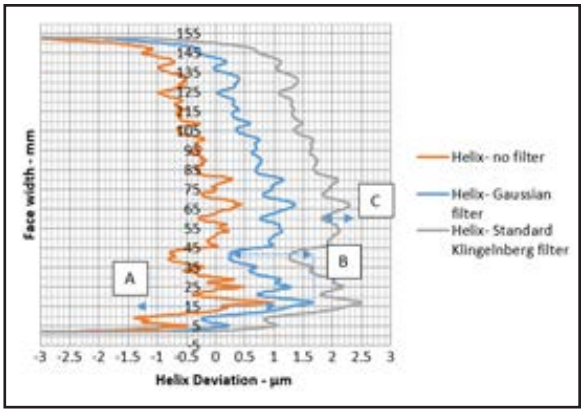

Figure 4 Helix results with different filters (Sample 1).

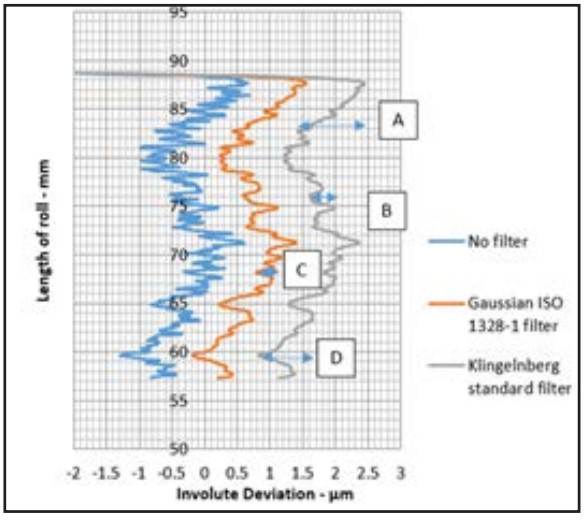

Figure 5 Profile results with different filters (Sample 1).

Table 3 Data sampling requirements for helix measurement

Stage	Module m_n [mm]	Face width (b) [mm]	ISO max data spacing for 150 points [mm]	ISO number of points at (5/mm)
1st (epicyclic)	18	400	2.67	2000
2nd (epicyclic)	16	260	1.73	1300
3rd (gear pair)	8	300	2.00	1500

Table 4 ISO 1328-1:2013 filter cut-off length

Stage	Module m_n [mm]	Profile length L_α [mm]	Face (b) [mm]	Involute profile λ_α [mm]	Helix λ_β [mm]	Tan^{-1} ($\lambda_\alpha/\lambda_\beta$)
1st (epicyclic)	18	85	400	2.83	13.33	11.98°
2nd (epicyclic)	16	80	260	2.67	8.66	17.14°
3rd (gear pair)	8	45	300	1.50	10.00	8.53°

expected differences with the ISO filter.

2-D helix and profile measurement results are illustrated (Figs. 4 and 5, respectively); a visual examination of the results shows clearly the attenuation in high-frequency content. The influence on the helix and profile slope deviation, form deviation and total deviation was < 0.5 µm.

Some individual characterizing features in the results have also been examined, and the findings summarized in Table 6. The results show that typically 10% greater attenuation of feature transmission with the traditional 2CR filter compared to the ISO Gaussian filter. It also shows that as λ/λ_β or λ/λ_α reduces, the effect of the filter and feature amplitude increases — as expected.

Table 6 shows that, based on the typical noise requirements and most contact stress needs, the ISO 1328-1:2013 filter requirements are reasonable and provide a good platform to develop GPS measurement strategies.

3-D Gear Flank Reconstruction and Evaluating Parameters

Part of the EMRP ENG56 project was to establish how many measurement scans on a conventional GMM were needed to characterize the 3-D surface geometry. A 2-stage Gaussian interpolation method was developed (Ref. 8), which shows that a gear tooth surface could be accurately generated from as few as 3 profile and 1 helix scans. The optimum number of profile scans required depends on the manufacturing process characteristic. The method involves 5 steps:

- Select the number of profile measurements to model the tooth surface (5 are selected in the example in Fig. 6).
- Fit a surface polynomial to the selected profile and helix data (Fig. 6), and then subtract the surface polynomial surface to create 5 residual deviation profile scans.
- Use these to synthesize the high-frequency surface deviations using Gaussian interpolation (Fig. 7).
- Add the surface polynomial back to the synthesized surface from the previous step to reconstruct the tooth surface (Fig. 7).
- Test the sampling strategy by comparing the reconstructed surface to the high-density measured surface and quantify the deviations (deviations in Fig. 7 are ×10 magnification).

This process allows for the accurate modeling of gear teeth surfaces and the

Table 6 Sample 1 feature attenuation

Profile/helix	Feature	Feature λ [mm]	λ/λ_β or λ/λ_α	Amplitude [µm]		
				No filter	Gaussian filter	2RC filter
Helix λ_β = 5.16 mm	A	10.68	2.06	2.33	1.90 (82%)	1.65 (71%)
	B	21.68	4.20	1.71	1.38 (81%)	1.21 (71%)
	C	7.12	1.38	0.67	0.56 (84%)	0.44 (66%)
Profile λ_α = .08 mm	A	7.37	6.82	1.64	1.27 (77%)	1.17 (71%)
	B	0.47	0.44	0.72	0.38 (53%)	0.35 (47%)
	C	0.67	0.62	0.58	0.21 (40%)	0.15 (26%)
	D	4.52	4.19	1.18	0.91 (77%)	0.83 (70%)

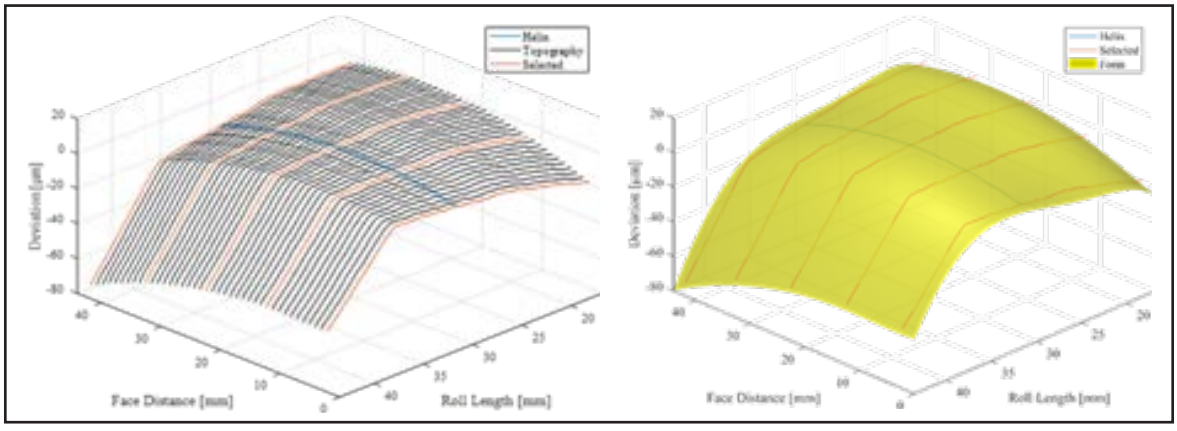

Figure 6 Selected 2-D profile scans (left) for surface polynomial fitting (right).

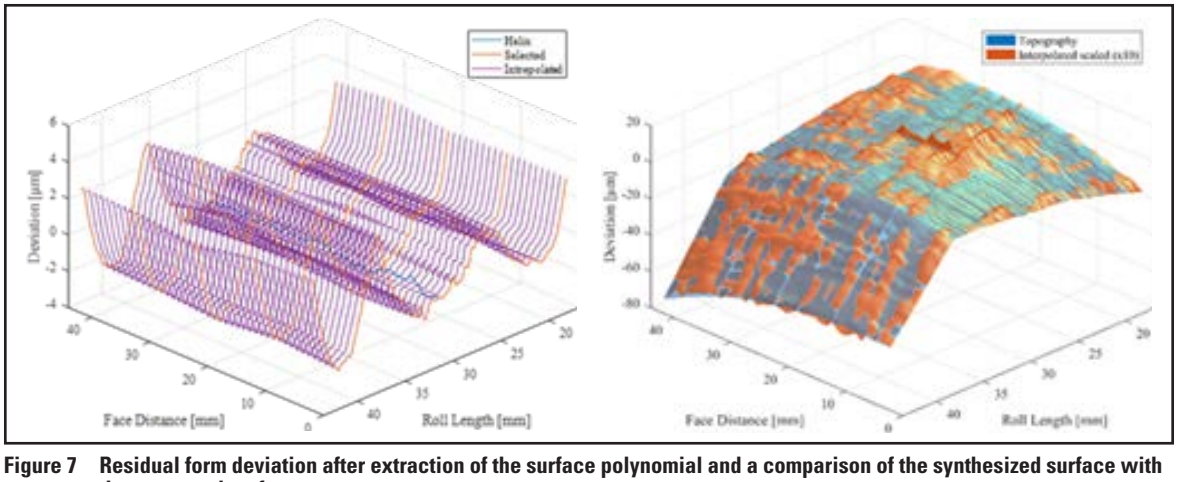

Figure 7 Residual form deviation after extraction of the surface polynomial and a comparison of the synthesized surface with the measured surface.

development of efficient GPS-compatible measurement and evaluation strategies based on functional KPIs required for the gear application. The KPIs should consider the gear geometry deviations, microgeometry corrections, elastic deflections and the sliding and rolling speeds at the mesh, among other requirements. This is only practical if the actual measured gear geometry is used in a TCA model to predict performance and the TCA is validated by testing. This approach has already been developed for gear tribology modeling, and researching the initiation and progression of micropitting (Refs. 12–13).

GPS Implementation Recommendations — General

Gear geometry measurement standards should be part of the GPS matrix of standards. ISO TC60 WG2 should retain the technical responsibility for standard development, with appropriate support from ISO Technical Committee TC213 delegates. It is expected this process will take 10–15 years to implement. Specific comments on the key ISO documents follow.

ISO 1328 -1: 'ISO system of flank tolerance classification.' Tolerance standards are required for user guidance. The compliance/non-compliance with tolerance in accordance with ISO 14253-1 should be optional. Measurement uncertainty statements should accompany all measurement results. Tolerance values should remain unchanged. References to measurement methods and minimum strategies should remain with the GPS document and not in a separate document. In addition, datum surfaces should make reference to ISO 5459.

ISO 18653: 'Evaluation of instruments for the measurement of individual gears.' ISO 18653 requires revision of measurement uncertainty calculations to more accurately account for uncorrected bias from the comparator method. References to ISO 10360, ISO 14253 (all parts), ISO 15530 (all parts) should be strengthened. A review of artifact requirements for the assessment of measurement uncertainty and a strategy for using a combination of uncalibrated and calibrated workpieces is recommended.

ISO TR 10064. ISO TR 10064-3: Review and revise the TR for compatibility with ISO 5459 datum surfaces and datum systems; provide new examples.

ISO TR 10064-5. Update this by removing all but the ISO 14253-1 method of defining limits and add the (trivial) example where uncertainty is simply stated; update and align with ISO 1328-1. Removal of limits on alignment, runout and probe gain where machine manufacturer's recommendations take precedence.

Conclusions

The feasibility of the implementation of gears into the GPS matrix of standards has been carried out and the results conclude that this is practical, provided some key issues related to measurement uncertainty and establishing appropriate KPIs are addressed. A review of the revisions to ISO 1328-1:2013 concludes that they are compatible with GPS strategies. Also, the filter and data density requirements for profile and helix measurement are suitable for characterizing noise KPIs and some contact stress KPIs. A method to efficiently characterize the 3-D tooth surface form has been developed, with the specific intention of using the data in gear TCA models.

The development of a holistic approach to gear specification, measurement, modeling of gear performance, and validation by testing is a necessary requirement for implementing GPS measurement strategies.

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For more information. Questions or comments regarding this paper? Contact Robert Frazier at *robert.frazer@newcastle.ac.uk*.

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Rob Frazer received a BSc in Mechanical Engineering and Ph.D. from Newcastle University. He is a senior engineer with the Design Unit at Newcastle University and has spent the last 35 years working with gears. Rob leads gear measurement research at the UK's National Gear Metrology Laboratory (NGML), is chair of BSI's gear committee MCE-5, and is a member of the ISO gear accuracy committee (ISO TC60 WG2). Frazer provides technical support to the British Gear Association's research committee, helps deliver its KT program and teaches Newcastle University's MSc and MEng Mechanical Power Transmissions Modules.

Giorge Koulin received in 2013 a BEng degree in mechanical engineering with a specialization in mechatronics from Newcastle University, UK. Since graduation he worked as a researcher in the Design Unit, Newcastle University focusing on developing metrology techniques to allow simulation of real, as-manufactured versus as-designed ideal mechanical power transmissions meshing elements. In 2018 Koulin moved to the field of software engineering and currently works for Pulsic, developing the new-generation, smart placement tool for analogue integrated circuits, Pulsic Animate Ltd.

Tom Reavie received his Masters in Mechanical Engineering from Newcastle University in 2016. He has since been working as a research engineer at Newcastle University's Design Unit, specializing in gear design and analysis. Recently, Reavie joined the National Gear Metrology Laboratory team and has begun a Ph.D. in 3-D gear form measurement and geometric product specification (GPS) for gears.

Stephen Wilson received a Bachelor of Engineering in Mechanical Engineering from Northumbria University in 2000, after working in the manufacturing industry for several years. He has been working for the Design Unit at Newcastle for over 20 years in the manufacturing, gear testing and gear metrology fields. Wilson is the Technical Manager of the UK National Gear Metrology Laboratory and is an active member of national standardization body BSI – Gear Accuracy MCE/005/05-02, which is responsible for the UK input into the work of the ISO Technical Committee 60 Working Group 2 Accuracy of Gears.

Jishan Zhang received his bachelor degree in mechanical engineering from Hunan University (China) in 1988. After graduation, he worked in production engineering in the Dongfanghong Tractor Plant (China) for 4 years. He received his master degree in mechanical engineering from Zhengzhou Research Institute of Mechanical Engineering (China) in 1995, and started studying and testing gears, firstly as a research engineer and then as a senior research engineer up to 2000. He obtained his Ph.D. degree in mechanical engineering from Newcastle University (UK) in 2005 and has since worked in the Design Unit as a research associate, and was appointed senior test engineer by Newcastle University in 2016. Dr Zhang's current research interests include the scuffing, micro-pitting, macro-pitting and efficiency of case hardened involute gears

Brian Shaw received a BEng in Materials Engineering from Sheffield University and his Ph.D. from Newcastle University. He is Professor of Transmission Materials Engineering, the Director of the Design Unit and Director of Business and Engagement at the School of Engineering. Since 1993 he has worked within the field of gear metallurgy, carrying out research into micro-structural aspects of the fatigue strength of gear materials, and in particular the crack initiation and propagation in pitting and bending fatigue. Shaw's research includes the investigation of the influence of heat and surface treatments on the bending and contact fatigue strength of carburized, nitrided and induction hardened gears, the effect of residual stress, surface texture and lubricant additives on pitting in gears.

Forest City Gear

HIRES NEW DIRECTOR OF SALES

Forest City Gear has hired **Brad Lindmark** as director of sales to help meet the growing demands of its wide and diverse customer base throughout the world's gear-making industries.

Lindmark brings a wealth of sales and marketing experience and a deep familiarity with all facets of inside and outside sales and customer service, along with a strong background in the metalworking industries. This background, combined with his sales and marketing leadership skills, made him an ideal candidate for the position, says Forest City Gear President and CEO Wendy Young.

"Manufacturing the world's best gears has always been the company's focus – Brad will help take our sales efforts to that same level," says Young. "Our sales representatives, and the customers they serve, will benefit greatly from Brad's hands-on approach, as he works to strengthen existing customer relationships and build new ones." (*www.forestcitygear.com*)

Index

HIRES SERVICE MANAGER

Index has announced the hiring of **Matt Voyles** for the role of service manager. In his position, Voyles will be responsible for overseeing the 22 field service engineers that respond to customer needs across the US and Canada, as well as coordinating with personnel at Index's network of 19 distributors, many of whom provide service to customers as well.

The service manager role will be key to maintaining Index's current trajectory, as the company expands its service department to meet the needs of a growing customer base that has resulted from back-to-back record sales years in 2018 and 2019.

Voyles possesses over 20 years of manufacturing equipment service experience, first at Carl Zeiss and then with Makino/Single Source Technologies. He has been in a management role for nearly a decade, overseeing a service team that grew to include over 40 team members. Over the course of his career, he has established a strong competency for understanding the diverse needs of a large customer base and aligning resources to efficiently and effectively respond to those needs.

"Matt possesses a skill set that perfectly matches our needs as a rapidly growing organization," said Tom Clark, president and CEO of Index Corporation. "Over the past two years, Index has expanded our team in the US and Canada by 25 people, a 40% increase, to meet the growing customer demand for advanced machine tools. Managing a team that is undergoing that rate of growth requires unique skills and talents, and Matt's experience and expertise make him the perfect individual for this role."

(*www.index-usa.com*)

Cloyes Gear

MAINTAINS MANUFACTURING EXCELLENCE WITH ARKANSAS PLANT PURCHASE

After opening its Paris, Ark., manufacturing plant in 1963, Cloyes Gear and Products announced it has successfully regained ownership of the manufacturing operation from American Axle & Manufacturing (AAM). AAM held ownership of the plant following its 2017 acquisition of Metaldyne Performance Group Inc. (MPG), which included Cloyes. In April 2018, Hidden Harbor Capital Partners, an operationally focused private equity firm specializing in control investments in lower middle market companies, acquired Cloyes and immediately started the process of purchasing the Paris plant to continue Cloyes' nearly 100-year-old manufacturing history in the United States.

"Cloyes came to Paris in 1963 and has been a big part of the town's economy for more than 56 years. Many of our employees have worked for Cloyes their entire adult life and have more than 30 years of seniority with the company," said Steve Fairbanks, vice president of manufacturing for Cloyes. "It is a huge advantage for our company to be able to stay in this area and retain our employees' skill set and wealth of knowledge. It is also a great opportunity for the town to maintain high paying manufacturing jobs, which coincidently are closely linked to jobs that our local career center is preparing our young and upcoming workforce for."

The 155,00-square-foot manufacturing plant manufactures highly machined powertrain gears, sprockets, and idler assemblies for automotive original equipment manufacturers, the automotive aftermarket, marine, and high-performance applications. The plant's key processes include machining, hobbing and shaping, heat treatment, and finishing, and is also home to a quality and metrology laboratory that supports both manufacturing and engineering product development.

"Our team is focused on growing the Cloyes brand and business which is evident with our continued investments in marketing, sales personnel, global expansion, manufacturing and

overall operations," said John Bohenick, chief executive officer for Cloyes. "Cloyes, the management team, and the owners are committed to our customers, the communities we work and live in, our people, and to the betterment of the industries we serve. We will continue to work to be a leading supplier by providing exceptional products, quality, and service to all customers." (*www.cloyes.com*)

Hy-Tech Engineered Solutions

ACQUIRES BOTH BLAZ-MAN AND GEAR PRODUCTS & MANUFACTURING

Hy-Tech Engineered Solutions is pleased to announce the acquisition of Blaz-Man Gear and Gear Products & Manufacturing; both Chicago based companies specializing in the manufacture and distribution of custom gears and power transmission gear products. The addition will triple Hy-Tech's capacity in gear production, as well as bring new expertise to expand into more complex spiral and straight bevel gear design and manufacture.

"Aside from the advantages this brings to new and existing customers in terms of expanded gear product availability, additional gear design engineering know-how and improved responsiveness, we expect it to help lower costs across the board as the new economies of scale come into play" observes Doug Ciabotti, Hy-Tech's president. "Adding Blaz-Man and Gear Products means we can better address the needs of dozens of industries for highly engineered gearing, design consulting and reverse engineering".

"We're most excited about our expanded capability to handle complex spiral, straight and hypoid bevel gearing applications which have traditionally been difficult to design and manufacture. Combining this bevel gear expertise with our dedicated production capacity for rush and breakdown requirements, as well as for "one-off" special orders, allows us to be a full-service partner to our customers, offering them complete gear solutions".

The new companies will operate together with Hy-Tech's current gear company, Quality Gear, forming a new "Power Transmission Division" in Punxsutawney, PA. (*www.hy-techinc.com*)

Emuge

HOSTS GRAND OPENING OF EXPANDED MANUFACTURING FACILITY

Emuge Corp. held a Grand Opening ceremony of its significantly expanded, custom-designed manufacturing facility on October 15, 2019. Marking a 35-year presence in the U.S. along with increased growth in North America, the Emuge expansion includes more manufacturing and tool reconditioning space, the addition of a new PVD coating center as well as an expanded Technology and Training Center. The expanded facility doubles the size of the original building to over 50,000 square feet total.

Over 150 attendees joined Emuge to celebrate the occasion. The Grand Opening featured a formal ribbon cutting, a special unveiling of a statue of Emuge Founder Richard Glimpel, a full facility tour and live machining technology demonstrations. The impressive gathering demonstrated the importance of retaining and growing manufacturing technology in Massachusetts and the U.S.A.

"The expansion will allow us to better serve our customer base in the U.S. and Canada," said Bob Hellinger, president of Emuge Corp. "The growth we have experienced in our aerospace and power generation customer base has been significant in the past few years. The expanded facility will provide additional capacity to domestically manufacture special solid carbide tooling and other standard solutions within our milling tools portfolio."

Thomas Zeus (left) congratulates Bob Hellinger, Emuge president (right).

Hellinger added, "Our facility expansion will also allow us to continue our commitment to creating jobs in Massachusetts. We project to add 25 to 30 new employees over the next five years to our current roster of 75. I would also like to take the opportunity to thank all our employees who made this happen, and with special thanks to the Glimpel Family, owners of Emuge-Franken, for making this expansion a reality."

Emuge executives were joined by officials including John Killam, president/CEO for the Massachusetts Manufacturing Extension Partnership (MassMEP) who made remarks at the Grand Opening. "I would like to extend my congratulations to Emuge Corp. for its impressive facility expansion as well as its progressive employee training program. The Company is an excellent example of the importance of investing in its employees and why Massachusetts leads the nation in innovation," said Killam.

The expansion construction began in September 2018 and accelerated rapidly throughout 2019. Emuge currently has tool reconditioning capabilities in West Boylston for taps, end mills and drills, combined with the ability to manufacture tools such as spot drills, chamfer mills, carbide end mills, carbide special tooling, carbide step drills and make other round tool modifications. (*www.emuge.com*)

Gear Motions

ANNOUNCES PERSONNEL CHANGES

Gear Motions announces the promotion of **Brittany McVea Dankiw** to manufacturing engineer, and the new hire of **Kris Gardner** as customer service/purchasing coordinator at its Nixon Gear Division in Syracuse, NY.

Dankiw has been a member of the team at Nixon Gear for nearly five years, previously serving as customer service/purchasing coordinator. When the need arose to add a member to the growing engineering team, Brittany was the obvious choice and was recently promoted to manufacturing engineer.

Dankiw's engineering education includes a B.E. in mechanical engineering and a US Coast Guard 3rd Assistant Engineer License from SUNY Maritime. Here, she gained experience working in the ship's engine room and developed skills in troubleshooting and problem solving. Her previous work experience also includes testing and design engineering for gears and gearboxes. She is currently furthering her training to become more proficient in the areas of gear and manufacturing engineering to help her succeed in her new role. As manufacturing engineer, Dankiw will help to improve processes and productivity in all areas of manufacturing, including streamlining and reducing waste.

Additionally, Gardner was hired to fill the role of customer service/purchasing coordinator.

Gardner brings many years of experience that will help him excel in his new role. He earned a B.S. in business management from SUNY Oswego in 2015, and most recently held a purchasing position as a contract administrator for government contracts. He also has experience in warehouse operations management and as a machine/heavy equipment operator at

Novelis in Oswego, NY. Everyone at Nixon Gear is excited to have Gardner on board and is confident he will do a wonderful job working with customers and vendors to provide excellent service. (*gearmotions.com*)

NIMS

LAUNCHES FIRST-EVER INDUSTRY RECOGNIZED CAM CREDENTIALS

The National Institute for Metalworking Skills (NIMS) is now offering standardized Computer Aided Manufacturing (CAM) credentials, CAM Milling and Turning. "The CAM field continues to grow and is expected to create almost 100,000 new programmer, designer, and engineer jobs by 2024," said NIMS Executive Director Montez King. "It is imperative that people entering the field are properly trained and capable, and these credentials show a potential employer that applicants are ready to program CNC machine tools. Further, employees already on the job may wish to secure an official, portable, industry-recognized certification."

The new credentials are based on standards developed in partnership with and sponsored by Autodesk, a leader in 3D design and engineering software. Over 125 subject matter experts from organizations such as CNC Software, developer of Mastercam; Barefoot CNC; Arkansas State University Mid-South; CamInstructor, and custom machining technology leader, Rosenburger of North America, volunteered their insight during the rigorous development and piloting process of the standards.

Throughout the development process, field experts, within their technical work groups, identified the skills expected for entry-level CAM positions. As a result, these standards now define necessary competencies associated with job preparation, modeling, toolpath generation, documentation, written oral communication, machining mathematics, decision making and problem solving, social skills and personal qualities, engineering drawings and sketches, computer operations, and technologies.

"CAM is the first set of NIMS credentials to use our new Performance Measure (PM) Development Requirements for the hands-on component of the credential," said King. "The new model will allow schools and employers to customize their credentialing experience by using their own projects to validate performance for NIMS credentials as long as they meet the minimum NIMS requirements."

Manufacturing companies are expected to benefit greatly by having properly trained CAM programmers, designers, and engineers. As cycle times decline, material waste and machining errors decrease, and the quality of parts increases with more capable personnel. It is predicted that individuals trained according to these standards will be in high demand in coming years. (*www.nims-skills.org*)

Mitutoyo America

ANNOUNCES PARTNERSHIP WITH TITANS OF CNC

Mitutoyo America Corporation is pleased to announce a sponsorship agreement with Titans of CNC, a free project-based education platform that helps guide students and teachers on CNC machine operation and programming. The Academy provides over 3,000 free online courses in CAD, CAM and CNC machining techniques, and is now used by over 45,000 members in 170 different countries.

Mitutoyo metrology products will be featured in both the Titans of CNC show airing on Titan TV and will be utilized on Titan CNC Academy videos for demonstration purposes.

"As a leader in the field of precision metrology, Mitutoyo America is excited to partner with Titans of CNC Academy. We look forward to supporting skill development in US manufacturing by providing metrology experience and leading technology to the Titans of CNC team," says Matt Dye, president of Mitutoyo America Corporation.

Titans of CNC will highlight Mitutoyo products through video tutorials in Gilroy's personal manufacturing facility located in Rocklin, CA. These videos, along with other content, will be featured on Titans of CNC social media platforms including YouTube, Facebook, Twitter and Instagram.

Some of the Mitutoyo equipment featured will include: a MiSTAR Shop Floor CMM, Quick Image Vision System, SJ-200/400 Surface Roughness Tester, LH-600 Linear Height Gage, QuantuMike/QuickMike coolant proof micrometers, coolant proof calipers, U-Wave T and U-Wave FIT, MeasurLink 9 Data Management System, and other Mitutoyo metrology instruments and software.

Titans of CNC was started by Titan Gilroy as a CNC machine shop in Northern California focused on making the most difficult parts in aerospace. The company transitioned into a massive reality TV series as a world-first CNC educational platform recognized by a global network of engineers, machinists, hobbyists, students and educators.

"We are excited to officially partner with Mitutoyo," says Titan Gilroy, CEO, Titans of CNC, Inc. "Our mutual focus on educating the next generation of manufacturing professionals will not only inspire, but will also give practical knowledge of inspection practices to all." (*www.mitutoyo.com*)

Gear Technology's Statement of Ownership, Management and Circulation

Additional information about *Gear Technology* and its audience can be found in our 2020 media kit. Download it at *www.geartechnology.com/adinfo.htm*

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Statement of Ownership, Management, and Circulation (Requester Publications Only)

1. Publication Title	2. Publication Number	3. Filing Date
GEAR TECHNOLOGY , the Journal of Gear Manufacturing	0 7 4 3 - 6 8 5 8	October 1, 2019
4. Issue Frequency	**5. Number of Issues Published Annually**	**6. Annual Subscription Price (if any)**
Monthly except Feb., Apr., Oct., Dec.	8	$70.00

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PS Form **3526-R**, July 2014 (Page 1 of 4 (See instructions page 4)) PSN: 7530-09-000-8855 **PRIVACY NOTICE:** See our privacy policy on www.usps.com.

13. Publication Title	14. Issue Date for Circulation Data Below
GEAR TECHNOLOGY, the Journal of Gear Manufacturing	AUGUST 2019

15. Extent and Nature of Circulation			Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies (Net press run)			10,715	11,265
b. Legitimate Paid and/or Requested Distribution (By mail and outside the mail)	(1)	Outside County Paid/Requested Mail Subscriptions stated on PS Form 3541. (Include direct written request from recipient, telemarketing, and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)	4,694	4,104
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	(4)	Requested Copies Distributed by Other Mail Classes Through the USPS (e.g., First-Class Mail®)	-	-
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f. Total Distribution (Sum of 15c and e) ▶			10,415	10,965
g. Copies not Distributed (See Instructions to Publishers #4, (page #3)) ▶			300	300
h. Total (Sum of 15f and g)			10,715	11,265
i. Percent Paid and/or Requested Circulation (15c divided by 15f times 100) ▶			50%	41%

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PS Form **3526-R**, July 2014 (Page 2 of 4)

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16. Electronic Copy Circulation	Average No. Copies Each Issue During Previous 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Requested and Paid Electronic Copies ▶	4,090	4,033
b. Total Requested and Paid Print Copies (Line 15c) + Requested/Paid Electronic Copies (Line 16a) ▶	9,254	8,551
c. Total Requested Copy Distribution (Line 15f) + Requested/Paid Electronic Copies (Line 16a) ▶	14,474	14,998
d. Percent Paid and/or Requested Circulation (Both Print & Electronic Copies) (16b divided by 16c × 100) ▶	64.3%	57%

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17. Publication of Statement of Ownership for a Requester Publication is required and will be printed in the November/December 2019 issue of this publication.

18. Signature and Title of Editor, Publisher, Business Manager, or Owner — Date
Michael Goldstein, Publisher & Editor-in-Chief — 10-1-19

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

PS Form **3526-R**, July 2014 (Page 3 of 4) **PRIVACY NOTICE:** See our privacy policy on www.usps.com.

December 3–5—AGMA Epicyclic Gear Systems: Application, Design and Analysis Seattle, Washington. Learn and define the concept of epicyclic gearing including some basic history and the differences among simple planetary gear systems, compound planetary gear systems and star drive gear systems. Cover concepts on the arrangement of the individual components including the carrier, sun, planet, ring and star gears and the rigid requirements for the system to perform properly. Critical factors such as load sharing among the planet or star gears, sequential loading, equal planet/star spacing, relations among the numbers of teeth on each element, calculation of the maximum and optimum number of planet/star gears for a specific system will be covered. This session provides an in-depth discussion of the methodology by which noise and vibration may be optimized for such systems and load sharing guidelines for planet load sharing. The instructor is Raymond Drago and Steve Cymbala. For more information, visit *www.agma.org*.

December 9–12—CTI Symposium Germany 2019 Berlin, Germany. CTI Symposium Germany provides the latest automotive transmission and drive engineering for passenger cars and commercial vehicles. The international industry event delivers the appropriate platform to find new partners for purchase and sales of whole systems and components. Automobile manufacturers, transmission and component companies give an overview and outlook on technical and market trends including digital manufacturing, IoT, zero-emissions, electric vehicles, hybrid transmissions and more. Speakers include representatives from Porsche, Volkswagen, StreetScooter, Continental, BorgWarner, Magna Powertrain and more. For more information, visit *https://drivetrain-symposium.world/*.

January 6–10—SciTech 2020 Orlando, Florida. From its creation in 1963, the American Institute of Aeronautics and Astronautics (AIAA) has organized conferences to serve the aerospace profession as part of its core mission. Spanning over 70 technical discipline areas, AIAA's conferences provide scientists, engineers, and technologists the opportunity to present and disseminate their work in structured technical paper and poster sessions, learn about new technologies and advances from other presenters, further their professional development, and expand their professional networks that furthers their work. Five focus areas include science and technology, aviation, space, propulsion and energy/defense. For more information, visit *https://scitech.aiaa.org/*.

January 13–15—A3 Business Forum 2020 Orlando, Florida. The Association for Advancing Automation (A3) Business Forum is the world's leading annual networking event for robotics, vision & imaging, motion control, and motor professionals. Over 650 global automation leaders attended the 2018 show. The event includes keynote and breakout sessions on the human exploration of Mars, a global economic outlook, automation market update, trends in robotics, responsible artificial intelligence and others to be announced. Networking opportunities include a golf scramble, a wellness walk, and a first timer's reception. For more information, visit *www.a3automate.org*.

January 28–30—AGMA Gear Manufacturing and Inspection Garden Grove, California. Attendees will discover key factors in the inspection process that lead to better design of gears, develop a broad understanding of the methods used to manufacture and inspect gears and interpret how the resultant information can be applied and interpreted in the design process. The class will be from 8:00 am–5:00 pm each day. This course also includes a tour of Western Precision Aero in Garden Grove, CA. Participants will be required to fill out paperwork prior to the tour and must be US citizens. AGMA will distribute the paperwork upon registration. Gear design engineers, management involved with design, maintenance, customer service, and sales should consider attending the event. Ray Drago, chief engineer of Drive Systems Technology, Inc., will be the instructor. For more information, visit *www.agma.org*.

January 28–30—IPPE 2020 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. Combining the expertise from the American Feed Industry Association, North American Meat Institute and U.S. Poultry & Egg Association, IPPE will also feature more than 200 hours of dynamic education sessions focused on the latest industry issues. The International Production & Processing Expo (IPPE) is a collaboration of three shows—International Feed Expo, International Meat Expo and the International Poultry Expo—representing the entire chain of protein production and processing. For more information, visit *ippexpo.org*.

February 3–7—World of Concrete 2020 Las Vegas, Nevada. Original equipment manufacturers from around the world and exclusive U.S. distributors of equipment, tools, products and services for the commercial construction, concrete and masonry industries attend World of Concrete. The show attracts approximately 1,500 exhibitors and occupies more than 700,000 net square feet of indoor and outdoor exhibit space. World of Concrete is the premier event for the commercial construction trades. Education tracks include engineering, safety and risk management, general business, business and project management and concrete 101. Interactive workshops include trainer training, construction boot camp, sales and more. For more information, visit *www.worldofconcrete.com*.

February 18–20—AGMA Fundamentals of Worm and Crossed Axis Helical Gearing Alexandria, Virginia. Provides an introduction and emphasize the differences between parallel (the experience base) axis and worm and crossed axis helical gears. Describe the basics of worm and crossed axis helical gears, their fundamental design principals, application guidelines and recommendations, lubrication requirement, a discussion of accuracy and quality and summarize with a brief review of common failure modes. Class will take place at AGMA Headquarters and class times will be 8:00 am–5:00 pm each day. The course will be instructed by William "Mark" McVea, president and principal engineer at KBE+, Inc. For more information, visit *www.agma.org*.

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A Look at Mechanical Principles

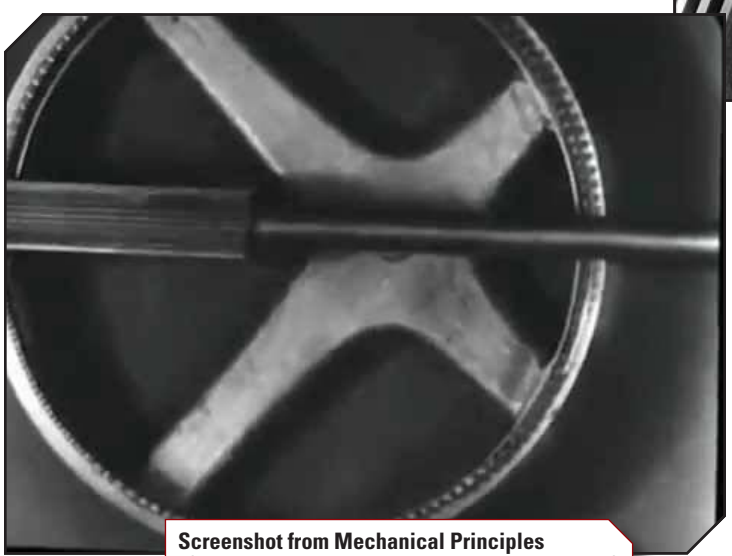
Photographer/filmmaker Ralph Steiner made poetry out of a simple short film on machine components in the 1930s

Matthew Jaster, Senior Editor

Ralph Steiner (1899–1986) had a vision. It was unlike other photographers and filmmakers of his time. Browsing through some of his work, it's easy to see that the man had an eye for patterns, abstract compositions, odd shapes and the engineering behind ordinary household items.

A documentary filmmaker, photographer and pioneer of the avant-garde film movement in the 1930s, Steiner originally studied chemistry at Dartmouth, but changed his career path by entering the Clarence H. White School of Modern Photography in 1921. He first worked as a freelance photographer in advertising and for publications like the *Ladies Home Journal*.

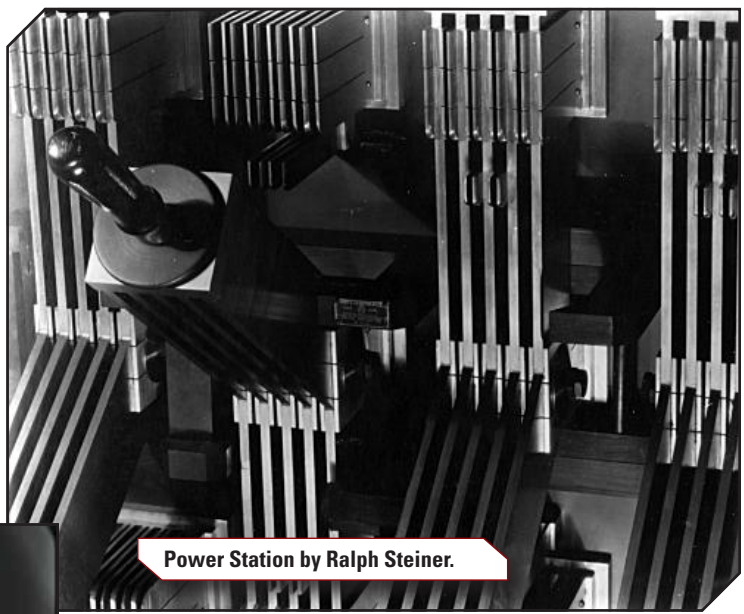
In 1929, Steiner made the documentary film *H2O*, a silent film showing water in many different forms — from flowing naturally down a river to zipping through a pipe in the city. Steiner went on to create the famous documentary film *The City* with Willard Van Dyke for the New York World's Fair of 1939. The film examined the problems of the contemporary urban environment due to industrialization, pollution and overcrowding. Later in life, Steiner would produce and direct experimental films like the *Joy of Seeing* which focused on an incredibly diverse range of themes focusing on everything from seaweed to laundry.



Screenshot from Mechanical Principles
(All photos courtesy of the Library of Congress)

Gear Tech readers will be interested to learn that he created a short abstract film in 1930 called *Mechanical Principles*, a documentary based entirely on the movement of mechanical elements. An excerpt on the film from *www.faena.com* described it like this:

"Cogs and pistons move with graceful fluidity, making their geometric forms become living and functioning organs. The hypnotic dance of the gears is masterfully captured by Steiner and effectively underscored by the music of Eric Beheim. Before our eyes, the camera performs the conjuring act of giving real life to artificially created movement. As if cinema itself saw itself in a mirror for self-validation."



Power Station by Ralph Steiner.

Yes, it's artsy. It's avant-garde. But you can't argue that there's not something hypnotic about the way mechanical machines move. Several filmmakers/engineers/designers have posted excerpts from the film online accompanied by everything from classical to electronic and industrial music. Some prefer watching the gears move to the music of Claude Debussy, others to Duke Ellington or David Bowie.

One example can be found here: *www.youtube.com/watch?v=mkQ2pXkYjRM*.

Whether shooting images of old Camel cigarette billboards or a black and white maze of ham and eggs, Steiner certainly had his own point of view and transformed rudimentary objects like typewriter keys, clotheslines, rocking chairs and fire escapes into compelling, historic slices of urban and rural Americana. *Mechanical Principles* was his vision of the future, a vision of motion, machines, movement and uncertainty — as relevant in 2019 as it was back in 1930.

Steiner's work has appeared in the J. Paul Getty Museum in Los Angeles, the Museum of Modern Art in New York and most recently at a photography exhibition at the Haggerty Museum of Art in Milwaukee. (April 2019).

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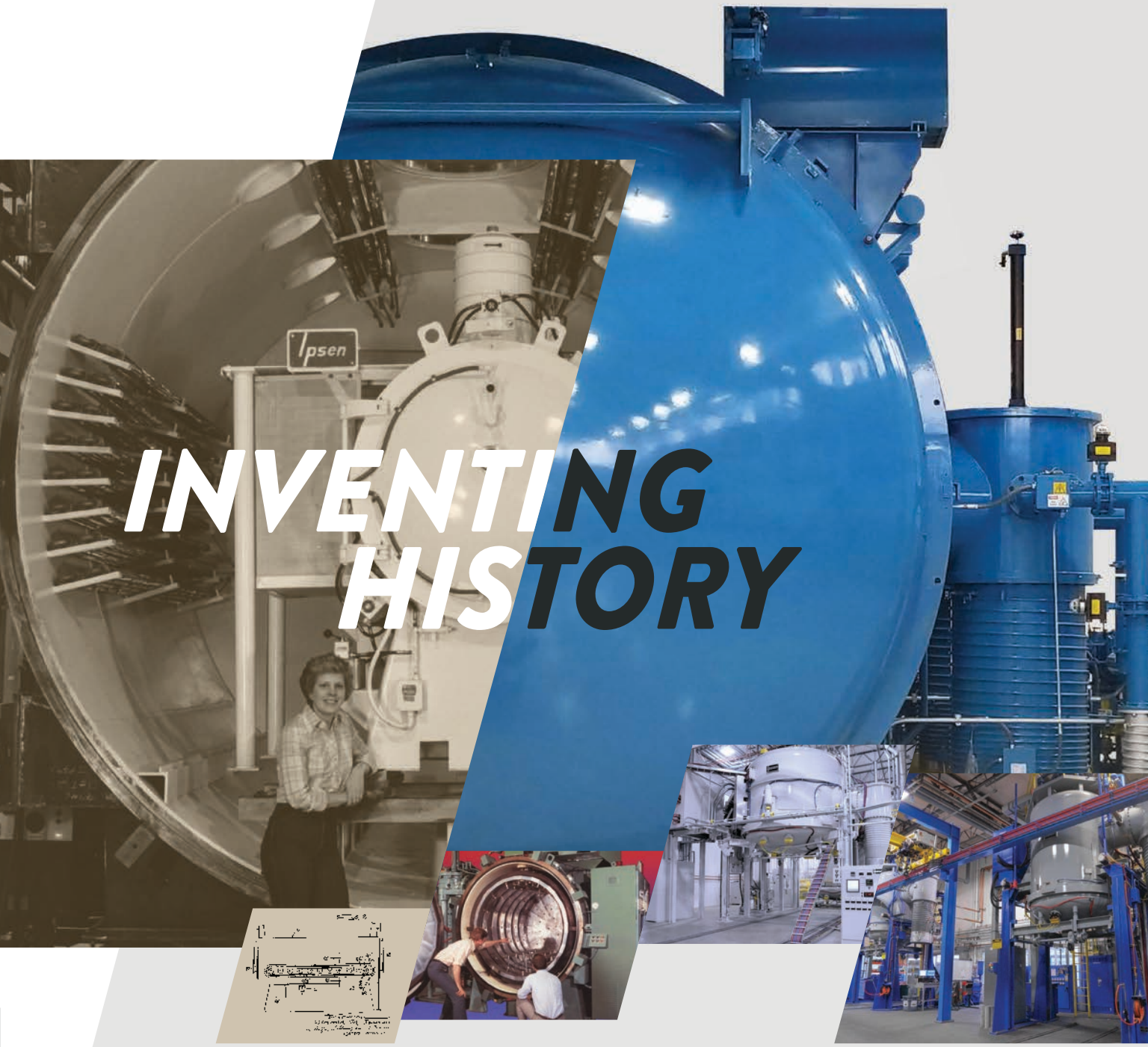

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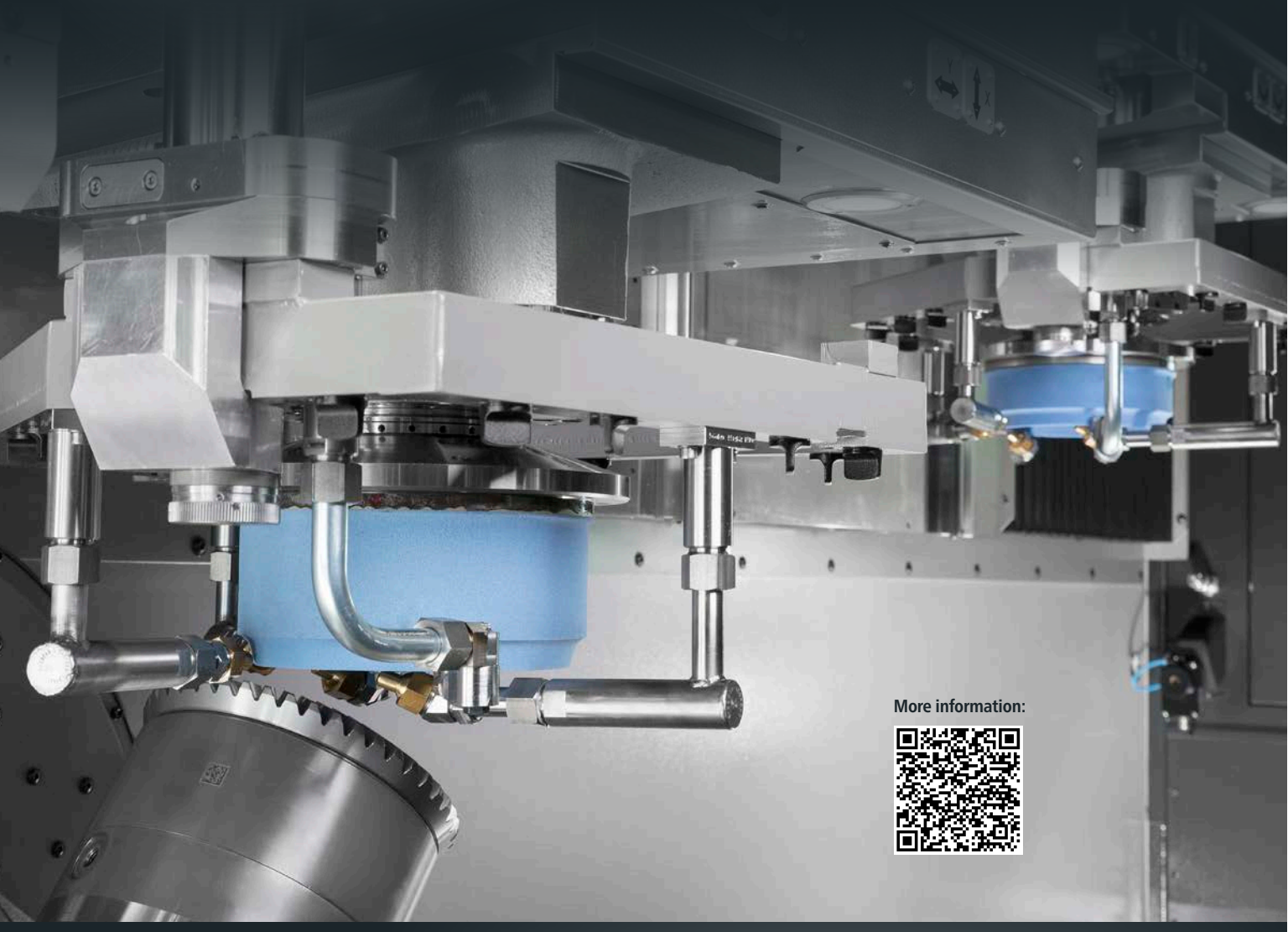

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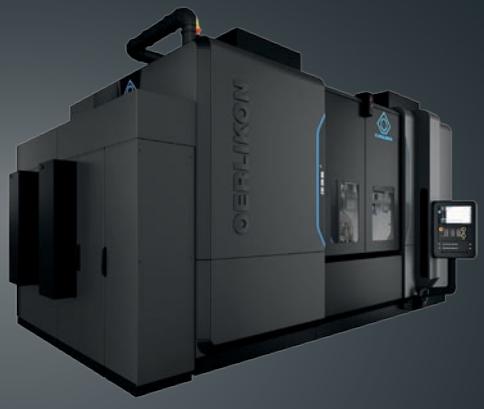

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