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www.star-su.com
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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 skiving³ the delivery of an integrated solution for the customer is of primary interest. Skiving³ 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 LHe@rTec control system.

Machine
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• Deburring and tool changer
• Stiffness

Tool
• Design
• Manufacturing
• Reconditioning

Process
• Technology design
• Implementation
• Optimization
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-

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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To: Yours
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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.

Michael Goldstein
BIG BANG for your buck.

KAPP NILES KN³3P gear profile grinding

Installation and set-up in a blink!
The KN³3P comes with machine mounted electrical panel and is easily accessible. New KN³Grind software graphically guides you through applications.

Not rocket-science to operate! Well-known KAPP NILES quality.
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 to control the manufacturing process in 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
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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
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

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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 1/8" × 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

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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
GMS200 Skiving Machining Center
for Gears

- High Efficiency Gear Skiving & Integrated Processing for Reduced Production Time
- Superior Workability & Operability

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DTR is a world class supplier of the finest high performance long-life gear manufacturing tools, for small and large gear cutting applications. Established in 1976, we are one of the world’s largest producers of cutting tools, shipping to over 20 countries.

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

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

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Learn more about our outstanding quality tools at www.dtrtool.com. Call us at 847-375-8892 for your local sales representative or Email alex@dtrtool.com for a quotation.

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All the Gear Cutting Tools You Will Ever Need Are Right Here

DTR is one of the world’s largest producers.

higher temperature ranges, heat treat-
ers can expect faster cycle times which translates into a more productive work center.”

For more information: Seco/Warwick
Phone: (814) 332-8400
www.secowarwick.com

Vomat

RELEASES UBF FILTRATION SYSTEM

The Vomat UBF concept is a vacuum band filter equipped to handle a wide variety of sludge materials, such as ceramic, HSS, brass, aluminum oxide, disc abrasion and more. It operates with oil as well as water-miscible coolants. If necessary, it can be combined with a Vomat fine filtration unit. It is currently available in three sizes with the following filtration capacities: 110 Gal./Min., 264 Gal./Min. and 528 Gal./Min. As with all Vomat designs, the UBF system has a small footprint for its capacity. Vomat filtration systems are distributed by Oelheld in the United States.

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
German Machine Tools of America

4630 Freedom Drive Ann Arbor, MI 48108   734-973-7800 info@gmtamerica.com

The gear skiving machine is a vertical configuration, with the patented Scudding® head design and capable of machining 150mm (5.90”) diameters both internal and external. Equipped with a Heidenhain encoder/resolver assembly and Siemens top-end CNC, this new machine features opposing workpiece and work tool spindles, A6 and HSK standard. With AC servo motor drive on both X and Y axes, this sturdy performer offers a small footprint with BIG production capacity, all at a fraction of the price of a conventional broaching machine.

Call Walter (again, if you asked the secret previously) and he’ll tell you all about this game-changing machine tool for the North American gear industry.

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 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.

GEAR TECHNOLOGY | November/December 2019

[www.geartechnology.com]
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
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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.

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 change 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.

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.
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 electromobility 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.
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.
“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  
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**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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About This Directory
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.

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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/

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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.

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www.cdtusa.net
D.C. Morrison Company
www.dcmorrison.com

P37
DTR Corp. (formerly Dragon Precision Tools)
1865A HICKS ROAD
ROLLING MEADOWS IL 60008
Phone: (847) 375-8892
Fax: (224) 230-1131
alex@dragon.co.kr
www.dragon.co.kr

Danthal Tool & Gauge Co. Ltd.
www.danthal.co.uk

Diametal AG
www.diametal.ch

Dianamic Abrasive Products Inc. www.dianamic.com

ESGI Tools Pvt. Ltd.
esgtools.com

Eagle Tool Company Inc.
www.eaglebroach.com

Etto Tool Corp.
www.ettool.com

Etro Services, Inc.
www.etroservices.com

Emuge Corp.
www.emuge.com

Engineered Tools Corp.
www.eltroservices.com

Eltool Corp.
www.eltool.com

Dianamic Abrasive Products Inc.
www.dianamic.com

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Dianamic Abrasive Products Inc.
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Dianamic Abrasive Products Inc.
www.dianamic.com

Dianamic Abrasive Products Inc.
Permanent Steel Manufacturing Co., Ltd.  
www.permsteel.com
Philadelphia Carbide Co.  
www.philcarbide.com
Pinpoint Laser Systems  
pinpointlaser.com
Pioneer Broach Co.  
www.pioneerbroach.com
PlasmaRoute CNC  
www.cnclasers.com
Polygon Solutions  
www.polygonsolutions.com
Productivity Inc.  
www.productivityinc.com
QC American  
www.qcamerican.com
R.A. Heller  
www.raheller.com
Rotec Tools Ltd.  
www.rotectools.net
Russell Holbrook & Henderson  
www.tru-automotive.com
S.S. Tools  
www.sstools.net
SU (Shanghai) Machine & Tools Co., Ltd.  
www.samputensili.com
SWG Solutions  
www.swgsolutions.com
Saatz  
www.saatz.de
Samputsenili S.p.A.  
STAR SU LLC  
5200 PRAIRIE STONE PARKWAY  
HOFFMAN ESTATES IL 60192  
Phone: (847) 649-1450  
Fax: (847) 649-0112  
www.samputsenili.com
Sandvik Coromant  
www.sandvik.coromant.com
Schnyder SA  
JAKOBSTRASE 52  
CH-2504 BIEL  
SWITZERLAND  
Phone: (+41)(32) 344-0404  
Fax: (+41)(32) 344-0404  
george.boon@schnyder.com  
www.schnyder.com
Seco Tools Inc.  
www.secostools.com/us
Shape-Master Tool Company  
www.shapemaster.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: (248) 649-1450  
Fax: (248) 649-0112  
www.starcutter.com
Star SU LLC  
5200 PRAIRIE STONE PARKWAY, SUITE 100  
HOFFMAN ESTATES IL 60192  
Phone: (847) 649-1450  
Fax: (847) 649-0112  
www.star-su.com
Steelmans Broaches Pvt. Ltd.  
www.steelmans.com
Sunnen Products Company  
www.sunnen.com
Super Hobs & Broaches Pvt. Ltd.  
www.suppertools.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.watkins-mfg.com
West Michigan Spline Inc.  
www.wmsplines.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.geartechtechnology.com.

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

Accurate Specialties Inc.  
www.accuratespecialties.com
Aksan Steel Forging  
www.aksanforging.com
All Metals & Forge Group, LLC  
www.steelforge.com
American Friction Welding  
www.amfw.com
Amorphology  
145 N. ALTAGEÑA DRIVE  
PASADENA CA 91107  
www.amorphology.com

Anahas Castings  
www.anahas.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.brookebrothersforgings.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.nitrogengenerator.com
Concast Metal Products  
www.concast.com
Cornell Forge  
www.cornellforge.com
Cruccible Industries LLC  
www.cruccible.com
DSM Engineering Plastics  
www.dsm.com
Dayton Forging and Heat Treating  
www.daytonforging.com
Deco Products Company  
www.decorprod.com
DuPont  
www.dupont.com
Dura-Bar  
www.dura-bar.com
Earle M. Jorgensen Co.  
www.ejorgensenco.com
ElectroHeat Induction  
www.electroheatinduction.com
Elwood City Forge  
www.elwoodcityforge.com
Erasteel Inc.  
www.erasteel.com
Eutectix, LLC  
www.eutectix.com
Excel Gear  
www.excelgear.com
Fomas USA  
www.fomasgroup.com
Forging Solutions LLC  
www.forging-solutions.com
Fox Valley Forge  
www.foxvalleyley Forge.com
Fuji Machine America Corp.  
www.fujimachineamerica.com
Galaxy Sourcings Inc.  
www.galaxysourcings.com
Guven Bronz Metal  
www.guvenkomuri.com
Hunter Chemical LLC  
www.hunterchemical.com
IMT Forge Group including Clifford-Jacobs Forge  
www.imtforgegrup.com
Intech Corporation  
www.intechpower.com
Interstate Tool Corp.  
www.itcgroup.com
Kuraray America, Inc.  
www.kuraray.com
Laision Tools Corporation  
www.laisoncuttingtools.com
Larson Forgings  
www.larsonforgings.com
Mackell Ipsat & Forging Ltd.  
www.mackellforging.com
Maguire Technologies  
www.maguiretech.com
Martin Tool & Forge  
www.martinsprocket.com
Masteremet Ltd.  
www.mastermet Ltd.
Maxwell Tools Co. USA  
www.maxwelltools.com
McINNES ROLLED RINGS
1533 EAST 12TH STREET
ERIE PA 16511
Phone: (814) 569-1420 or (814) 459-4495
Fax: (814) 459-8443
sales@mcrings.com
mcinnesrolledrings.com

McKees Rocks Forgings
www.mckeesrocksforgings.com

Midwest Thermal-Vac Inc.
www.mtvac.com

Moore-Addison Precision Plastic Blanking
www.mooreadison.com

Mosey Manufacturing Co. Inc.
www.moseymfg.com

National Bronze Mfg. Co.
www.nationalbronce.com

Ovako AB
www.ovako.com

PKC Buderus India
www.pkcbuderus.com

Parag Casting Co.
www.paragcasting.com

Patriot Forge
www.patriotforge.com

Pentcton Foundry Ltd.
www.pentctonfoundry.com

Permanent Steel
www.permanentsteel.com

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

Perry Technology Corporation
www.perrygear.com

Presrite Corporation
3665 E. 78TH STREET
CLEVELAND OH 44106
Phone: (216) 441-4990
Fax: (216) 441-2844
www.presrite.com

QSC Forge & Flange
www.qscforge.com

QuesTek Innovations LLC
www.ques tek.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.sampotensui.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

Timken Steel Corporation
www.timkensteel.com

UMC - United Metals Co.
www.umcmetal.com

United Cast Bar, Inc.
www.unitedcastbar.com

Viking Forge
www.vikingforge.com

Voestalpine High Performance Metals
www.voestalpine.com

Walker Forge
www.walkerforge.com

Wiggins Mfg. Inc.
www.wigginsmfg.com

Willman Industries Inc.
www.willmanind.com

Yarde Metals
www.yarde.com

Yash International
www.yash工具s.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.acccutdiamond.com

AccuBrass
www.accubrass.com

Acme Manufacturing Co.
www.acmenfg.com

Advico
www.advico.co.uk

Affolter
www.roketools.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.btsbroaching.com

BUDERUS Schleiftechnik GmbH
www.buderus-schleiftechnik.de

Banyan Global Technologies LLC
www.banyang.com

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

Bates Technologies, LLC
www.batesstechnology.com

Becker GearMeisters, Inc.
www.maguarmachines.com

Blackbox Technologies
www.blackboxtech.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

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.
cdmachines.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.
40409 PLYMOUTH OAKS BLVD.
PLYMOUTH MI 48170
UNITED STATES
Phone: (734) 636-2073
Fax: (734) 636-2091
ralf.georg.eitel@dvs-technology.com
www.dvs-technology.com

DVS Universal Grinding GmbH
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.dpg.ch

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

EMAG LLC.
www.emag.com

Electronics Inc.
www.electronics-inc.com

Eltro Services, Inc.
www.eltronline.de

Engineered Abrasives
www.engineeredabrasives.com

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

FGG - 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

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**CATEGORY LISTINGS**

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 Kessel GmbH & Co. KG  
www.kessel.com

**German Machine Tools of America**  
4630 FREEDOM DRIVE  
ANN ARBOR MI 48108  
Phone: (734) 973-7800  
Fax: (734) 973-3063  
info@gmtamerica.com  
www.gmtamerica.com

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

Gleason Works (India) Private Ltd.  
PLOT NO. 37  
DODDANAKUNDU INDUSTRIAL AREA  
WHITEFIELD ROAD, MAHADEVPURA  
BANGALORE 560 048  
INDIA  
Phone: 011-91-80-2850-4376/15/16/91  
www.gleason.com

Goldstein Gear Machinery LLC  
www.goldstingearmachinery.com

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

Greg Allen Company  
www.gallenco.com

HÖFLER - A Brand of KLINGBELNBERG  
www.hoefler.com

HARO Technologies  
harrotechnologies.com

Haas Multigrind LLC  
www.multigrind.com

Hamai Co. Ltd.  
www.hamai.com

Hankik Machine Corp.  
201 E. OGDEN AVE., SUITE 34  
HINSDOLE IL 60177  
Phone: (773) 470-8278  
Fax: (773) 316-2158  
info@hankikcorp.com  
www.hankikcorp.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  
635 SCHNEIDER DRIVE  
SOUTH ELGIN IL 60177  
Phone: (847) 851-4121  
Fax: (847) 931-4192  
sales@koepferamerica.com  
www.heliosgearproducts.com

Heller Machine Tools  
www.heller-machinetools.com

IMPCO Microfinishing  
www.impeco.com

ITW Heartland  
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.itmll.com

Involute Gear & Machine Company  
www.involutegearmachine.com

J. Schneebberger Corp.  
www.schneebberger-us.com

JRM International, Inc  
www.jrminternational.com

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

James Engineering  
www.james-engineering.com

Kapp Technologies  
28/0 WILDERNESS PLACE  
BOULDER CO 80301  
Phone: (303) 447-1130  
Fax: (303) 447-1131  
info-USA@kapp-niles.com  
www.kapp-niles.com

Khema Broach & Spline Gauge  
www.khemabroach.com

Kinfac Corporation  
www.kinfac.com

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

Klingelnberg America Inc.  
118 E. MICHIGAN AVENUE, SUITE 200  
SALINE MI 48176  
Phone: (734) 429-2275  
Fax: (734) 429-2276  
info@klingelnberg.com  
www.klingelnberg.com

Klingelnberg GmbH  
PETERSSTRASSE 45  
HUECKESWAGEN 42499  
GERMANY  
Phone: +(49) 2192-81200  
Fax: +(49) 2192-81220  
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.leistritz.com

Liebherr America  
1465 WOODLAND DRIVE  
SALINE MI 48176  
Phone: (734) 429-2275  
Fax: (734) 429-2276  
info.lst@liebherr.com  
www.liebherr.com

Liebherr-Vorzahntechnik GmbH  
KAUFBEURER STRASSE 141  
D-87437 KEMPTEN  
GERMANY  
Phone: +(49) 831-7861279  
Fax: +(49) 831-7861135  
info.vt@liebherr.com  
www.liebherr.com

Machine Tool Builders  
7723 BURDEN ROAD  
MACHESNEY PARK IL 61115  
Phone: (815) 636-7560  
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.novagninders.com

Meister Abrasives USA  
www.meisterabrasives.com/USA

Miller Broach  
www.millerbroach.com

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

Mutschler Edge Technologies  
mutschleredgetech.com

Nachti America Inc.  
715 PUSHVILLE ROAD  
GREENWOOD IN 46143  
Phone: (317) 538-1001  
Fax: (317) 538-1011  
info@nachiamerica.com  
www.nachiamerica.com

Nagel Precision  
www.nagelusa.com

Normac, Inc.  
www.normac.com

ORT Italia  
www.ortitalia.com

Ohio Broach & Machine Co.  
www.ohiobroach.com

Okuma America Corporation  
www.okuma.com

PTG Holroyd  
www.ptgholroyd.com

Parker Industries Inc.  
www.parkerind.com

Penta Gear Metrology LLC  
www.pentagear.com

Prime Technologies  
www.gear-testers.com

QC American  
www.qacamerican.com

PRECO Inc.  
www.precoinc.com

PlasmaRoute CNC  
www.cncplasmacutterinc.com

Prime Programming  
www.prepriminginc.com

Prime Technologies  
www.gear-testers.com

Prime Technologies  
www.gear-testers.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.geartechfnology.com.

2L Inc.
www.2linc.com

3M Abrasives
www.3m.com/Abrasives

Abtec Corp.
www.abtec.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.batesitech.com

Brighton Laboratories
www.brightonlabs.com

CGW - Camel Grinding Wheels
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

Cleveland Deburring Machine Co.
cdmcmachine.com

Comco Inc.
www.comcoinc.com

Continental Diamond Tool Corporation
www.cdtusa.net

DTR Corp. (formerly Dragon Precision Tools)
1985A HICKS ROAD
ROLLING MEADOWS IL 60008
Phone: (847) 375-8892
Fax: (224) 220-1311
alex@dragon.co.kr
www.dragon.co.kr

DVS Technology America, Inc.
44099 PLYMOUTH OAKS BLVD.
PLYMOUTH MI 48170
UNITED STATES
Phone: (734) 656-2073
Fax: (734) 656-2091
info@dvs-tooling.de
www.dvs-tooling.de

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

Diametal AG
www.diametal.ch

Diamond Abrasive Products
www.diamondabrasiveproducts.com

Dianamic Abrasive Products Inc.
www.dianamic.com

Dr. Kaiser Diamantwerkzeuge
www.drkaiser.de

EGSI Tools Pvt. Ltd.
esgitools.com

FGF - Modul
www.fgf.de

Gear Resource Technologies Inc.
www.gear-resource.com
Klingelnberg AG
BÄNZNLEHERRSCHNEE 171
CH-8050 ZURICH
SWITZERLAND
Phone: (+41) 44-278-1594
Fax: (+41) 44-278-7979
info@klingelnberg.com
www.klingelnberg.com
Klingelnberg America Inc.
118 E. MICHIGAN AVENUE, SUITE 200
SALINE MI 48176
Phone: (734) 470-6274
Fax: (734) 316-2158
Klai.info@klingelnberg.com
www.klingelnberg.com
Klingelnberg GmbH
PETERSTRASSE 45
HUECKEWSAGEN 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
Lambda Technologies
www.lambdatechs.com
Liebherr America
1465 WOODLAND DRIVE
SALINE MI 48176
Phone: (734) 429-7225
Fax: (734) 429-2294
info.igt@liebherr.com
www.liebherr.com
Liebherr-Verzahnhtechnik GmbH
KAUFBEURER STRASSE 141
D-97427 KEMPTEN
GERMANY
Phone: (+49) 831-786-0
Fax: (+49) 831-7861279
info.igt@liebherr.com
www.liebherr.com
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
mutschleredge.org
NAXOS-DISKUS Schleifmittelwerke GmbH
WEBER-VON-SIEMENS-STR. 1
BUTZBACH HESSEN 35510
GERMANY
Phone: (+49) 6033-899-300
Fax: (+49) 6033-899-300
info@naxos-diskus.de
www.naxos-diskus.de
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.philcarbide.com
Precision Spindle & Accessories Inc.
www.preciospindlinc.com
QC American
www.qcamerican.com
Radiac Abrasives
www.radiac.com
Rajveet Engineering Specialty Ltd.
www.rajveet.com
RedLine Tools
www.redlinetools.com
Redin Production Machine
www.redinmachine.com
Reishauer AG
INDUSTRIESTRASSE 36
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SWITZERLAND
Phone: (+41) 44-382-22-11
Fax: (+41) 44-382-22-90
info@reishauer.com
www.reishauer.com
Reishauer Corporation
1525 HOLMES ROAD
ELGIN IL 60123
Phone: (847) 889-3828
Fax: (847) 888-0343
usa@reishauer.com
www.reishauer.com
Rex-Cut Products, Inc.
www.rexcut.com
S.L. Munson & Company
www.slmunson.com
Sampatensili 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.sampatensili.com
Schneider SA
JAKOBSTRASSER 52
CH-2504 BIEL
SWITZERLAND
Phone: (+41)(32) 344-0406
Fax: (+41)(32) 344-0404
george.boon@schneider.com
www.schneider.com
Sitab Srl
www.sitab-abrasives.com
Star Cutter Co. 5241 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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HOFFMAN ESTATES IL 60192
Phone: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com
Steelman 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. www.ultramatic-equipment.com
Vargus USA www.vargususa.com
Weldon Solutions www.weldon-solutions.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.thermal-spray.com
AFC-Holcroft www.afc-holcroft.com
Abbott Furnace Company www.abbottfurnace.com
Advanced Nitriding Solutions www.ans-ion.net
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.accuratetreethreating.com
Advanced Heat Treat Corp.  www.ahtcorp.com
Advanced Nitriding Solutions  www.ans-ion.net
Ajax Tocco Magnethermic  1745 OVERLAND AVENUE NE
WARREN OH 44483 Phone: 330-372-9877 Fax: 330-372-8686
sales@ajaxtocco.com  www.ajaxtocco.com
Akaron Steel Treating Company  www.akarontreating.com
Aksan Steel Forging  www.aksanforging.com
American Metal Treating Co.  www.americannmetaltreating.com
American Metal Treating, Inc.  www.americannmetaltreatinginc.com
Ampere Metal Finishing  www.ampremenalmetal.com
Applied Process  www.appliedprocess.com
Applied Thermal Technologies  www.appliedthermalexhibitions.com
Avion Manufacturing Company Inc.  www.avionmfg.com
BG&S Peening and Consulting LLC  www.peening-consultants.com
BOS Services Company  www.boshheat treating.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.braddockmft.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 TKE  www.cascadetek.com
Certified Steel Treating  www.certifiedsteeltreating.com
Chicago Flame Hardening  www.cfhlame.com
Cleveland Deburring Machine Co.  www.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.cwsat.com
Dayton Forging and Heating Treating  www.daytonforging.com
Duffy Company, The  www.dyffco.com
ECM USA  9505 72ND AVE. SUITE 400
PLEASANT PRARIE WI 53158 Phone: (262) 609-4810
info@ecm-usa.com  www.ecm-usa.com
EFInduction Inc.  www.efinduction-usa.com
ERS Engineering Corp.  www.ersengine.com
Eagle Tool Company Inc.  www.eaglebroach.com
East-Lind Heat Treat, Inc.  www.easlind.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.mpmht.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.gensmetalheat.com
General Surface Hardening Inc.  www.gshinc.net
Gleason Corporation  1000 UNIVERSITY AVENUE
P.O. BOX 32970
ROCHESTER NY 14692-2970 Phone: (585) 473-1000
Fax: (585) 461-4548
sales@gleason.com  www.gleason.com
Härtetei Reese Bochum GmbH  www.hardening.com
Heat Treating Services Corporation of America  www.htsmsi.com
Hi TecMetal Group  www.hf-l.cc
Horsburgh & Scott Co.  www.horsburgh-scott.com
Hudapack Metal Treating  www.hudapack.com
IHI Ionbond Inc.  www.iionbond.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
Inductotherm Corp.  www.inductotherm.com
Industrial Hard Carbon LLC  www.indhardcarbon.com
Industrial Metal Finishing, Inc.  www.indmetalfin.com
Infrared Heating Technologies  www.infraredheating.com
Ionics Technologies Inc.  www.ionic-tech.com
Iontech Ltd.  www.iontech.com
Irwin Automation Inc.  www.irwinautomation.com
Khemka Broach & Spline Gauge  www.khemkaabroach.com
Klingelnberg AG  BANZHULIESTRASE 171
CH-8050 ZURICH
SWITZERLAND Phone: (+41) 44 2781797 Fax: (+41) 44 2781594
info@klingelnberg.com  www.klingelnberg.com

Solar Manufacturing
1983 CLEARVIEW ROAD
SOUDERTON PA 19464 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
Vacuum Heat Treating Services

Vacuum Atmospheres
Carburizing and nitriding for critical gearing

Solar Atmospheres
1999 CLEARVIEW ROAD
SOUDERTON PA 18964
Phone: 855-934-3284
Fax: (215) 723-6460
info@solaratm.com
www.solaratm.com

Somers Forge
www.somersforge.com

Specialty Steel Treating Inc.
www.sst.net

Spectrum Thermal Processing
www.spectrumtp.com

Stack Metallurgical Services, Inc.
www.stackmetal.com

Sun Steel Treating Inc.
www.sunsteeltreating.com

Super Systems Inc.
www.supersystems.com

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

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.wpc treating.com

Wickert USA
www.wickert-usa.com

Willman Industries Inc.
www.willmanind.com

ZRIME
www.zrime.com.cn

Zion Industries
www.zioninduction.com

INSTRUCTION EQUIPMENT

Klingelnberg GmbH
PETERSTRASSE 45
HUECKESWAGEN 42499
GERMANY
Phone: +(49) 2192-8120
Fax: +(49) 2192-81200
info@klingelnberg.com
www.klingelnberg.com

Kowalski Heat Treating
www.khtreating.com

Lsalon Tools Corporation
www.lsalonconsultingttools.com

Lambda Technologies
www.lambdatech.com

Mackeil Ispat & Forgining Ltd.
mackeilforgings.com

Magnum Induction
www.magnuminduction.com

McLeod and Norquay Ltd.
www.mcleodandnorquay.com

Metallurgical Processing, Inc.
www.mpmetalprocessing.com

Metallurgical Solutions, Inc.
www.metsol.com

Metlab
www.metlabheattreat.com

Mid-South Metallurgical
www.midsouthmetallurgical.com

Midwest Thernal-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

National Heat Treat
nationalheatreat.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

Palla
www.pallaco.com

Penna Flame Industries
www.pennafame.com

Penticton Foundry Ltd.
www.pentictonfoundry.com

Peters Heat Treating
www.petersheattreating.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

Roket Incorporated
www.roket-nc.com

Rubig US, Inc.
www.rubig.com

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

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

Somers Forge
www.somersforge.com

Specialty Steel Treating Inc.
www.sst.net

Spectrum Thermal Processing
www.spectrumtp.com

Stack Metallurgical Services, Inc.
www.stackmetal.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.wpc treating.com

Wickert USA
www.wickert-usa.com

Willman Industries Inc.
www.willmanind.com

ZRIME
www.zrime.com.cn

Zion Industries
www.zioninduction.com

INSTRUCTION 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.
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.  
2900 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

Celanea  
www.celanese.com

Certified Comparator Products (CCP)  
www.certifiedcomparator.com

Contmorgage Corporation  
www.contmorgage.com

Dino-Lite  
www.dino-lite.us

Donner+Pfister AG  
www.dpag.ch

Drewco Workholding  
www.drewco.com

Dyer Company  
dyergage.com

Emuge Corp.  
www.emuge.com

Erwin Juncker 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

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

Gleason Metrology Systems  
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.  
PLOT NO. 37  
DODDENAKUNDI INDUSTRIAL AREA  
WHITEFIELD ROAD, MAHADEVAPURA  
BANGALORE 560 048  
Phone: 011-91-80-2850-4376/15/16/91  
www.gleason.com

Gleason-Hurth Tooling GmbH  
MOOSACHER STR. 42-46  
D-88099 MUCHEN  
GERMANY  
Phone: 011-49-89-35401-0  
www.gleason.com

Goldstein Gear Machinery LLC  
www.goldsteinmachinery.com

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

Greg Allen Company  
gallenco.com

HITEC Sensor Developments  
www.hit趺corp.com

HVH Industrial Solutions  
www.hvhiindustrial.com

Hank Corporation  
201 E. OGDEN AVE., SUITE 34  
HINSDALE IL 60521  
Phone: (630) 364-4840  
Fax: (630) 364-4850  
info@hanik corp.com  
www.hanik corp.com

Hansford Sensors  
www.hansfordsensors.com/us/

Helios Gear Products  
635 SCHNEIDER DRIVE  
SOUTH ELGIN IL 60177  
Phone: (847) 931-4123  
Fax: (847) 931-4192  
sales@koepferamerica.com  
www.heliosgearproducts.com

Hexagon Metrology  
www.hexagonmetrology.us

HobSource Inc  
304 E. RAND ROAD, SUITE 2  
MOUNT PROSPECT IL 60056  
Phone: (847) 398-3320  
Fax: (847) 398-6326  
sales@hobsource.com  
www.hobsource.com

Hydra-Lock Corporation  
www.hydralock.com

ITW Heartland  
1205 36TH AVENUE WEST  
ALEXANDRIA MN 56308  
Phone: (320) 762-0138  
Fax: (320) 762-9655  
info@itwheartland.com  
www.itwheartland.com

Innovative Analytical Solutions  
www.steelanalysier.com

Interstate Tool Corp.  
www.itctoolcorp.com

Involute Gear & Machine Company  
www.involutegearmachine.com

Kapp Technologies  
2870 WILDERNESS PLACE  
BOULDER CO 80301  
Phone: (303) 447-1130  
Fax: (303) 447-1133  
info-USA@kapp-niles.com  
www.kapp-niles.com

Khemka Broach & Spline Gauge  
www.khemkabroach.com

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Fax: +(41) 44-2787594  
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www.klingelnberg.com

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Fax: (734) 316-2158  
kie.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

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Fax: (734) 429-1294  
info.1gt@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.themodalshop.com

Modern Gearing  
www.modern gearing.com

Mutschler Edge Technologies  
mutschleredgetech.com

Modern Gear Technologies  
www.mutschleredge.com

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715 PUSHLIEVE ROAD  
GREENWOOD IN 46143  
Phone: (317) 528-1001  
Fax: (317) 530-1011  
info@nachiamerica.com  
www.nachiamerica.com

Newage Testing Instruments  
www.newagetesting.com

Ono Sokki Technology, Inc.  
www.onosokki.net

Optical Gaging Products, Inc. (OGP)  
www.ogpnets.com
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Proto Manufacturing
Parker Industries Inc.
PCE Instruments
SMS Elotherm North America
S.S. Tools
PCE Instruments
Star Cutter Co.
Star SU LLC
Quality Solutions
Proto Manufacturing
Quality Vision Services (QVS)
Pentagear Metrology LLC
Quality Vision Services
Pentagear Metrology LLC
Proto Manufacturing
Prihood
Protex
Premise
Pentagear Metrology LLC
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Precise Q-Gage
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Proceq USA, Inc.
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Prime Technologies
Proceq USA, Inc.
Pentagear Metrology LLC
Proto Manufacturing
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Prime Technologies
Proceq USA, Inc.
Pentagear Metrology LLC
Proto Manufacturing
Precise Q-Gage
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Proceq USA, Inc.
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.thermalpspray.com
ADF Systems Ltd.  www.adfsys.com
ANCA, Inc.  www.anca.com
Accu-Cut Diamond Tool Co.  www.accucutdiamond.com
AccuBrass  accubrass.com
Aciera  www.aciera.com/robotics-products/gripper-systems/
Acme Manufacturing Co.  www.acmeinc.com
Akciv  www.akciv.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.amparemetal.com
Andec Mfg. Ltd.  www.andec.ca
ArborTech Corporation  www.arborTech.com
Asolutica LLC  12693 MONTE CASTILLO PARKWAY AUSTIN TX 78722  www.asolutica.com
BFK Solutions LLC  www.bfksolutions.com
BTS Broaching Tools  www.brostakismanayi.com.tr
BUDERUS Schleiftechnik GmbH  www.buderus-schleiftechnik.de
Balantar Corp  www.balantar.com
Barber-Colman, Giv of Bourn & Koch  www.bourn-koch.com
Bates Technologies, LLC  www.batestech.com
Becker GearMeisters, Inc.  www.beckergameisters.com
Best Technology Inc.  www.besttechnologyinc.com
Blackbox Technologies  www.blackboxtech.in
Bohle Machine Tools, Inc.  www.bohle.com
Bourn & Koch Inc.  2500 KISHWAUKEE STREET ROCKFORD IL 61104 Phone: (815) 965-4013 Fax: (815) 965-3019 sales@bourn-koch.com  www.bourn-koch.com
Broten USA  www.brotenusa.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. PO BOX NO. 2727 TIROVOTTIYUR CHENNAI - 600018 TAMIL NADU INDIA Phone: (+91) 44 4924 9000 Fax: (+91) 44 4924 9045 sales_abrasives@cumi.murugappa.com www.cumiaabrasives.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. www.cdmachine.com
Colonial Tool Group www.colonialtool.com
Comco Inc.  www.comcoinc.com
Cortec Corporation  www.cortecvi.com
Cosen Saws USA  www.cosensaws.com
Creative Automation, Inc.  www.cautamation.com
Crest Ultrasone Corp. www.crest-ultrasone.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
Diskus Werke Schleiftechnik GmbH JOHANNES-GUTENBERG-STR. 1 DIETZENBACH HESSEN 63128 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.  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 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 www.descase.com
Nachi America Inc.
715 PUSHLVILLE ROAD
GREENWOOD IN 46143
Phone: (317) 530-1091
Fax: (317) 530-1011
info@nachiamerica.com
www.nachiamerica.com

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.oiohobroach.com

Okuma America Corporation
www.okuma.com

PITTLER T&S GmbH
JOHANNES-GUTENBERG-STR. 1
DIETZENBACH HESSEN 63129
GERMANY
Phone: +49-6074-4873-0
Fax: +49-6074-4873-291
christian.rhiedl@pittler.de
www.pittler.de

PRAEWEMA Antriebstechnik GmbH
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ESCHWEGE HESSEN 37269
GERMANY
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praewema.de-gruppe.com

PTG Holroyd
www.holroyd.com

Penna Flame Industries
www.pennafame.com

Penta Gear Metrology LLC
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DAYTON OH 45414
Phone: (937) 660-3182
michelson@pentagear.com
www.pentagear.com
Permanent Steel Manufacturing Co.,Ltd
www.permsteel.com

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.precisionspindlecinc.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 rahatsız.com

RAM Optical Instrumentation, Inc.
www.ramoptical.com

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Renegade Parts Washers and Detergents
www.renegadepartswashers.com

Renishaw Inc.
www.renshaw.com

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www.riten.com

Russell Holbrook & Henderson
www.tru-volute.com

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www.schunk.com

SETCO Precision Spindles
www.setcousa.com

SINTO AMERICA
www.sintomecanica.com

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us.sms-elotherm.com/en/

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www.swdinc.com

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HOFFMAN ESTATES IL 60192
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Fax: (847) 649-0112
sales@star-su.com
www.samputensili.com

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www.schutteusa.com

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Fax: (810) 649-0112
sales@starcutter.com
www.starcutter.com

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SUITE 100
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www.sunnen.com

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www.surplex.com

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

Titanium Coating Services Inc.
www.pvdamerica.com

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Toolmax Corporation - Lathe group
www.toolmaxlathes.com

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U.S. Equipment
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ultramatic-equipment.com

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www.ultrasonicllc.com

United Grinding
grinding.com

Vaporkote, Inc.
www.vaporkote.com

Venture Mfg. Co.
www.venturemfgco.com

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Vooler Sensors, Inc.
www.voolersensors.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.swi-lotcom

Weldon Solutions
www.weldon solutions.com

West Michigan Spline, Inc.
www.westmichiganspline.com

Westfalia Technologies
www.westfaliausa.com

Wheelabrator
www.wheelabratorgroup.com

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www.wolverinebroach.com

Yaskawa Motoman
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www.oelheld.com

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

AGMA - American Gear Manufacturers Association
www.AGMA.org

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

ASM International
www.asminternational.org

American Bearing Manufacturers Association
www.americanbearings.org

American Wind Energy Association
www.awea.org

BUDERUS Schleiftechnik GmbH
www.buderus-schleiftechnik.de

Balanstar Corp
www.balanstar.com

Banyan Global Technologies LLC
www.banyangt.com

CATHERINE LISTINGS
buyers guide

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<table>
<thead>
<tr>
<th>Company Name</th>
<th>Website</th>
<th>Contact Information</th>
</tr>
</thead>
</table>
| Cincinnati Gearing Systems Inc. | www.cincinnatigearingsystems.com | Fax: (513) 527-8635
| DVS Technology America, Inc. | www.dvs-technology.com | ralf-georg.eitel@dvs-technology.com |
| Frenco GmbH | www.frenco.de | |
| Gear Technology | |
| Gleason Corporation | www.gleason.com | |
| Gleason Cutting Tools Corporation | www.gleason.com | |
| Gleason Metrology Systems | www.gleason.com | |
| Gleason Works (India) Private Ltd. | www.gleason.com | |
| Gleason-Hurth Tooling GmbH | www.gleason.com | |
| Global Physical Asset Management | www.gleason.com | |
| GoHz Inc. | www.gohz.com | |
| Great Lakes Gear Technologies, Inc. | www.greatlakesgear.com | |
| Grindal Company | www.grindal.com | |
| Hansford Sensors | www.hansfordsensors.com/us/ | |
| Helios Gear Products | www.heliosgearproducts.com | |
| HobSource Inc. | www.hobsource.com | |
| Hydrotex | www.hydrotxlube.com | |
| IHI Hauzer Techno Coating B.V. | www.hauzer.nl | |
| IHI Ionbond Inc. | www.ionbond.com | |
| IMPCO Microfinishing | www.impcos.com | |
| Index Technologies Inc. | 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 | involutegearmachine.com | |
| Ion Vacuum (IVAC) Technologies Corp. | www.ivactech.com | |
| Jesse Garant Metrology Center | jgarantmc.com | |
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| Kapp Technologies | www.kapp-niles.com | |
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| Kingsford Broach & Tool Inc. | kingsfordbroach.com | |
| Klingelnberg America Inc. | www.klingelnberg.com | |
| Koro Sharpening Service | www.koroint.com | |
| Lafert North America | www.lafertna.com | |
| Lalson Tools Corporation | www.laslontooling.com | |
| Laser Tools Co. | www.laserbltco.com | |
| Liebherr-Verzahntechnik GmbH | www.liebherr.com | |
| Liebherr-Verzahntechnik GmbH | www.liebherr.com | |
| Longevity Coatings | www.longevitycoatings.com | |
| MAItools | www.maitools.com | |
| MESS AG | www.messy.de | |
| MRO Electric and Supply | www.mroelectric.com | |
| MTI Systems, Inc. | www.mtisystems.com | |
| Machine Tool Builders | www.machinetoolbuilders.com | |

[www.geartechnology.com]
### CATEGORY LISTINGS

**Diametals AG**  
www.diametals.ch  

**Donner-Pfister AG**  
www.dapag.ch

**Dontyne Systems**  
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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.dradefmg.com

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

**EES KISSsoft GmbH**  
www.kees-kisssoft.ch  

**ESI ITI GmbH**  
www.simulation.com

**Eltro Services, Inc.**  
www.eltroservices.com  

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

**Estudio Piñol dea**  
www.estudioopia.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

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www.fenco.de

**GWJ Technology GmbH**  
www.gwj.de

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sales@gleason.com  
www.gleason.com

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Phone: (937) 859-6273  
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gleason-metrology@gleason.com  
www.gleason.com

**Great Lakes Gear Technologies, Inc.**  
www.greatlakesgearitech.com

**Heller Machine Tools**  
www.heller-machinetools.com

**Hexagon Industriesoftware GmbH**  
www.hexagon.de

**Hexagon Metrology**  
www.hexagonmetrology.us

**HITech e Soft**  
www.hitechsoft.com

**Involute Simulation Softwares Inc.**  
www.hygears.com

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Fax: 0041 (0)55 254 20 71  
info@KISSsoft.ch  
www.KISSsoft.ch

**KISSsoft/Gleason**  
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EAGLE RIVER WI 54521  
Phone: (715) 477-3828  
Fax: (715) 923-7269  
info@KISSsoft.ch  
www.kisssoft.com

**Khemka Broach & Spline Gauge**  
www.khemkabroach.com

**Klingelnberg AG**  
BUNZMÜHLESTRASSE 171  
CH-8050 ZURICH  
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Fax: (+41) 44-2781594  
info@klingelnberg.com  
www.klingelnberg.com

**Klingelnberg GmbH**  
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HUECKESWAGEN 42499  
GERMANY  
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Fax: (+49) 2192-812-236  
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www.klingelnberg.com

**Kollmorgen**  
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**Liebherr America**  
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SALINE MI 48176  
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Fax: (734) 429-2294  
info.li@liebherr.com  
www.liebherr.com

**MESYS AG**  
www.mesys.ch

**MSC Software Corp.**  
www.mscsoftware.com

**MTI Systems, Inc.**  
www.mtisystems.com

**Machine Tool Builders**  
7722 BURDEN ROAD  
MACHESNEY PARK IL 61115  
Phone: (815) 636-7502  
Fax: (815) 636-5912  
KCWarren@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**  
6181 WEBSTER STREET  
DAYTON OH 45414  
Phone: (937) 680-8126  
micholson@pentagear.com  
www.gearinspection.com

**Point 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.smartmnt.com

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

**SWG Solutions**  
www.swgsolutions.com

**Szaor**  
www.szaor.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

**Storz Gaging Co.**  
www.storz-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.waterlooftware.com

**Web Gear Services Ltd.**  
www.webgearervices.com

**Wenzel America**  
www.wenzelamerica.com

**Yash International**  
www.yashtools.com

**Zontec**  
www.zontec-sp.com

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**USED MACHINERY**

All of the suppliers listed here are broken down by category (auctioneers, used machine dealers, etc.) at [www.geartechnology.com](http://www.geartechnology.com).

**Advice**  
www.advice.co.uk

**Ajax Tocco Magnethermic**  
1745 OVERLAND AVE NE  
WARREN OH 44483  
Phone: 330-372-8511  
Fax: 330-372-9868  
sales@ajaxtocco.com  
www.ajaxtocco.com

**Apex Auctions Inc.**  
www.apexauctions.com

**Blackbox Technologies**  
www.blackboxtech.com

**CBI Industrial Asset Management bv**  
www.cbiworld.com

**Cincinnati Industrial Auctioneers**  
www.cia-auction.com

**Corporate Assets Inc.**  
www.corapassets.com

**Dixitech CNC**  
www.dixitechcnc.com

**Fairfield Auctions**  
www.fabsurf.com

**Gear Machinery Exchange**  
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These are the last, and very best, of a large company’s Gleason 641 department, loaded with features and in very excellent condition. This is the perfect job shop machine, able to cut most every Gleason system with few cutters. 1979–1980

michael@GoldsteinGearMachinery.com

www.gearmachineryexchange.com

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Dontyne Systems

Skiving and Honing

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www.2channeltransmission.com

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SHARON TN 38255
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Fax: (731) 456-2037
inquiry@brgear.com
www.brgear.com

Beyta Gear Service
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CINCINNATI OH 45227
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Fax: (513) 527-8635
gearsales@cst-c.com
www.cincinnatigearingsystems.com

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CICERO IL 60604
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Fax: (708) 652-1100
sales@circlegear.com
www.circlegear.com

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5757 MARIEMONT AVE.
CINCINNATI OH 45227
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Fax: (513) 527-8635
gearsales@cst-c.com
www.cincinnatigearingsystems.com

Forest City Gear Co.
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ROSCOE IL 60073
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www.forestcitygear.com

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gdiaz@gleason.com
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www.spiroidgear.com

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Fax: 0041552542051
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www.kisssoft.ag

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Phone: (877) 589-4432
www.lubriplate.com

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Fax: (814) 456-8443
sales@mcringrs.com
www.mcinnlesrolledrings.com

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Fax: (586) 775-6790
mvgear@midwestgear.net
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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.
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 $360^\circ/(2 \times \text{Number of Blade Groups})$. 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 $\delta_w$ is known, then the blade offset can be calculated with the following relationship:

$$\text{Blade Offset} = \tan(\delta_w) \times R_w$$

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:

$$\delta_w = \arcsin\left(\frac{z_w \times m_n}{2 \times R_n}\right)$$

Where:
- $\delta_w$ Offset angle
- $z_w$ Number of blade groups
- $m_n$ Normal module
- $R_n$ 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 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 advantage or offset angle of the cutter head and work spiral direction is the same. Another process-related reason is that the chip removal 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 Klingenberg used left-hand cutter heads for cutting right-hand bevel gears, and vice versa (Ref. 2). When a manufacturer of Cyclo-Palloid 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, Klingenberg 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 $R_w = [(\text{normal cutter radius})^2 + \text{offset}]^{1/2} = \text{constant}$, 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.

References

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.

Figure 1  Two gear test rigs.

(a) Dry running conditions

(b) Oil lubricated conditions

This paper was first presented at the 2018 Lyon International Gear Conference and is published here with Conference and author permission.
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

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<th>HDPE</th>
<th>PC</th>
<th>POM</th>
<th>PA46</th>
<th>PEEK650</th>
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<tr>
<td>Specific gravity (g/cm³)</td>
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### Table 2  Nominal geometry for all gears

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<tr>
<td>Thickness (mm)</td>
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<td>Contact ratio</td>
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</table>

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 testing.

![Figure 2](image-url)  
**Figure 2** Experimental results for polycarbonate gears.

![Figure 3](image-url)  
**Figure 3** Experimental results for polycarbonate gears.
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 10⁷ 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.

Figure 4  Gear surface wear (Ref. 2).

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

Figure 6  PEEK gear tooth SEM results.

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 coefficient 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.

**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.

References
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
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 $F_{\alpha}$, the profile slope deviation $f_{sl\alpha}$, 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 ISO6336 stress analysis standard (Ref. 8) is not so clear. ISO6336 uses the ISO1328-1 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.

In summary, the parameters evaluated in both previous and current versions of the ISO1328-1 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.
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 5.6/λ).
- If waviness is to be checked, a minimum of 300 points or 5/mm is required.
- A profile filter cut-off is defined as λ = Lα/30, where Lα is the profile length of roll [mm] and the helix filter cut-off is λ = b/30 where b is the face width [mm].
- The filter is a Gaussian 50%, defined in 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 fmax values of 14.0 μm and 16.2 μm for length of roll and radially spaced data; deviation in form parameters fα varies between 19.7 μm, and total form Fα of 27.1 and 27.0 μm. These are significant differences in values compared to the tolerance.

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 Lα — 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 (fmax = 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.

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

Where:

- Lα profile length of roll [mm]
- fmax tooth passing harmonic (relative frequency)
- n number of data points per frequency
- εa 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.
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, λα and λβ, respectively, are low-pass cut-offs that exclude high-frequency deviations. The cut-off lengths are specified as Lα/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 (βb) 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 (βb) is greater than the Tan⁻¹(λβ/λα) 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).
- A Klingelnberg 2CR filter. This is the standard filter offered by Klingelnberg — with a cut-off wavelength λα of Lα/15 and λβ of Lβ/15 — and thus removes higher frequencies than the ISO filter. It provides an example of an existing filter and illustrates the

<table>
<thead>
<tr>
<th>Table 5 Test gear geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module m,</td>
</tr>
<tr>
<td>Profile length Lα</td>
</tr>
<tr>
<td>Helix βb</td>
</tr>
<tr>
<td>Face with (b)</td>
</tr>
<tr>
<td>Involute profile λα</td>
</tr>
<tr>
<td>Helix λβ</td>
</tr>
<tr>
<td>Profile data (n)</td>
</tr>
<tr>
<td>Helix data (n)</td>
</tr>
<tr>
<td>Tan⁻¹(λα/λβ)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4 ISO 1328-1:2013 filter cut-off length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1st (epicyclic)</td>
</tr>
<tr>
<td>2nd (epicyclic)</td>
</tr>
<tr>
<td>3rd (gear pair)</td>
</tr>
</tbody>
</table>

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

Figure 5 Profile results with different filters (Sample 1).
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/λβ or λ/λα 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 ISO1328-1:2013 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

![Figure 6](image1)

![Figure 7](image2)

Table 6: Sample 1 feature attenuation

<table>
<thead>
<tr>
<th>Profile/helix</th>
<th>Feature</th>
<th>Feature λ (mm)</th>
<th>λ/λβ or λ/λα</th>
<th>No filter</th>
<th>Gaussian filter</th>
<th>2RC filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helix λβ = 5.16 mm</td>
<td>A</td>
<td>10.68</td>
<td>2.06</td>
<td>2.33</td>
<td>1.90 (82%)</td>
<td>1.65 (71%)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>21.68</td>
<td>4.20</td>
<td>1.71</td>
<td>1.38 (81%)</td>
<td>1.21 (71%)</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7.12</td>
<td>1.38</td>
<td>0.67</td>
<td>0.56 (84%)</td>
<td>0.44 (66%)</td>
</tr>
<tr>
<td>Profile λα = .08 mm</td>
<td>A</td>
<td>7.37</td>
<td>6.82</td>
<td>1.64</td>
<td>1.27 (77%)</td>
<td>1.17 (71%)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.47</td>
<td>0.44</td>
<td>0.72</td>
<td>0.38 (53%)</td>
<td>0.35 (47%)</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.67</td>
<td>0.62</td>
<td>0.58</td>
<td>0.21 (40%)</td>
<td>0.15 (26%)</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>4.52</td>
<td>4.19</td>
<td>1.18</td>
<td>0.91 (77%)</td>
<td>0.83 (70%)</td>
</tr>
</tbody>
</table>
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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**References**

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.

Giorgi 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 155,000-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.”

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)
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 ippeexpo.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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☐ My company BUYS GEARS (22)

☐ I DESIGN gears (23)

☐ I am a SUPPLIER to the GEAR INDUSTRY (24)

☐ OTHER (Please describe) ________________________________

What is your company’s principal product or service? __________________________

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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.

“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.”

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](http://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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