Gear cutting tools and services

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

- Gear hobs
- Chamfer hobs
- Milling cutters
- Shaper cutters
- Scudding® and Power Skiving cutters
- Shaving cutters
- Chamfer and deburring tools
- Rack and saw cutters
- Master gears
- Ring and plug gauges
- Advanced coatings including ALTENSA and ALCRONA PRO
- Tool re-sharpening

**Total tool life cycle management**

Control your tool costs and let Star SU manage your tool room. From new tools to design work to re-sharpening and recoating, we have the equipment and resources to help keep your gear cutting operation running smoothly.

See our latest gear manufacturing solutions at Motion + Power Technology Expo. October 15-17, 2019.

Phone: 847-649-1450
5200 Prairie Stone Pkwy. | Ste. 100 | Hoffman Estates | IL 60192
Economical hob sharpening and in-house tool maintenance

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

18 Motion + Power Technology Expo
   Complete floor map and booth listings.

26 MPT Expo Booth Previews
   Our guide to the exhibit.

50 Heat Treat 2019
   Complete floor map and booth listings.

64 The Additive Advantage
   How 3-D printing is changing the powder metal performance game.

technical

70 Influence of Thermal Distortion on Spur Gear Tooth Contact
   Results of this study will allow setting limits of design backlash to avoid gear jamming and to size the initial profile modifications to reach the desired contact behavior at operating temperatures.

79 Design Parameters for Spline Connections
   Eliminating the confusion caused by picking dimensions and tolerances from different standards, this article presents a firm guideline for each step of the design, tolerancing and cutting tool definition.

84 A Precise Prediction of Tooth Root Stresses for Involute External Gears with any Fillet Geometry under Consideration of Exact Meshing Condition
   An efficient design with high power density characterizes a modern transmission, which leads, in many ways, to optimized constructions. Reaching a high utilization of material strength requires an exact prediction of occurring stress under given load carrying capacity to guarantee sufficient endurance.
Internal Gear Honing

Improve the inner values of your gear

- Significantly higher quality for internal gearings
- Finer tooth flank surfaces for gear noise level reduction
- Ideal for gear parts running at high torque
- Single- or Twin Spindle machine for higher output or further machining processes like hard turning or grinding

Curious to learn more?
CONTACT US:
DVS Technology America Inc.
734-656-2080 sales.america@dvs-technology.com
www.praewema.de l www.dvs-technology.com
06 GT Extras
GT Videos: Gleason Power Skiving; Sandvik Coromant Machine Tool Monitoring; Event Spotlight: K2019, Düsseldorf, Germany.

09 Publisher’s Page
Get Answers Live and in Person.

10 Product News
TimkenSteel touts automation in forging process; Solar Atmospheres installs new vacuum furnace; KISSsoft introduces 2019 release.

89 Industry News
Octave Labath: 1941-2019; Siemens Digital Industries Software and Sonaca to work on additive manufacturing for space applications; Bourn & Koch gets new parent company; Ipsen expands sales engineering presence; SMT announces global user forums.

92 Calendar of Events

94 Advertiser Index
Contact information for companies in this issue.

95 Subscriptions
Fill out the form to continue receiving Gear Technology.

96 Addendum
The Million Dollar Clock.
New gear skiving machine LK 300-500
Machine, tool and process from a single source

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

Machine
- Automation
- Deburring and tool changer
- Stiffness

Tool
- Design
- Manufacturing
- Reconditioning

Process
- Technology design
- Implementation
- Optimization
Event Spotlight:
K 2019 in Düsseldorf, Germany, features over 3,000 exhibitors in the entire plastics and rubber industry to demonstrate the industry’s capabilities, discuss current trends and set the course for the future. The event takes place October 16–23. Learn more here: www.geartechnology.com/news/9860/K_2019/
TRUSTED
TO GET IT DONE RIGHT... EVERY TIME

Cut teeth capabilities so good, even our competitors come to us.

Excellence without exception.

forestcitygear.com
Born from the widely acclaimed ZE-B series, the all new ZE26C has been specifically designed to meet the exacting demands of the electric vehicle and robotics industries.

Featuring increased rigidity of the column, table and grinding wheel head—coupled with revamping of the spindle structure—the ZE26C produces finished gears with enhanced grinding precision and stability. By increasing cutting speed and reducing non-cutting time by roughly 50%, the ZE26C maximizes high-volume production capability and promotes lower running costs. The expanded wheel width provides longer wheel life and supports the use of combination grinding/polishing wheels for improved gear surface finish, making the ZE26C a compact and operationally efficient machine that’s responsive to in-factory needs. To learn more about how the ZE26C has been optimized for the evolving needs of the industry, visit www.mitsubishigearcenter.com or contact sales at 248-669-6136.
Get Answers LIVE and in Person

You have challenges. We all do. If your challenges are related to any aspect of gear design, manufacturing, inspection, heat treating or use, the solutions can be found at Motion + Power Technology Expo, which takes place October 15–17 in Detroit.

So come and ask your questions about how to implement the latest gear manufacturing technology. Ask about how best to solve you latest design challenges. Ask about cutting tools, gear rating standards, lubrication and bearings.

This is a unique opportunity to ask and get answers from the very top people in all facets of our industry.

In fact, we've lined up panels of experts — the who's who of our industry — to answer those questions for you, live and in person. As we've done at previous shows, we're hosting four sessions of our popular “Ask the Expert LIVE!” series at our booth (#3826). Each session will be video recorded and become part of our permanent video library on Gear Technology TV (found at www.geartechnology.com/tv/). Each session covers a specific topic, and we've lined up an appropriate panel of experts for each one:

**Gear Manufacturing — Tuesday, October 15, 10:30 a.m.**
- Dr.-Ing. Andreas Mehr, Gear Grinding and Shaping Technology Development, Liebherr.
- Dr.-Ing. Hartmuth Müller, Head of Technology and Innovation, Klingelnberg.
- Dr.-Ing. Deniz Sari, Sales Manager Middle Europe, Samputensili.
- Dr. Hermann J. Stadtfeld, VP Bevel Gear Technology and R&D, Gleason

**Gear Design — Tuesday, October 15, 2:30 p.m.**
- Charles Schultz, President Beyta Gear Services (also Gear Technology technical editor and author of Gear Talk with Chuck on the geartechnology.com blog).
- Prof. Dr.-Ing. Karsten Stahl, Director of the Gear Research Center (FZG) at the Technical University of Munich.
- Frank Uherek, Principal Engineer, Gear Engineering Software Development, Rexnord.

**Lubrication — Wednesday, October 16, 10:30 a.m.**
- Paul Conley, Chief Technologies, SKF.
- Sib Hamid, VP, Director of Operations and Corporate Director of Technology, Lubriplate.
- Dr.-Ing. Thomas Tobie, Head of the Department Load Carrying Capacity of Gears at the Gear Research Center (FZG) at the Technical University of Munich.

**Bearings — Wednesday, October 16, 2:30 p.m.**
- Mike Allegra, Application Engineer Specialist, Timken.
- George Lutzow, Manager Application Engineering, SKF.
- Jitesh Modi, Engineering Director, Transmission Applications North America, Schaeffler Group USA Inc.
- Chris Napoleon, President, Napoleon Engineering Services.

We're counting on you to come to the show and participate. We've lined up top-notch experts who are sure to have the experience and insight to help you solve your gear-related problems. So come to the show and participate. Even if you don't have questions, just sitting in the audience is a great way to learn.

Come to booth #3826 and absorb the knowledge!

Even if you're not coming to Motion + Power Technology Expo, you can still participate in Ask the Expert Live! Just e-mail your question to publisher@geartechnology.com, and we'll pose it to the appropriate panel during one of our live segments. Then, you can watch and listen to the answers after the show on Gear Technology TV.

In addition to Ask the Expert LIVE! we’ll also be recording episodes of Revolutions at the show. Our booth will be pretty busy throughout the three days. We'll be interviewing experts from Advanced Heat Treat Corp., AGMA, ERS Engineering, Gleason, KISSsoft, Helios Gear Products, Klüber Lubrication, Ovako, THORS, TimkenSteel and many others. We’ll be asking about the latest technological innovations from the leading companies in our industry. We hope you’ll be there to hear what they have to say.

Hope to see you in Detroit.

P.S. Don't forget to renew your FREE subscription when you visit our booth.
EXSYS
OFFERSTOOLINGTECHNOLOGY AT SOUTHTEC 2019

Exsys Tool, Inc. will offer attendees at Southtec the chance to experience its comprehensive range of tooling technology for turning machines and innovative gearbox solutions at the Greenville Convention Center in Greenville, South Carolina, October 22–24. Visitors to Booth 1829 will have the opportunity to learn how Exsys’ modular toolholding solutions and Eppinger’s gear-making expertise offer exceptional cost-savings and greater manufacturing efficiency.

In addition to its Preci-Flex modular toolholding system, which speeds turning center tooling changeovers and improves productivity with longer tool life, Exsys will showcase the Deco-Flex tooling interface, which adds flexible precision for small-part manufacturing and includes holders for all generations of Star CNC brand Swiss-style machines. Exsys will also highlight Eppinger gear solutions and their German-made precision, including standard spiral bevel, planetary, planetary bevel, hypoid and cycloidal gearboxes, along with custom gear-making services.

For more information:
Exsys Tool, Inc.
Phone: (800) 397-9748
www.exsys-tool.com

GMTA
EXTENDS ITS PRODUCT OFFERING TO INCLUDE BASKETS, TROLLEYS AND LIFT TABLES

GMTA is adding to its product line. Known for gear cutting and honing, parts washing, special machine tools, tooling, laser welding, surface grinding, deburring machines, multi-spindle lathes and multi-station vertical machinery, GMTA is now selling baskets, trolleys and lift tables.

Walter Friedrich, GMTA’s president said, “We felt that we needed to have an intermediate step between the machining and cleaning processes.”

Products available include bearing turntables, lift tables, custom carts and conveyor systems. Lift tables include single position lift tables, single position lift and rotate tables, single position lift and tilt tables, rotate tables, hydraulic lift tables, air spring lift tables and fork free lift tables for cart access. In addition, custom carts for manufacturing and production operations are available. These include 4-wheel carts, 6-wheel carts, low profile carts, flat top carts, rotate carts and tilt carts, fork free carts and custom part sequencing carts.

Besides being a link between gear-making machines and parts washers, GMTA makes these products available to users in the material handling industry.

For more information:
GMTA
Phone: (734) 973-7800
www.gmtamerica.com
BIG BANG for your buck.

KAPP NILES KCe3P

Installation and set-up in a blink!

The KCe3P comes with machine mounted electrical panel and is easily accessible. New KNC3P software graphically guides you through applications.

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

KAPP Technologies
2870 Wilderness Place Boulder, CO 80301
kapp-niles.com info@kapp-niles.com (303) 447-1130
Mitutoyo America Corporation is pleased to announce the release of the MiSTAR 555 CNC Shop Floor Coordinate Measuring Machine to its CMM product line that operates without compressed air and on conventional 120V 20 AMP electrical service with movement speeds of 606mm/s and acceleration of 2,695mm/s² (3D).

The MiSTAR 555 is a compact, space-saving in-line or near-line CNC coordinate measuring machine designed for high-speed, high-accuracy measurements with accuracy assurance from 10°C to 40°C. It features an open-structure design with a single support moving bridge enabling users to mount workpieces from the front, rear and right for installation and a walk-up inspection station for easier operability.

The modular control unit and PC are stored in the base of the main body structure, making the MiSTAR more compact, reducing the installation area to approximately 70 percent from a conventional moving bridge model for location flexibility. The MiSTAR also uses a Mitutoyo-designed and manufactured robust scale detection system with a high resistance to airborne contaminants, eliminating the need for costly environmental controlled enclosures.

The MiSTAR features several Industry 4.0 integrations, including the Mitutoyo-developed Smart Measuring System (SMS), which enables monitoring the operation state required by smart factories and a Status Monitor that retrieves current CMM status features using the MTConnect protocol. Condition Monitor provides a system that collects and evaluates different operational information such as measuring, movement lengths, machine error, probe functions, and many more for long-term preventative maintenance and machine use statistics.

For more information:
Mitutoyo America Corporation
Phone: (630) 820-9666
www.mitutoyo.com
A visit to the Gleason booth connects you to powerful gear and transmission design tools, economical Chamfer Hobbing, hard finishing innovations like Combi Honing™ and polish grinding, in-process laser inspection as well as productive new tooling and services. All working together to connect your gear manufacturing to maximum efficiency, from design to finished gear.

At CMTS 2019, Index and Mitcham Machine Tools recently demonstrated how to increase output per operator via integrated automation and single-machine production of complex parts.

The TNL20-11 features eleven linear axes, frontworking attachment with six stations, autonomous counter spindle and two turrets, each with eight stations providing up to 12,000 rpm and 2.0 kW of power. The TNL20-11 can apply up to four tools simultaneously, and the lower turret can be equipped with a backworking attachment capable of allowing independent machining of the rear of a part. The machine offers identical, twin liquid-cooled spindles with up to 10,000 rpm, 5.5 kW of power and 17.2 Nm of torque.

When integrated with the iXcenter robot cell, the TNL20-11 becomes even more productive. With compact vertical storage of up to 14 pallets, this cell uses an articulated arm to load and unload parts.

The G220 features fluid-cooled, identical main and counter spindles that provide power of 31.5/32 kW (100%/40%), torque of 125/170 Nm and maximum speed of 5,000 rpm. The fluid-cooled, five-axis motorized milling spindle is available in both HSK-T40 and HSK-T63 configurations. The HSK-T40 version offers power of 11 kW, torque of 19/30 Nm and speed of up to 18000 rpm, while the HSK-T63 version offers power of 17 kW, torque of 62/90 Nm and speed of up to 12,000 rpm. Both milling spindle options feature hydrostatic bearings in the Y and B axes, and a stable circular guide further ensures excellent rigidity and damping. The Y axis features a ±80 mm stroke, while the B axis is driven directly by a torque motor and has a swivel range of −50/+230 degrees. With a large travel distance in the X direction, machining at up to 30 mm below the turning center height is possible.

The G220’s motorized milling spindle operates using a one-row tool chain magazine which features space for 70 tools for the HSK-T40 configuration or 50 tools for HSK-T63. An optional double-row tool magazine enables setup during machining and accommodates twice as many tools as the standard solution.

For more information:
Index Corporation
Phone: (317) 770-6300
www.index-usa.com
Dillon Manufacturing
OFFERS JAW NUTS AND KEYS TO IMPROVE CHUCK SAFETY, ACCURACY AND PERFORMANCE

As machine tool technology continues to advance, including greater horsepower, larger material cuts, and higher machine tool speeds, the stress and mechanical forces upon jaw nuts and t-nuts being used within these operating conditions has also increased. Jaws nuts and keys made from case hardened 1018 CRS can fracture, crack, and break under high speed machine stress loads causing damaged workpieces and chucks, and endangering operators. Dillon Jaw Nuts and Keys, manufactured from 4140 heat treated steel, provide superior wear resistance, impact resistance, higher tensile strength, and extended jaw nut life. Operator safety and chuck life are greatly improved by eliminating the use of low carbon jaws nuts and t-nut in the machining process.

Dillon Jaw Nuts, T-nuts, and Keys are available to fit all popular power chucks from 6” in diameter to 24” in diameter including Forkhardt, Gamet, Howa, Kitigawa, Matsumoto (MMK), Nikko, Pratt Burnerd, Rohm, Samchully, Schuck, SMW, SMW-Autoblok, and more. Standard sizes are stocked for immediate shipment. They are ideal for workholding applications requiring durability and high strength such as high speed machining. Dillon also offers a special T-Nut design and manufacturing service for custom workholding requirements.

For more information:
Dillon Manufacturing
Phone: (800) 428-1133
www.dillonmfg.com

FORGING AHEAD OF THE PACK

At McInnes Rolled Rings, we provide quality products, shipped fast. And we partner that with exceptional customer service to forge the perfect partnership with our customers.

1.877.695.0280 • www.McInnesRolledRings.com

VISIT US AT M+PT EXPO 2019 Booth #2922
Klüber Lubrication offers heat transfer oils for open or closed heating and cooling systems

Klüber Lubrication, a worldwide manufacturer of specialty lubricants, introduces heat transfer oils for use in open or closed heating and cooling systems in the wood-processing industry.

Lubricants used in wood processing must withstand extreme temperatures, high loads and aggressive media. The excellent thermal properties of new heat transfer oils from Klüber Lubrication make them ideal for wood-processing applications. Specially formulated for use in indirect closed heating units, the high resistance of these oils to thermal degradation ensures reliable, lasting performance. With good oxidation stability, the oils protect equipment and prevent deposit formation. They maintain viscosity, even in low temperatures, and have a long service life.

Klüberfluid HT 1 Series is a highly refined mineral oil heat transfer fluid that offers excellent thermal stability. Its advanced formulation supports long service life without viscosity changes or deposit formation.

Klüberfluid HT 4 US Series is a synthetic heat transfer oil designed to overcome heat stress that high-temperature heat transfer mediums endure. Its synthetic hydrocarbon base stock combats issues related to carbon formation as well as extends fluid life compared to petroleum-based fluids. The extremely low vapor pressure and subzero pour points of the oil increase efficiency and reduce pressure buildup and evaporation losses.

The tough requirements of the wood-processing industry demand high-performance lubricants. The advanced formulations of new heat transfer oils from Klüber Lubrication ensure reliable performance under extreme heat-related stress.

For more information:
Klüber Lubrication
Phone: (603) 647-4104
www.klueber.com

Satisfaction Guaranteed.

Cincinnati Gearing Systems
Manufactured Domestically, Trusted Internationally.™

Cincinnati Gearing Systems
www.cincinnatigearingsystems.com | 513-527-8600 | sales@cincinnatigearingsystems.com

Precision Gear Manufacturing and Design Engineering

For more information: Klüber Lubrication
Phone: (603) 647-4104
www.klueber.com

GEAR TECHNOLOGY | September/October 2019
Shop and compare the full range of power transmission solutions utilizing mechanical power transmission, pneumatics, hydraulics, electric motors, and drives.

250+ exhibiting companies
50 first-time exhibitors
showcasing unique solutions

FLUID POWER PAVILION — your destination to learn if hydraulics and pneumatics could improve your project.

EMERGING TECHNOLOGY PAVILION — provides a look at new, cutting-edge technology that is coming into the manufacturing space.

To search a complete list of exhibitors by name or product category, visit MotionPowerExpo.com
<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Booth#</th>
<th>Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M Company</td>
<td><a href="http://www.3m.com">www.3m.com</a></td>
<td>2008</td>
<td></td>
</tr>
<tr>
<td>ADF Systems Ltd.</td>
<td><a href="http://www.adfsys.com">www.adfsys.com</a></td>
<td>3718</td>
<td></td>
</tr>
<tr>
<td>Advanced Heat Treat Corp.</td>
<td><a href="http://www.ahtcorp.com">www.ahtcorp.com</a></td>
<td>4600</td>
<td></td>
</tr>
<tr>
<td>Advanced Manufacturing Research Centre</td>
<td>amrc.co.uk</td>
<td>3433</td>
<td></td>
</tr>
<tr>
<td>Affolter Technologies SA</td>
<td><a href="http://www.affoltergroup.ch">www.affoltergroup.ch</a></td>
<td>3131</td>
<td>21</td>
</tr>
<tr>
<td>AGMA</td>
<td>wwwAGMA.org</td>
<td>3426</td>
<td>17</td>
</tr>
<tr>
<td>ALD Thermal Treatment, Inc.</td>
<td><a href="http://www.alddt.net">www.alddt.net</a></td>
<td>3200</td>
<td></td>
</tr>
<tr>
<td>Alro Steel &amp; Plastics</td>
<td><a href="http://www.alro.com">www.alro.com</a></td>
<td>2628</td>
<td></td>
</tr>
<tr>
<td>American Broach</td>
<td><a href="http://www.americabroach.com">www.americabroach.com</a></td>
<td>2826</td>
<td></td>
</tr>
<tr>
<td>Ancon Gear &amp; Instrument Corporation</td>
<td><a href="http://www.ancongear.com">www.ancongear.com</a></td>
<td>4400</td>
<td></td>
</tr>
<tr>
<td>Anmark</td>
<td><a href="http://www.anmark.com">www.anmark.com</a></td>
<td>4507</td>
<td></td>
</tr>
<tr>
<td>ASCO Sintering Co</td>
<td><a href="http://www.ascosintering.com">www.ascosintering.com</a></td>
<td>3237</td>
<td></td>
</tr>
<tr>
<td>Ash Gear &amp; Supply</td>
<td><a href="http://www.ashgear.com">www.ashgear.com</a></td>
<td>3309</td>
<td></td>
</tr>
<tr>
<td>ASI Drives</td>
<td>asidrives.com</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>Automation Controls &amp; Engineering, LLC</td>
<td><a href="http://www.ace-automation.net">www.ace-automation.net</a></td>
<td>2803</td>
<td></td>
</tr>
<tr>
<td>Balance Systems Corp.</td>
<td><a href="http://www.balancesystems.com">www.balancesystems.com</a></td>
<td>4428</td>
<td></td>
</tr>
<tr>
<td>Beijing Worldia Diamond Tools Co., Ltd.</td>
<td><a href="http://www.worldia-tools.com">www.worldia-tools.com</a></td>
<td>3644</td>
<td></td>
</tr>
<tr>
<td>Benz</td>
<td><a href="http://www.benz.com">www.benz.com</a></td>
<td>4608</td>
<td>60</td>
</tr>
<tr>
<td>Bevel Gears India Pvt. Ltd.</td>
<td><a href="http://www.bevelgearsindia.com">www.bevelgearsindia.com</a></td>
<td>4210</td>
<td>48</td>
</tr>
<tr>
<td>Blaser Swisslube, Inc.</td>
<td><a href="http://www.blaser.com">www.blaser.com</a></td>
<td>4426</td>
<td></td>
</tr>
<tr>
<td>Bomatec International Corp</td>
<td><a href="http://www.bomatec.com">www.bomatec.com</a></td>
<td>4613</td>
<td></td>
</tr>
<tr>
<td>Bourn &amp; Koch Inc.</td>
<td><a href="http://www.bourn-koch.com">www.bourn-koch.com</a></td>
<td>3813</td>
<td>57</td>
</tr>
<tr>
<td>Brelie Gear Co.</td>
<td><a href="http://www.breliegear.com">www.breliegear.com</a></td>
<td>3310</td>
<td></td>
</tr>
<tr>
<td>Brinkmann Pumps Inc.</td>
<td><a href="http://www.brinkmannpumps.com">www.brinkmannpumps.com</a></td>
<td>3337</td>
<td></td>
</tr>
<tr>
<td>Broach Masters/Universal Gear Co.</td>
<td>broachmasters.com</td>
<td>3009</td>
<td></td>
</tr>
<tr>
<td>Broaching Machine Specialties</td>
<td><a href="http://www.broachingmachine.com">www.broachingmachine.com</a></td>
<td>3223</td>
<td></td>
</tr>
<tr>
<td>C &amp; B Machinery</td>
<td><a href="http://www.cbmachinery.com">www.cbmachinery.com</a></td>
<td>2507</td>
<td></td>
</tr>
<tr>
<td>Canton Drop Forge</td>
<td><a href="http://www.cantondropforge.com">www.cantondropforge.com</a></td>
<td>3918</td>
<td></td>
</tr>
<tr>
<td>Capstan Atlantic</td>
<td><a href="http://www.capstanatlantic.com">www.capstanatlantic.com</a></td>
<td>3322</td>
<td></td>
</tr>
<tr>
<td>Casappa Corporation</td>
<td><a href="http://www.casappa.com">www.casappa.com</a></td>
<td>2734</td>
<td></td>
</tr>
<tr>
<td>Catalus Corporation</td>
<td>cataluscorp.com</td>
<td>4134</td>
<td></td>
</tr>
<tr>
<td>Century Precision Co., Ltd.</td>
<td><a href="http://www.cty.co.kr">www.cty.co.kr</a></td>
<td>2828</td>
<td></td>
</tr>
<tr>
<td>Ceramtec GmbH</td>
<td><a href="http://www.spk-tools.com">www.spk-tools.com</a></td>
<td>3836</td>
<td></td>
</tr>
<tr>
<td>CGI, Inc.</td>
<td><a href="http://www.cgimotion.com">www.cgimotion.com</a></td>
<td>4018</td>
<td></td>
</tr>
<tr>
<td>Changzhou Gelisen Qianjin Gear Co., Ltd.</td>
<td><a href="http://www.cz-cl.com">www.cz-cl.com</a></td>
<td>4335</td>
<td></td>
</tr>
<tr>
<td>Chao-Chia Gear Industry Co., Ltd</td>
<td><a href="http://www.chaochia.com.tw">www.chaochia.com.tw</a></td>
<td>4526</td>
<td></td>
</tr>
<tr>
<td>Chardam Gear Co.</td>
<td><a href="http://www.chardam.com">www.chardam.com</a></td>
<td>3218</td>
<td></td>
</tr>
<tr>
<td>CHONGQING XINXING GEAR WHEEL CO., LTD</td>
<td><a href="http://www.xinxing999.com">www.xinxing999.com</a></td>
<td>3740</td>
<td></td>
</tr>
<tr>
<td>Cincinnati Gearing Systems</td>
<td><a href="http://www.cincinnatiengg.com">www.cincinnatiengg.com</a></td>
<td>3018</td>
<td>16</td>
</tr>
<tr>
<td>Cincinnati Steel Treating</td>
<td><a href="http://www.steeltreating.com">www.steeltreating.com</a></td>
<td>3018</td>
<td></td>
</tr>
<tr>
<td>Circle Gear and Machine Company</td>
<td><a href="http://www.circlegear.com">www.circlegear.com</a></td>
<td>4318</td>
<td>56</td>
</tr>
<tr>
<td>Cleveland Deburring Machine Company</td>
<td><a href="http://www.cdmcmachine.com">www.cdmcmachine.com</a></td>
<td>3435</td>
<td></td>
</tr>
<tr>
<td>Cold Forming Technology, Inc</td>
<td><a href="http://www.coldformingtechnology.com">www.coldformingtechnology.com</a></td>
<td>3136</td>
<td></td>
</tr>
<tr>
<td>Columbia Gear Corporation</td>
<td><a href="http://www.columbiagear.com">www.columbiagear.com</a></td>
<td>4209</td>
<td></td>
</tr>
<tr>
<td>Creative Automation Inc.</td>
<td><a href="http://www.cautomation.com">www.cautomation.com</a></td>
<td>4407</td>
<td></td>
</tr>
<tr>
<td>Cruix Gear</td>
<td><a href="http://www.cruixgear.com">www.cruixgear.com</a></td>
<td>4503</td>
<td></td>
</tr>
<tr>
<td>CSB Americas Inc.</td>
<td><a href="http://www.csbamericac.com">www.csbamericac.com</a></td>
<td>2633</td>
<td></td>
</tr>
<tr>
<td>Cumia America Inc.</td>
<td><a href="http://www.cumiausa.com">www.cumiausa.com</a></td>
<td>4130</td>
<td>61</td>
</tr>
<tr>
<td>Curtis Machine Company, Inc.</td>
<td>curtismachine.com</td>
<td>3436</td>
<td></td>
</tr>
<tr>
<td>Curtiss-Wright: Metal Improvement Company</td>
<td><a href="http://www.cwst.com">www.cwst.com</a></td>
<td>4310</td>
<td></td>
</tr>
<tr>
<td>Cy-Car USA Inc.</td>
<td></td>
<td>3841</td>
<td></td>
</tr>
<tr>
<td>Delta Gear</td>
<td><a href="http://www.delta-gear.com">www.delta-gear.com</a></td>
<td>3618</td>
<td></td>
</tr>
<tr>
<td>Diametal</td>
<td><a href="http://www.diametal.ch">www.diametal.ch</a></td>
<td>3131</td>
<td></td>
</tr>
<tr>
<td>DixiTech CNC</td>
<td><a href="http://www.dixitechnc.com">www.dixitechnc.com</a></td>
<td>2509</td>
<td></td>
</tr>
<tr>
<td>DMIC</td>
<td>DMIC.com</td>
<td>2535</td>
<td></td>
</tr>
<tr>
<td>Donald Engineering</td>
<td><a href="http://www.donaldengineering.com">www.donaldengineering.com</a></td>
<td>2536</td>
<td></td>
</tr>
<tr>
<td>Dongguan Silent Industrial Co., Ltd.</td>
<td><a href="http://www.silentg">www.silentg</a> earmotor.com</td>
<td>3341</td>
<td></td>
</tr>
<tr>
<td>Dontyne Systems Limited</td>
<td><a href="http://www.dontynesystems.com">www.dontynesystems.com</a></td>
<td>3234</td>
<td></td>
</tr>
<tr>
<td>Doppler Gear Company</td>
<td><a href="http://www.dopplergear.com">www.dopplergear.com</a></td>
<td>3635</td>
<td></td>
</tr>
<tr>
<td>DTR Corporation</td>
<td><a href="http://www.dtrtool.com">www.dtrtool.com</a></td>
<td>3818</td>
<td>24</td>
</tr>
<tr>
<td>Dunkes Precision Straightening Presses</td>
<td><a href="http://www.dunkes.de">www.dunkes.de</a></td>
<td>3533</td>
<td></td>
</tr>
<tr>
<td>Dura-Bar</td>
<td>dura-bar.com</td>
<td>2937</td>
<td></td>
</tr>
<tr>
<td>DVS Technology America</td>
<td><a href="http://www.dvstechnology.com">www.dvstechnology.com</a></td>
<td>4007</td>
<td>3</td>
</tr>
<tr>
<td>Elevat Inc</td>
<td><a href="http://www.elevat-iot.com">www.elevat-iot.com</a></td>
<td>3044</td>
<td></td>
</tr>
<tr>
<td>Elgeti Engineering GmbH</td>
<td><a href="http://www.elgeti-engineering.com">www.elgeti-engineering.com</a></td>
<td>3637</td>
<td></td>
</tr>
<tr>
<td>EMAG LLC</td>
<td><a href="http://www.emag.com">www.emag.com</a></td>
<td>2400</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Website</td>
<td>Booth#</td>
<td>Ad</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------</td>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>Emuge Corporation</td>
<td><a href="http://www.emuge.com">www.emuge.com</a></td>
<td>3307</td>
<td></td>
</tr>
<tr>
<td>Engineered Abrasives</td>
<td><a href="http://www.engineeredabrasives.com">www.engineeredabrasives.com</a></td>
<td>2807</td>
<td></td>
</tr>
<tr>
<td>Engineered Tools Corporation</td>
<td><a href="http://www.engineeredtools.com">www.engineeredtools.com</a></td>
<td>2707</td>
<td></td>
</tr>
<tr>
<td>Enplas (USA) Inc.</td>
<td><a href="http://www.enplas.co.jp">www.enplas.co.jp</a></td>
<td>4337</td>
<td></td>
</tr>
<tr>
<td>Ernst Grob AG</td>
<td><a href="http://www.ernst-grob.com">www.ernst-grob.com</a></td>
<td>3800</td>
<td></td>
</tr>
<tr>
<td>ERS Engineering Corp</td>
<td><a href="http://www.ersengine.com">www.ersengine.com</a></td>
<td>3741</td>
<td></td>
</tr>
<tr>
<td>Euro-Tech Corp.</td>
<td><a href="http://www.eurotechcorp.com">www.eurotechcorp.com</a></td>
<td>3209</td>
<td>14, 47</td>
</tr>
<tr>
<td>Ever Sharp Tools</td>
<td>est-us.com</td>
<td>2823</td>
<td></td>
</tr>
<tr>
<td>EWAB Engineering Inc.</td>
<td>ewab.com</td>
<td>4127</td>
<td></td>
</tr>
<tr>
<td>F.B. &amp; B. Gear Machine Inc.</td>
<td>fbbgears.com</td>
<td>4603</td>
<td></td>
</tr>
<tr>
<td>Fanuc America Corporation</td>
<td><a href="http://www.fanucamerica.com">www.fanucamerica.com</a></td>
<td>3536</td>
<td></td>
</tr>
<tr>
<td>Federal Fluid Power Inc.</td>
<td><a href="http://www.federalfp.com">www.federalfp.com</a></td>
<td>4626</td>
<td></td>
</tr>
<tr>
<td>Filtrec North America, Inc.</td>
<td><a href="http://www.filtrec.com">www.filtrec.com</a></td>
<td>3437</td>
<td></td>
</tr>
<tr>
<td>Fluidyne Fluid Power</td>
<td><a href="http://www.fluidynefp.com">www.fluidynefp.com</a></td>
<td>2631</td>
<td></td>
</tr>
<tr>
<td>Foerster Instruments Inc.</td>
<td>foerstergroup.com</td>
<td>2926</td>
<td></td>
</tr>
<tr>
<td>Follett Hydraulics</td>
<td></td>
<td>2739</td>
<td></td>
</tr>
<tr>
<td>Forest City Gear Company</td>
<td><a href="http://www.forestcitygear.com">www.forestcitygear.com</a></td>
<td>3418</td>
<td>7</td>
</tr>
<tr>
<td>Forging Industry Association</td>
<td><a href="http://www.forging.org">www.forging.org</a></td>
<td>3140</td>
<td></td>
</tr>
<tr>
<td>FVA GmbH</td>
<td><a href="http://www.fva-service.de">www.fva-service.de</a></td>
<td>3737</td>
<td></td>
</tr>
<tr>
<td>Galdabini Spa</td>
<td><a href="http://www.galdabini.us">www.galdabini.us</a></td>
<td>3339</td>
<td></td>
</tr>
<tr>
<td>Gear Motions, Inc.</td>
<td>gearmotions.com</td>
<td>3531</td>
<td></td>
</tr>
<tr>
<td>Gear Resource Technologies, Inc.</td>
<td><a href="http://www.gear-resource.com">www.gear-resource.com</a></td>
<td>4320</td>
<td></td>
</tr>
<tr>
<td>Gear Solutions Magazine</td>
<td><a href="http://www.gearsolutions.com">www.gearsolutions.com</a></td>
<td>4036</td>
<td></td>
</tr>
<tr>
<td>Gear Technology magazine</td>
<td><a href="http://www.geartechnology.com">www.geartechnology.com</a></td>
<td>3826</td>
<td></td>
</tr>
<tr>
<td>GearKing, Inc.</td>
<td><a href="http://www.gearking.com">www.gearking.com</a></td>
<td>4322</td>
<td></td>
</tr>
<tr>
<td>Geku Getriebe&amp;Kupplung Technologie GmbH</td>
<td><a href="http://www.gekugmbh.de">www.gekugmbh.de</a></td>
<td>3036</td>
<td></td>
</tr>
<tr>
<td>Gibbs Machinery Company</td>
<td><a href="http://www.gibbsmachinery.com">www.gibbsmachinery.com</a></td>
<td>2709</td>
<td></td>
</tr>
<tr>
<td>GIF Media Inc.</td>
<td><a href="http://www.todaysmotorvehicles.com">www.todaysmotorvehicles.com</a></td>
<td>4235</td>
<td></td>
</tr>
<tr>
<td>Gleason Corporation</td>
<td><a href="http://www.gleason.com">www.gleason.com</a></td>
<td>3400</td>
<td>13, 65</td>
</tr>
<tr>
<td>Global Gear</td>
<td><a href="http://www.globalgearllc.com">www.globalgearllc.com</a></td>
<td>4609</td>
<td></td>
</tr>
<tr>
<td>GMTA German Machine</td>
<td><a href="http://www.gmtamerica.com">www.gmtamerica.com</a></td>
<td>4439</td>
<td>23</td>
</tr>
<tr>
<td>Great Lakes Gear Technologies, Inc.</td>
<td><a href="http://www.greatlakesgeartech.com">www.greatlakesgeartech.com</a></td>
<td>3800, 4000</td>
<td></td>
</tr>
<tr>
<td>Great Lakes Industry</td>
<td><a href="http://www.greatlakesind.com">www.greatlakesind.com</a></td>
<td>3141</td>
<td></td>
</tr>
</tbody>
</table>

No Money for Capital Equipment Purchases? NO PROBLEM!

**REPOWER**

SIGMA 3

**M&M 3025**

**REPOWERED BY Penta Gear**

- Analytical Inspection Machine
- Roll Testers
- Single Flank
- DOB Inspection Gauges

6161 Webster St. Dayton, OH • Tel: 937-660-8182 • Fax: 937-660-4521 • Sales@Pentagear.com • gearinspection.com
<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Booth#</th>
<th>Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Taiwan Gear Ltd.</td>
<td><a href="http://www.greattaiwangear.com">www.greattaiwangear.com</a></td>
<td>3207</td>
<td></td>
</tr>
<tr>
<td>GWJ Technology GmbH</td>
<td><a href="http://www.gwj.de">www.gwj.de</a></td>
<td>3834</td>
<td>47</td>
</tr>
<tr>
<td>Hainbuch America Corp.</td>
<td><a href="http://www.hainbuchamerica.com">www.hainbuchamerica.com</a></td>
<td>3203</td>
<td>35, 46</td>
</tr>
<tr>
<td>Hanbo America</td>
<td>hanhoinc.com</td>
<td>3637</td>
<td></td>
</tr>
<tr>
<td>Hanik Corporation</td>
<td><a href="http://www.hanikcorp.com">www.hanikcorp.com</a></td>
<td>2407</td>
<td>65</td>
</tr>
<tr>
<td>Hans-Juergen Geiger Maschinen-Vertrieb GMBH</td>
<td><a href="http://www.geiger-germany.com">www.geiger-germany.com</a></td>
<td>3820</td>
<td></td>
</tr>
<tr>
<td>Hayakawa USA Corporation</td>
<td>hayakawa-team.com</td>
<td>2609</td>
<td></td>
</tr>
<tr>
<td>Helios Gear Products</td>
<td>heliosgearproducts.com</td>
<td>3213</td>
<td>4, 49</td>
</tr>
<tr>
<td>Hermes Abrasives, Ltd</td>
<td><a href="http://www.hermesabrasives.com">www.hermesabrasives.com</a></td>
<td>4409</td>
<td></td>
</tr>
<tr>
<td>HEVI Systems</td>
<td><a href="http://www.hevihybrid.com">www.hevihybrid.com</a></td>
<td>2831</td>
<td></td>
</tr>
<tr>
<td>HobSource Inc.</td>
<td><a href="http://www.hobsource.com">www.hobsource.com</a></td>
<td>4401</td>
<td>61</td>
</tr>
<tr>
<td>Hoffmann Filter Corporation</td>
<td><a href="http://www.hoffmannfilter.com">www.hoffmannfilter.com</a></td>
<td>3022</td>
<td></td>
</tr>
<tr>
<td>Horn USA, Inc.</td>
<td><a href="http://www.hornusa.com">www.hornusa.com</a></td>
<td>3844</td>
<td></td>
</tr>
<tr>
<td>Hydra-Lock Corporation</td>
<td><a href="http://www.hyralock.com">www.hyralock.com</a></td>
<td>3944</td>
<td></td>
</tr>
<tr>
<td>Hydrapulse</td>
<td><a href="http://www.hydrapulse.com">www.hydrapulse.com</a></td>
<td>2831</td>
<td></td>
</tr>
<tr>
<td>Hydraulics &amp; Pneumatics</td>
<td><a href="http://www.hydraulicspneumatics.com">www.hydraulicspneumatics.com</a></td>
<td>2634</td>
<td></td>
</tr>
<tr>
<td>IC Fluid Power, Inc.</td>
<td><a href="http://www.icfluid.com">www.icfluid.com</a></td>
<td>2539</td>
<td></td>
</tr>
<tr>
<td>IDC Industries Inc.</td>
<td><a href="http://www.idcind.com">www.idcind.com</a></td>
<td>4508</td>
<td></td>
</tr>
<tr>
<td>IMT Forge</td>
<td><a href="http://www.cilford-jacobs.com">www.cilford-jacobs.com</a></td>
<td>2526</td>
<td></td>
</tr>
<tr>
<td>Index Technologies Inc.</td>
<td><a href="http://www.indextechnologiesinc.com">www.indextechnologiesinc.com</a></td>
<td>3227</td>
<td>46</td>
</tr>
<tr>
<td>Industrial Machinery Digest</td>
<td><a href="http://www.industrialmachinerydigest.com">www.industrialmachinerydigest.com</a></td>
<td>3640</td>
<td></td>
</tr>
<tr>
<td>Ingersoll Cutting Tools</td>
<td><a href="http://www.ingersoll-inc.com">www.ingersoll-inc.com</a></td>
<td>3822</td>
<td></td>
</tr>
<tr>
<td>Ingranaggi Morelli Mario S.p.A.</td>
<td><a href="http://www.moreali.com">www.moreali.com</a></td>
<td>3041</td>
<td></td>
</tr>
<tr>
<td>Innovative Rack &amp; Gear Co.</td>
<td><a href="http://www.gearacks.com">www.gearacks.com</a></td>
<td>2907</td>
<td></td>
</tr>
<tr>
<td>International Fluid Power Society</td>
<td><a href="http://www.ifps.org">www.ifps.org</a></td>
<td>2834</td>
<td></td>
</tr>
<tr>
<td>Involute Gear &amp; Machine Company</td>
<td><a href="http://www.involutegearmachine.com">www.involutegearmachine.com</a></td>
<td>3026</td>
<td></td>
</tr>
<tr>
<td>IoT Diagnostics</td>
<td><a href="http://www.iotdiag.com">www.iotdiag.com</a></td>
<td>2533</td>
<td></td>
</tr>
<tr>
<td>IPM, Inc.</td>
<td><a href="http://www.ipminc.com">www.ipminc.com</a></td>
<td>3240</td>
<td></td>
</tr>
<tr>
<td>James Engineering</td>
<td><a href="http://www.james-engineering.com">www.james-engineering.com</a></td>
<td>2726</td>
<td></td>
</tr>
<tr>
<td>JRM International Inc.</td>
<td><a href="http://www.jrminternational.com">www.jrminternational.com</a></td>
<td>3222</td>
<td></td>
</tr>
<tr>
<td>Kapp-Niles</td>
<td><a href="http://www.kapp-niles.com">www.kapp-niles.com</a></td>
<td>3607</td>
<td>11, 20</td>
</tr>
<tr>
<td>KISSsoft AG</td>
<td><a href="http://www.kisssoft.ch">www.kisssoft.ch</a></td>
<td>3400</td>
<td>65</td>
</tr>
<tr>
<td>Company</td>
<td>Website</td>
<td>Booth#</td>
<td>Ad</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-----------------------------------------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>Klingelnberg</td>
<td><a href="http://www.klingelnberg.com">www.klingelnberg.com</a></td>
<td>3631</td>
<td>Back Cover</td>
</tr>
<tr>
<td>Knoll America</td>
<td><a href="http://www.knollamerica.com">www.knollamerica.com</a></td>
<td>3441</td>
<td></td>
</tr>
<tr>
<td>Laser Marketing Technologies</td>
<td>lasermarktech.com</td>
<td>4627</td>
<td></td>
</tr>
<tr>
<td>LEAX Group</td>
<td><a href="http://www.leax.com">www.leax.com</a></td>
<td>4032</td>
<td></td>
</tr>
<tr>
<td>Liebherr Gear Technology, Inc.</td>
<td><a href="http://www.liebherr.com">www.liebherr.com</a></td>
<td>3413</td>
<td>5</td>
</tr>
<tr>
<td>Linamar Forgings Carolina, Inc</td>
<td><a href="http://www.linamar.com">www.linamar.com</a></td>
<td>4431</td>
<td></td>
</tr>
<tr>
<td>Louis Belet</td>
<td><a href="http://www.louisbelet.ch">www.louisbelet.ch</a></td>
<td>3033</td>
<td></td>
</tr>
<tr>
<td>Lucrent Bearing</td>
<td>lucrescentbearing.com</td>
<td>2836</td>
<td></td>
</tr>
<tr>
<td>Machine Tool Builders Inc.</td>
<td><a href="http://www.machinetoolbuilders.com">www.machinetoolbuilders.com</a></td>
<td>3407</td>
<td>22</td>
</tr>
<tr>
<td>MachineMetrics</td>
<td><a href="http://www.machinemetrics.com">www.machinemetrics.com</a></td>
<td>3044</td>
<td></td>
</tr>
<tr>
<td>Magnetic Inspection Laboratory</td>
<td><a href="http://www.milinc.com">www.milinc.com</a></td>
<td>3831</td>
<td></td>
</tr>
<tr>
<td>Makishinko Co., Ltd.</td>
<td><a href="http://www.makishinko.com">www.makishinko.com</a></td>
<td>3937</td>
<td></td>
</tr>
<tr>
<td>Matrix Design, LLC</td>
<td><a href="http://www.matrixdesignllc.com">www.matrixdesignllc.com</a></td>
<td>4022</td>
<td></td>
</tr>
<tr>
<td>Matrix Precision Co., Ltd</td>
<td><a href="http://www.luren.com.tw">www.luren.com.tw</a></td>
<td>2613</td>
<td></td>
</tr>
<tr>
<td>MB Metal Technologies LLC</td>
<td><a href="http://www.mbmetaltech.com">www.mbmetaltech.com</a></td>
<td>3541</td>
<td></td>
</tr>
<tr>
<td>McInnes Rolled Rings</td>
<td><a href="http://www.mcinnesrolledrings.com">www.mcinnesrolledrings.com</a></td>
<td>2922</td>
<td>15</td>
</tr>
<tr>
<td>Meritor</td>
<td><a href="http://www.meritor.com">www.meritor.com</a></td>
<td>2818</td>
<td></td>
</tr>
<tr>
<td>MESYS AG</td>
<td><a href="http://www.mesys.ag">www.mesys.ag</a></td>
<td>3933</td>
<td></td>
</tr>
<tr>
<td>Metalcastello</td>
<td><a href="http://www.metalcastello.com">www.metalcastello.com</a></td>
<td>3735</td>
<td></td>
</tr>
<tr>
<td>Mitsubishi Heavy Industries America, Inc.</td>
<td><a href="http://www.mitsubishigearcenter.com">www.mitsubishigearcenter.com</a></td>
<td>4418, 3044</td>
<td>8, 48</td>
</tr>
<tr>
<td>Machine Tool Division</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mohawk Machinery Inc.</td>
<td><a href="http://www.mohawkmachinery.com">www.mohawkmachinery.com</a></td>
<td>3920</td>
<td></td>
</tr>
<tr>
<td>MTI</td>
<td><a href="http://www.slmti.com">www.slmti.com</a></td>
<td>4307</td>
<td></td>
</tr>
<tr>
<td>Nagel Precision Inc.</td>
<td><a href="http://www.nagelusa.com">www.nagelusa.com</a></td>
<td>4308</td>
<td></td>
</tr>
<tr>
<td>Napoleon Engineering Services</td>
<td><a href="http://www.nesbearings.com">www.nesbearings.com</a></td>
<td>3620</td>
<td></td>
</tr>
<tr>
<td>National Fluid Power Association</td>
<td><a href="http://www.nfpa.com">www.nfpa.com</a></td>
<td>2731</td>
<td></td>
</tr>
<tr>
<td>New England Gear</td>
<td><a href="http://www.newenglandgear.com">www.newenglandgear.com</a></td>
<td>3422</td>
<td></td>
</tr>
<tr>
<td>Nichiei Co. Ltd.</td>
<td><a href="http://www.nichiei-ind.com">www.nichiei-ind.com</a></td>
<td>3326</td>
<td></td>
</tr>
<tr>
<td>Nichols Portland, LLC</td>
<td>nicholsportland.com</td>
<td>3040</td>
<td></td>
</tr>
<tr>
<td>Norton/Saint-Gobain</td>
<td><a href="http://www.nortonabrasives.com">www.nortonabrasives.com</a></td>
<td>2607</td>
<td>46</td>
</tr>
<tr>
<td>Oberlin Filter Company</td>
<td><a href="http://www.oberlinfilter.com">www.oberlinfilter.com</a></td>
<td>3334</td>
<td></td>
</tr>
<tr>
<td>Oelheld U.S., Inc.</td>
<td><a href="http://www.oelheld.com">www.oelheld.com</a></td>
<td>3803</td>
<td>48, 58</td>
</tr>
<tr>
<td>OEM Controls, Inc</td>
<td><a href="http://www.oemcontrols.com">www.oemcontrols.com</a></td>
<td>2939</td>
<td></td>
</tr>
</tbody>
</table>

**MTB Launches New Hobbing Machines at Motion+Power**

The SMG SH210 will be exclusively available for demos with special show discounts!

- Next generation hobbing machines with advanced capabilities
- Rare combination of high speed, rigidity, accuracy & reliability
- Special show pricing & value-added features deliver an unmatched ROI

**SMG**

Ultra-precision gear grinding  
Portable gear inspection  
Inspection for gears & hobs

**Donner + Pfister AG**

World-class grinding machines  
Quick-change work-holding tooling  
PM Profiling for pre-dressing of grinding & honing wheels

**Machinetoolbuilders.com**
When you visit Motion & Power Technology Expo (aka Gear Expo)
in Detroit, be sure you stop at booth 4439 and see GMTA, a leader in gear machine technology, as well as laser joining and parts washing equipment for the industry.

Say hi to Walter Friedrich and ask him, “OK, Walter, what’s the big secret?”
He might tell you.

If you do broaching, you might want to hear his answer.

See you in the Motor City!
<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Booth#</th>
<th>Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotec Tools Ltd.</td>
<td>rotectools.com</td>
<td>3131</td>
<td>21</td>
</tr>
<tr>
<td>Rubig Engineering</td>
<td><a href="http://www.rubig.com">www.rubig.com</a></td>
<td>2409</td>
<td></td>
</tr>
<tr>
<td>RUF Briquetting Systems</td>
<td><a href="http://www.ruf-briquetter.com">www.ruf-briquetter.com</a></td>
<td>3208</td>
<td></td>
</tr>
<tr>
<td>Russell, Holbrook &amp; Henderson</td>
<td><a href="http://www.tru-volute.com">www.tru-volute.com</a></td>
<td>4226</td>
<td></td>
</tr>
<tr>
<td>S.L. Munson &amp; Co.</td>
<td><a href="http://www.silmunson.com">www.silmunson.com</a></td>
<td>2800</td>
<td></td>
</tr>
<tr>
<td>Schnyder SA</td>
<td><a href="http://www.schnyder.com">www.schnyder.com</a></td>
<td>2407</td>
<td>65</td>
</tr>
<tr>
<td>Schunk</td>
<td><a href="http://www.schunk.com">www.schunk.com</a></td>
<td>3231</td>
<td></td>
</tr>
<tr>
<td>Scott Forge</td>
<td><a href="http://www.scottforge.com">www.scottforge.com</a></td>
<td>2809</td>
<td></td>
</tr>
<tr>
<td>Senjo Seiki Gear Chamfering</td>
<td><a href="http://www.dynamicdetroit.com">www.dynamicdetroit.com</a></td>
<td>4509</td>
<td></td>
</tr>
<tr>
<td>Shanthi Gears Ltd.</td>
<td><a href="http://www.shanthigears.com">www.shanthigears.com</a></td>
<td>3133</td>
<td></td>
</tr>
<tr>
<td>Sinto America</td>
<td>sintoamerica.com</td>
<td>3039</td>
<td></td>
</tr>
<tr>
<td>SMT</td>
<td><a href="http://www.smartmt.com">www.smartmt.com</a></td>
<td>4227</td>
<td>55</td>
</tr>
<tr>
<td>SMW Autoblok Corp</td>
<td><a href="http://www.smwaublok.com">www.smwaublok.com</a></td>
<td>2821</td>
<td></td>
</tr>
<tr>
<td>Somaschini North America LLC</td>
<td><a href="http://www.somaschini.com">www.somaschini.com</a></td>
<td>4203</td>
<td></td>
</tr>
<tr>
<td>SONA BLW Präzisionsschmiede</td>
<td><a href="http://www.sona-blw.com">www.sona-blw.com</a></td>
<td>3439</td>
<td></td>
</tr>
<tr>
<td>Southern Gear &amp; Machine, Inc.</td>
<td><a href="http://www.southerngear.net">www.southerngear.net</a></td>
<td>4228</td>
<td>49</td>
</tr>
<tr>
<td>Specialty Ring Products, Inc.</td>
<td>specialtyring.com</td>
<td>4133</td>
<td></td>
</tr>
<tr>
<td>Specialty Steel Treating</td>
<td><a href="http://www.sst.net">www.sst.net</a></td>
<td>2426</td>
<td></td>
</tr>
<tr>
<td>Speedgrip Chuck Company</td>
<td><a href="http://www.speedgrip.com">www.speedgrip.com</a></td>
<td>4601</td>
<td></td>
</tr>
<tr>
<td>Star SU, LLC</td>
<td><a href="http://www.star-su.com">www.star-su.com</a></td>
<td>4013</td>
<td>IFC-1, 56</td>
</tr>
<tr>
<td>Stresstech</td>
<td><a href="http://www.astresstech.com">www.astresstech.com</a></td>
<td>4218</td>
<td></td>
</tr>
<tr>
<td>SuperAbrasives, Inc.</td>
<td>superabrasives.com</td>
<td>3226</td>
<td></td>
</tr>
<tr>
<td>Supreme Industrial Works</td>
<td><a href="http://www.gearsupreme.com">www.gearsupreme.com</a></td>
<td>3536</td>
<td></td>
</tr>
<tr>
<td>Synergy Additive Manufacturing</td>
<td>synergyadditive.com</td>
<td>3227</td>
<td></td>
</tr>
<tr>
<td>Techmode LLC</td>
<td><a href="http://www.techmode.com">www.techmode.com</a></td>
<td>3727</td>
<td></td>
</tr>
<tr>
<td>Techniques Surfaces USA, Inc.</td>
<td><a href="http://www.hefusa.net">www.hefusa.net</a></td>
<td>2839</td>
<td></td>
</tr>
<tr>
<td>The Estell Group LLC</td>
<td><a href="http://www.theestellgroup.com">www.theestellgroup.com</a></td>
<td>2728</td>
<td></td>
</tr>
<tr>
<td>The Modal Shop, Inc.</td>
<td><a href="http://www.ndt-ram.com">www.ndt-ram.com</a></td>
<td>4220</td>
<td></td>
</tr>
<tr>
<td>The Tekfor Group</td>
<td>amtektekfor.com</td>
<td>4403</td>
<td></td>
</tr>
<tr>
<td>THERMTECH</td>
<td><a href="http://www.thermtech.net">www.thermtech.net</a></td>
<td>4126</td>
<td></td>
</tr>
<tr>
<td>Thors, LLC</td>
<td><a href="http://www.thors.com">www.thors.com</a></td>
<td>2928</td>
<td></td>
</tr>
<tr>
<td>Thyssenkrupp Rothe Erde USA, Inc</td>
<td><a href="http://www.thyssenkrupp-rotheerde.com">www.thyssenkrupp-rotheerde.com</a></td>
<td>3228</td>
<td></td>
</tr>
</tbody>
</table>

**All The Gear Cutting Tools You Will Ever Need Are Right Here**

DTR is one of the world’s largest producers.

DTR. Your best choice for high quality gear cutting tools.

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.

DTR offers a full line of gear cutting tools including:
- Hobs
- Chamfering and Deburring Tools
- Shaper Cutters
- Master Gears
- Milling Cutters

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

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

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.

DTR has sales territories available. Call for more information.

**Visit Us at Booth #3818**

**U.S. Office Location (Chicago)**
Email inquiries to: alex@dtrtool.com.
1865 Hicks Road, Suite A, Rolling Meadows, IL 60008
PHONE: 847-375-8892 Fax: 224-220-1311

**Headquarters**
85, Namdong-daero 370beon-gil, Namdong-gu, Incheon, Korea, 21635
PHONE: +82.32.814.1540
FAX: +82.32.814.5381
<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Booth#</th>
<th>Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>TimkenSteel Corporation</td>
<td><a href="http://www.timkensteel.com">www.timkensteel.com</a></td>
<td>3431</td>
<td></td>
</tr>
<tr>
<td>Toolink Engineering Inc.</td>
<td><a href="http://www.toolink-eng.com">www.toolink-eng.com</a></td>
<td>4003, 3903</td>
<td></td>
</tr>
<tr>
<td>Toyota Americas Corporation</td>
<td><a href="http://www.toyoda.com">www.toyoda.com</a></td>
<td>3832</td>
<td></td>
</tr>
<tr>
<td>Tribute, Inc</td>
<td><a href="http://www.tribute.com">www.tribute.com</a></td>
<td>2733</td>
<td></td>
</tr>
<tr>
<td>Trojan Gear, Inc.</td>
<td><a href="http://www.trojan-gear.com">www.trojan-gear.com</a></td>
<td>2528</td>
<td></td>
</tr>
<tr>
<td>Trumpf</td>
<td><a href="http://www.trumpf.com">www.trumpf.com</a></td>
<td>4326</td>
<td></td>
</tr>
<tr>
<td>TTP-API Heat Transfer</td>
<td><a href="http://www.apiheattransfer.com">www.apiheattransfer.com</a></td>
<td>2531</td>
<td></td>
</tr>
<tr>
<td>Tuson Corporation</td>
<td>tuson.com</td>
<td>2934</td>
<td></td>
</tr>
<tr>
<td>Ty Miles, Inc.</td>
<td><a href="http://www.tymiles.com">www.tymiles.com</a></td>
<td>4607</td>
<td></td>
</tr>
<tr>
<td>United Gear &amp; Assembly, Inc.</td>
<td><a href="http://www.ugaco.com">www.ugaco.com</a></td>
<td>4207</td>
<td></td>
</tr>
<tr>
<td>United Tool Supply</td>
<td><a href="http://www.unite-a-matic.com">www.unite-a-matic.com</a></td>
<td>4614</td>
<td>45</td>
</tr>
<tr>
<td>Vantage Corporation</td>
<td>vantage-corp.com</td>
<td>4414</td>
<td></td>
</tr>
<tr>
<td>ViewTech Borescopes</td>
<td>viewtech.com</td>
<td>4415</td>
<td></td>
</tr>
<tr>
<td>Viking Forge Corp.</td>
<td><a href="http://www.viking-forge.com">www.viking-forge.com</a></td>
<td>2610</td>
<td></td>
</tr>
<tr>
<td>Virgo Communications &amp; Exhibitions</td>
<td><a href="http://www.virgo-comm.com">www.virgo-comm.com</a></td>
<td>3936</td>
<td></td>
</tr>
<tr>
<td>Visual Knowledge Share</td>
<td><a href="http://www.vksapp.com">www.vksapp.com</a></td>
<td>4239</td>
<td></td>
</tr>
<tr>
<td>Walker Forge, Inc.</td>
<td><a href="http://www.walkerforge.com">www.walkerforge.com</a></td>
<td>3031</td>
<td></td>
</tr>
<tr>
<td>Weiler Abrasives Group</td>
<td>weilercorp.com</td>
<td>3335</td>
<td></td>
</tr>
<tr>
<td>Weldon Solutions</td>
<td>weldonsolutions.com</td>
<td>4131</td>
<td></td>
</tr>
<tr>
<td>Western Michigan University’s Center for</td>
<td>wmich.edu/vehicledesign/consortium</td>
<td>2837</td>
<td></td>
</tr>
<tr>
<td>Advanced Vehicle Design and Simulation (CAVDS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WFL Millturn Technologies GmbH &amp; Co. KG</td>
<td><a href="http://www.wfl.at">www.wfl.at</a></td>
<td>4309</td>
<td>44</td>
</tr>
<tr>
<td>WS GearDynamics GmbH</td>
<td><a href="http://www.ws-geardynamics.com">www.ws-geardynamics.com</a></td>
<td>4603</td>
<td></td>
</tr>
<tr>
<td>Xubi Engranajes, S.L.</td>
<td><a href="http://www.xubi.com">www.xubi.com</a></td>
<td>3931</td>
<td></td>
</tr>
<tr>
<td>Yates Cylinders</td>
<td><a href="http://www.yatesind.com">www.yatesind.com</a></td>
<td>2636</td>
<td></td>
</tr>
<tr>
<td>ZEISS Industrial Quality Solutions</td>
<td><a href="http://www.zeiss.com/metrology">www.zeiss.com/metrology</a></td>
<td>4405</td>
<td></td>
</tr>
<tr>
<td>Zerust Corrosion Solutions</td>
<td><a href="http://www.zerust.com">www.zerust.com</a></td>
<td>4026</td>
<td></td>
</tr>
<tr>
<td>Zoller Inc.</td>
<td>zoller-d.com</td>
<td>3739</td>
<td></td>
</tr>
</tbody>
</table>

Trust nothing less than AFC-Holcroft for your heat treat production

- Our UBQ (Universal Batch Quench) furnaces feature the largest workloads in the industry, with superior quench results
- Advanced technology including Batchmaster controls system and Remote Diagnostics™ service (IIoT)
- Modular, flexible designs, customizable to your specific requirements, designed for ease of maintenance and serviceability
- Thousands of installations worldwide, trusted by leading global companies

Please visit us at www.afc-holcroft.com
AFC-Holcroft USA - Wixom, Michigan, USA, Phone +1 248 624 8191
AFC-Holcroft Europe - Delémont, Switzerland
AFC-Holcroft Asia - Shanghai

Reliability at work
MPT Expo 2019 Booth Previews

MPT Expo takes place October 15–17 at TCF CENTER (formerly the Cobo Center) in Detroit. Here are booth previews of some of the exhibitors most relevant to the gear industry.

ADVANCED HEAT TREAT

BOOTH 4600

Advanced Heat Treat Corp. (AHT) will feature its heat treat solutions to help manufacturers and engineers solve wear, fatigue and corrosion challenges.

AHT will have both technical and operational personnel available to help MPT Expo attendees get their heat treat and metallurgy questions answered on-the-spot. Exhibitors include Vasko Popovski, P.E. with over 25 years of metallurgy experience and Chad Clark, 16-year AHT veteran and plant manager at the AHT site located in Monroe, MI.

The Monty recently recognized AHT founder and chief executive officer, Gary Sharp, as “the man most responsible for making plasma nitriding a mainstream process in North America.”

Aside from ion/plasma nitriding, AHT also offers gas nitriding, ferritic nitrocarburizing, UltraOx, through hardening, carburizing, induction hardening, stress relief and more. Their 20+ surface treatments, multiple locations and dozens of accreditations/certifications make AHT well-equipped to provide the capabilities and expertise engineers and buyers desire.

ALD VACUUM TECHNOLOGIES

BOOTH 3200

Six years ago, “One-Piece-Flow” (OPF) for case hardening processes was introduced into the gear industry for the first time, using SyncroTherm technology. Based on low-pressure carburizing (LPC) and high-pressure gas quench (HPGQ), advantages include high quality parts, short process times, less part distortion and high environmental compatibility.

In the meantime, SyncroTherm technology has expanded to include other processes such as tool hardening, annealing, brazing and sintering. In addition, another possible use is flexible heat treatment of small batches or lots, the so-called “Small Batch Production” (SBP).

The new SyncroTherm 2.0 now offers additional control features in order to meet all the requirements of a modern Internet of Things (IoT) setting. These include standardized interfaces for simple integration of external plant components into the SyncroTherm 2.0 furnace system and IoT-compatible interfaces (XML) for data transmission to superior customer-ERP-systems.

Target markets include the automotive industry and their suppliers, especially parts for electromobility in the OPF. The SyncroTherm technology is also used successfully in the aviation industry. The use of flexible “Small Batch Production” (SBP) broadens the application range for captive heat treaters and commercial heat treaters.

AMERICAN GEAR MANUFACTURERS ASSOCIATION

BOOTH 3426

The American Gear Manufacturers Association will be in the center of the inaugural Motion + Power Technology Expo (MPT Expo). Everyone is invited to the booth to discuss the thought process behind the all-inclusive show and the future direction of the power transmission industry. You can direct questions to AGMA’s staff or board about standards, education, emerging technology, membership, committees and the strategy that AGMA and its members are using to move the future.

And although they want everyone to stop by their booth, AGMA encourages attendees and exhibitors to walk the entire show floor to see all the new and different companies that have come to showcase their importance in our industry. With the new Fluid Power Pavilion, the Emerging Technology Pavilion and 250 exhibitors — including over 50 new companies — attendees will be connected to the top manufacturers, suppliers, buyers and experts in the mechanical and gear power,
electric power and fluid power industries. This is the place where you can do real business.

When attendees and exhibitors need a break from making deals, AGMA highly encourages them to take an educational seminar, attend a Fall Technical Meeting session or sign up for the new Motion + Power Technology Conference (MPT Conference), where they will learn from the experts. Whether you are new to the business and want to take the “Basics of Gearing” course or are looking to expand your knowledge by taking the “Fundamental Understanding of Electro Fluid Power Technology” class, there is something for everyone across all industries. Not an engineer or operator? That is okay, the two-track MPT Conference boasts presentations from leaders on cybersecurity, IIoT, workforce, supply chain management, 3-D printing, automation, economics and more. These development tools make taking that extra person an easy choice when you can check off training for the year in just three days.

www.agma.org

BENZ
BOOTH 4608

Since 1898, Benz has been a leader in supporting manufacturers by developing industrial fluids and lubricants. During this time, their products and offerings have evolved along with the industry.

To guarantee all your metalworking and machining processes are running as smoothly and proficiently as possible, machining fluids and coolants are a necessity. Since each fluid is formulated to work with particular metals in different conditions, be sure and contact a Benz representative for the details and specifications of the appropriate lubricant for your metal cutting application.

Benz manufacturers and distributes the best coolants for CNC Machines to keep your metalworking products, machines and operators in the absolute best condition! Contact Benz today!

www.benz.com

BOURN & KOCH, INC.
BOOTH 3813

Bourn & Koch, Inc. will feature their newly designed 100H-T horizontal gear hobbing and turning center. Capable of producing high quality gears in a compact footprint, the 100H now features a 12-station turret to allow for turning and hobbing of workpieces in one setup. The 100H-T also features the latest BK-HMI conversational programming. The Bourn & Koch 100H has standard single- and multiple-cut cycles, Fanuc 0i-F CNC control, a power-programmable CNC hob swivel, automatic hob shift, along with crown and taper hobbing cycles. With the addition of turning, the 100H-T is designed for “one and done” gear manufacturing.

www.bevelgearsindia.com

BEVEL GEARS INDIA
BOOTH 4210

Bevel Gears India has been manufacturing bevel gears and bevel gearboxes for over 40 years. The range of bevel gears, from 0.40” to over 70”, is broad by international standards and serves several industries. They also manufacture a select range of fine pitch spur, helical and worm gears.

The bevel gear expertise has broadened over the years from custom gearing to include stock bevel gears and standard cube bevel gearboxes.

The stock bevel gear program is offered in both metric and imperial versions. Customers can select from ground or lapped spiral bevels, ground or lapped Zerols and soft or hardened straight bevel gears. Customization of stock products is an option to provide more flexibility.

Bevel gearboxes are available in standard ratios and sizes with the option to customize gear ratios, gearbox mounting requirements or housing materials for demanding applications. For power-dense applications, Bevel Gears India provides customers with high ratio hypoid gears with very high single-stage reductions. Their engineering department will be glad to review your requirements.

Applications include medical, robotics, packaging and positioning.

www.bevelgearsindia.com
Also on display will be the fully remanufactured CNC Fellows 10-4 with electronic guide and CNC backoff allowing for crown and taper. Numerous mechanical guides and cams are no longer required to shape a wide array of gears on a Fellows 10-4. Bourn & Koch has long provided quality OEM remanufactures of Fellows 10-4 gear shapers, but has now engineered their electronic guide and CNC backoff software into the machine, which is operable through their conversational programming. The addition of electronic guide and CNC backoff offers an efficient and affordable entry into the world of advanced gear shaping.

Bourn & Koch will also feature their 25H gear hobber in their booth. Designed for the economical hobbing of fine pitch gears up to 25 mm, the 25H is a compact machine capable of producing high quality gears for a wide variety of applications and industries.

www.bourn-koch.com

CUMI AMERICA INC.

BOOTH 4139

Achieve higher precision and productivity with high performance ceramic grains for gear grinding. Time tested and compatible with all major gear grinding machines, CUMI grinding wheels are now represented by a dedicated North American sales office.

www.cumiusa.com

DTR CORPORATION

BOOTH 3818

DTR is a supplier of high-performance, long-life gear manufacturing tools for small and large gear cutting applications. Established in 1976, DTR is one of the world's largest producers of cutting tools, shipping to more than 20 countries. DTR offers a full line of gear cutting tools, including hobs, carbide hobs, shaper cutters, milling cutters, chamfering and deburring tools, broaches and master gears.

Every tool is precision-made using high speed steel, premium powder metal or carbide, along with the latest in coatings, to achieve superior cutting and long life.

www.dtrtool.com

DURA-BAR

BOOTH 2937

Dura-Bar continuous cast gray and ductile iron is an alternative to steel, castings and aluminum that offers reliability and improved profitability for many applications, including gears.

Engineered to machine fast and consistently, Dura-Bar is customizable and available in a wide variety of sizes and shapes in the standard ASTM A48 and ASTM A536 gray and ductile iron grades.

Recently, Dura-Bar has added a tube portfolio to the launch of Dura-Tube. The new tube portfolio, produced utilizing either a proprietary continuous cast process or trepanned process, is now available in a selection of sizes and grades. The flexibility to choose Dura-Tube provides customers with options to select tube products to specifically meet requirements such as wall thickness, concentricity and even volume.

www.dura-bar.com
Nachi America Inc.
715 Pushville Rd., Greenwood, IN 46143
ml-nai.machinetools@nachi.com • www.nachiamerica.com

GMS200 Skiving Machining Center for Gears

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

Nachi America Inc.
715 Pushville Rd., Greenwood, IN 46143
ml-nai.machinetools@nachi.com • www.nachiamerica.com
requirements. Adaptable workholding solutions eliminate the need for an entirely new workholding device, saving cost and streamlining the manufacturing process. Attendees can learn more about these adaptable workholding solutions, and discuss any of their custom clamping application needs at the Emuge booth. (www.emuge.com/products/precision-workholding)

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

ERS ENGINEERING
BOOTH 3741

ERS Engineering Corp. will present Through Surface Hardening (TSH) technology—a unique metallurgy process that makes it possible to replace carburizing with induction hardening for a wide range of complexly shaped components, including parts previously thought to be unsuitable for induction hardening.

“The implementation of this technology provides a unique opportunity to the manufacturers who produce case hardened components to achieve two major goals,” Semyon Brayman, president of ERS, said. “First, to substantially reduce the production cost; and second, to significantly improve the quality of produced components.”

TSH is well suited for induction surface hardening helical bull gears, spiral bevel gears, crown wheel style hypoid gears, helical side gears and other gears and gear-like components. Applicability of the TSH technology is not limited to gears. Bushings, transmission shafts, kingpins, ball joints, driveshafts and differential crosses and bearings are also good candidates. www.ersengine.com

EURO-TECH CORP.
BOOTH 3209

Featuring Mytec mechanical & hydraulic expansion arbors & chucks; and Frenco spline gaging. Today’s solutions for efficiency and power density are often a combination of mechanical, fluid power, electric, and hybrid technologies.

Today’s gears and splines are precision items produced through special tools with very tight tolerances. When you need to inspect manufactured work pieces you need even more accurate measuring and inspection equipment. For over 40 years Frenco has committed itself to the challenge of providing customized solutions for individual gear and spline inspection requirements.

Euro-Tech is the exclusive North American distributor of the Frenco product line including master gears and master wheels, setting masters, artifacts, profiled clamping systems and gear and spline production; also instruments for size production including measuring pins and ball inserts, indicating gages including rocking type, face stop and profiled guiding body and special indicating gages.

eurotechcorp.com
www.frenco.com

FOREST CITY GEAR
BOOTH 3418

Forest City Gear is a family-owned and operated business and has been in the gear manufacturing industry since 1955. Industries across the globe have placed their trust in Forest City Gear and their ability to do what others can’t. Every day they manufacture custom gears across a diverse array of industries covering an equally diverse range of applications. These applications span land, sea, air and space. Forest City Gear was chosen to produce all the gears and splines in the Mars Rover where failure simply wasn’t an option. Forest City also regularly supports everything from telescopes, artificial elbows, aircraft, automotive, racing, medical implants, industrial equipment, marine applications and more. Be assured that when your gears made at Forest City arrive on your dock, they will not just meet your expectations; they will exceed it.

If you’d like to learn more of what they can do for your organization, contact them to arrange a “walk through the forest,” where you can tour their plant and see for yourself the difference a Forest City Gear will make in your application. www.forestcitygear.com

FVA
BOOTH 4237

The FVA-Workbench is a manufacturer-neutral software solution for the modeling, parameterization, and calculation of transmission systems. It bundles more than 50 years of research and development from the FVA (German Research Association for Drive Technology) expert network into a single platform and makes this accumulated knowledge directly available for practical application.

This unique software includes the latest results from the FVA research network — new calculation methods for fast, precise results. Thanks to powerful performance and intuitive operation, the new FVA-Workbench is easy to use and accelerates development processes significantly. Individual gearbox components and complete systems can be developed in the shortest time possible. www.fva-service.de

GALDABINI
BOOTH 3339

Galdabini’s PAS vertical straighteners are electromechanical machines designed for straightening short and medium length shafts. Their innovative C-shaped frame and the movable table holding
workpieces are two important features which are ideal for producing large quantities of parts as small batches.

The electromechanical technology enables energy saving and reduced floor space, flexible layout, low noise level, accessibility from three sides and reduced maintenance. PAS machines are the best technical straightening solution to achieve accurate tolerances in short cycle times.

The straightening process is fully automatic and 100% of parts are monitored and controlled; production statistics generated by machine software allow all the most significant production data (cycle time, initial and final tolerance...) to be recorded.

www.galdabini.us

GEAR MOTIONS
BOOTH 3531

Gear Motions will introduce new, non-backdriveable gearbox technology. Attendees can view demonstrations of the never-before-seen, patented technology at their booth. Gear Motions will also unveil its plan for a substantial new equipment investment. The precision manufacturer plans to add three new Reishauer robotic gear grinders to its facilities in Syracuse, New York, and Buffalo, New York, over the next two years. The first, a Reishauer RZ 260, is expected to be installed by the end of 2019. The new machines will further expand the company’s gear grinding capacity and add new capabilities such as twist control and super finishing.

Gear Motions’ top sales and engineering staff will be on-site and available to discuss customers’ precision manufacturing needs and project specifications.

www.gearmotions.com

GLEASON
BOOTH 3400

Gleason Corporation will showcase a wide array of new design, manufacturing and inspection technologies for cylindrical and bevel gears.

KISSsoft’s Release 2019 includes: KISSdesign, an instrument that allows intuitive concept design at system level; an interface to the latest bearing data from SKF; and power skiving manufacturability evaluation based on workpiece and tool data. The interface between GEMS and KISSsoft provides an exchange of gear and system information between the two software packages. This allows the user to realistically evaluate and optimize every type of bevel and hypoid gear — with a closed loop between the design and manufacturing software.

Gleason will demonstrate the 260GX Threaded Wheel Grinding Machine with twist-control and polish grinding, software-guided single tool setup and “closed loop readiness” with a multi-functional automation system including Gleason’s new GRSL Gear Roll Testing System with laser technology for fast and reliable 100% in-process gear inspection. The completely integrated solution interfaces directly with the grinding machine for automatic correction of tooth size, profile and lead angle as well as lead crowning.

Gleason’s new GRSL Gear Rolling System with laser technology provides both double flank roll testing as well as analytical index and involute measurement and a new lead measurement feature on all teeth for full, analytical and functional in-process inspection. The GRSL can be employed as either a standalone or a fully integrated, automated solution. Real time analytics and process trend analysis are clearly visible over the production run, allowing for automatic closed loop corrections on Gleason process equipment. Users can also sort by defect so gears for rework or scrap are tracked by characteristic.

The 300GMSL Gear Metrology System combines standard tactile probing methods with the power of non-contact laser scanning of tooth flank forms. The integration of laser scanning and associated 3-D graphics with a CAD interface considerably expands both the functionality and the range of applications for the machine platform and is designed for thorough gear analysis and development. Achieving a more complete analysis of process variable changes becomes much more intuitive with the high-resolution topographical surface mapping capability. A new host of tools for the detection and analysis of gear noise makes the 300GMSL well suited to addressing noise in today’s eDrive transmissions. The 300GMSL is “Closed Loop ready” to network to many of Gleason’s Hard Finishing Machines.

The latest edition of the Genesis gear hobbing machine family incorporates the newly developed chamfer hobbing, which produces precise chamfers according to customer specifications while minimizing tool cost-per-piece. Gleason will also demonstrate the integration of tool and machine workflows, reducing manual data input and minimizing input errors, tracking every aspect of tool information from supplier to machine, to crib, to sharpening, to end of tool life.

Gleason presents two new workholding products: The new generation of expanding and contracting hydraulic production arbors; and new, modular standard workholding featuring quick-change workholding solutions for cylindrical gear bores ranging from 18 to 100 mm in diameter.
Gleason diamond dressing tools can be re-plated multiple times to extend tool life and maintain the highest precision. With 30+ years of experience in diamond plating technology, Gleason can address every gear related dressing solution in the market including solutions for polished surfaces or asymmetrical gears. Tools can be equipped with RFID, barcode or QR technology to integrate in 4.0 tool management environments.

Gleason will present a host of new service offerings: The Gleason SPN Program (Safety-Productivity-Networking), a simple and economic field service alternative to a complete re-control of old Siemens 840D pl and many models of Gleason Metrology Inspection machines; Gleason Fingerprint, which diagnoses machine problems and potentially prevents downtime of installations; Tool-to-Machine communication adds intelligence to tool management, reduces manual data input and minimizes input errors; The new Gleason Academy platform of theoretical training classes and operator training in tutorial style.

GWJ
BOOTH 3934

GWJ Technology offers professional software development for mechanical engineering to support engineers and designers in their daily work — from standard software for classical machine elements with 3-D CAD integration modules to the determination of whole systems up to a complex special software for 5-axis milling of gears. Several of GWJ’s various software suites will be on display.

GWJ will introduce a lot of features, including a new and enhanced calculation for cylindrical gear pairs. The new version now supports the strength calculation of plastic gears. Ultra-clean steels and plastic materials were also added to the material database. In addition, the profile modifications can be dimensioned and the user gets recommendations for the flank modifications. The definition of load spectra has been extended and new options for the dimensioning of the profile shift coefficients were integrated. A calculation with a fixed center distance independently of the profile shift sum is also available. Additionally, the calculation of the load capacity according to AGMA has been updated.

Furthermore, a new calculation module for Hirth couplings will be introduced. Besides the generation of several gears and shafts, the 3-D CAD plugins offer the possibility to import shaft geometries in the calculation.

There is also a new version of the SystemManager software. The new version provides multiple enhancements that make the life of engineers easier than ever before. For example, the support of 3-D elastic gear bodies and 3-D elastic bearing rings, the import of background graphics of shafts, the import of shaft geometries such as 2-D DXF, 3-D STEP or the direct link between the face load coefficient with load capacity calculation with the load spectrum, extended parameter variation, new diagram functions, template file directory, periodic gear forces in the harmonic response, advanced results for planetary gear trains, and updated bearing database for SKF and Schaeffler (INA/FAG) bearings or the new exchange format REXS for the data exchange of systems between different software solutions like Bearinx, SystemManager and, in the future, e.g. multiple-body simulation tools.

During the exhibition, GWJ will give insight into the new calculation module for face gears, a part of the special software GearEngineer.
HAINBUCH AMERICA
BOOTH 3203
Stop by booth 3203 to see Hainbuch’s lineup of job shop mandrels for gear cutting, hobbing, grinding and shaping. The Mando G211 segmented mandrel for gear cutting features a slim interference contour; rigid radial clamping with pull-back effect; large clamping range and vibration damping due to vulcanized clamping bushings; integrated flushing channels and more.

HANIK CORPORATION
BOOTH 2407
Hanik Corporation is your source for Schnyder precision gear cutting tools, made in Switzerland. Schnyder hobs are available in up to 4A Quality.

HELIOS GEAR
BOOTH 3213
Helios solutions include the Helios Hera series of CNC gear hobbing machines from YG Tech. Hera machines offer several attractive features: Fanuc or Siemens CNC; high-speed hob heads with automatic retraction during power failure; direct-drive torque motors; friendly dialog programming for easy operating and quick training; re-hobbing (skiving); world-class construction and components; and compact footprints.

Helios will show the Hera 90 CNC gear hobbing machine. This machine features a unified, versatile gantry automation system for easy and productive hobbing of spur gears, helical gears and splines. It also features a high-swivel head for worm and thread milling. Manufacturers of parts up to 90 mm (3.543 in) diameter and 3 module (8.5 DP) should visit the Helios booth to see the machine in action.

Gear manufacturers can also see the Hera 350 CNC gear hobbing machine. With the series’ same high-quality feature set, the Hera 350 enables profitable vertical hobbing of spur gears, helical gears and other hobbed profiles. The machine is rated at 6 module (4.3 DP) and 350 mm (13.780 in) diameter for automatic loading (additional capacity is available for manually loaded parts).

The Helios TM 200-R3 gear deburring machine from Tecnomacchine deburrs parts up to 200 mm (7.874 in) in diameter with high-speed tool spindles. With five workstations and a unified, flexible automation system, the TM 200-R3 offers manufacturers a productive brushing, deburring and/or chamfering solution that enables consistent quality and reclaimed labor. Manufacturers can visit the Helios booth to see this machine produce deburred parts in as little as every 20 seconds.

Lastly, as part of Helios’s partnership with Kapp Technologies, the PGM 165 gear inspection machine will also be demonstrated. This CNC analytical measuring machine can inspect parts up to 180 mm (7.087 in) diameter using Renishaw 3-D probe technology and Penta Gear Metrolgy software.

In addition to machine tools, Helios offers manufacturers cutting and abrasive tools, including hobs, milling cutters, shaper cutters, generating grinding wheels, form grinding wheels, bevel gear grinding cups, diamond dressing gears and more. Gear manufacturers can also benefit from Helios’s services, such as gear cutting tool resharpening and recoating, contract inspection and application engineering.

HOBSOURCE
BOOTH 4401
HobSource delivers quality tools whether you hob, shape, skive, shave, broach or mill. Each tool is manufactured to exacting quality standards in ISO/QS facilities from the latest grades of high speed steel and carbide using CAD/CAM technology and state of the art CNC equipment. If you demand performance, reliability and dependability from your tools and vendors, HobSource challenges you to try their tools.

INDEX TECHNOLOGIES INC.
BOOTH 3327
Gear manufacturers need tools returned quickly. Index Technologies sharpens your perishable assets to meet or surpass original sharpening specifications. Offering hob sharpening and skive cutter sharpening. Visit the booth to see the company’s skive cutter sharpening machine in action.

INNOVATIVE RACK & GEAR CO.
BOOTH 2907
Innovative Rack & Gear Co., Inc. is a custom manufacturer of gear racks and gears to OEMs and suppliers in a variety of industries, including machine tool, automation, construction, mining, healthcare, aerospace and others. Investments in the latest technologies for precision gear rack manufacturing and highly skilled craftsmen are the reasons why Innovative Rack & Gear should be your quality source for gears, especially precision hard-cut and precision soft-cut gear racks. The recent acquisition of a Wenzel CMM ensures the accuracy and quality that customers have come to expect as well as being certified to ISO 9001:2015.
Robots and full-time CAD/CAM programmers are not required to achieve fast, consistent, precise results. James Engineering will highlight the variety of part types, shapes and sizes the MAX System can easily be programmed to process and execute in seconds using the simple Select—Enter—Cycle—Start interface to its unlimited number of part-processing recipes.

Today’s MAX System is a tested and proven innovation, which routinely applies its patented Focused Deburring skillset at speeds and production volumes that not only keep up with, but surpass CNC milling rates, while also producing finish quality and structural enforcements no other finishing solution can deliver. James Engineering’s CNC-style, multi-axis MAX System was first introduced in 2008, and a prototype of today’s second-generation series was first demonstrated at AGMA’s 2017 Gear Expo.

www.james-engineering.com

Klingelnberg will unveil leading-edge technology with the P 26 precision measuring center and optical measuring technology. At the same time, Klingelnberg will demonstrate its expertise in the “non-gear” sector. To be equipped for all measurement tasks, Klingelnberg combines Hispeed Optoscan optical measuring technology with the established, high-precision 3-D Nanoscan probing system. This system incorporates maximum precision with the required robustness for a production environment. Thanks to the high-speed changeover feature, the optimal measurement system can be used for every task. Optical measuring technology can be used for digitizing an entire, possibly unknown component or measuring splines quickly yet completely. The high measurement speed of the optical system with a high point density allows for measurements that would be time-intensive if performed with a tactile system. The tactile 3-D Nanoscan is designed to capture individual, high-precision measured values. For a rapidly generated, dense point cloud, Hispeed Optoscan is available. Roughness measuring technology is also available.

Klingelnberg also offers solutions in the “non-gear” sector. Whether turning blanks, ground workpieces or rolling bearings — Klingelnberg G variant precision measuring centers are specifically designed for use in the production process of axially symmetrical components. The G series precision measuring centers are suited to production processes that require not just dimensional measurement tasks, but also complex form and surface measurements in large numbers.

Klingelnberg G variant precision measuring centers are designed for use on the shop floor, including applications in the automotive and commercial vehicle industries, machine building and plant engineering, and the manufacture of rolling bearings.

The expo team will also be informing visitors about the exhibit highlights presented at EMO Hannover 2019. Among others, these include the Oerlikon G 35 Bevel Gear Grinding Machine for the aviation industry and the Höfler Viper 500 MFM cycloid grinding machine, which is of special interest to the robot industry.

Specifically tailored to the requirements of the aviation industry, the newly developed Oerlikon G 35 bevel gear grinding machine incorporates two vertical grinding spindles.

The Viper 500 MFM makes it possible to mass-produce high-precision cycloid gearings without requiring complex pairing of components. In combination with the precision measuring centers and closed loop technology, Klingelnberg now has a complete system for the production of highly accurate cycloid gearings. In the cycloid grinding cell, the processing machine and the precision measuring center are connected by automation. Thanks to the use of GearEngine, this cycloid grinding cell is “fit” for Industry 4.0 processes. Combined with closed loop, this gives rise to an autonomous, self-optimizing production system that makes it possible to utilize the machining and measuring capacity of the machines to optimal effect.

Klingelnberg G variant precision measuring centers are designed for use on the shop floor, including applications in the automotive and commercial vehicle industries, machine building and plant engineering, and the manufacture of rolling bearings.

www.klingelnberg.com
We have all heard the phrase WORK SMARTER, NOT HARDER. Makes sense, right? In times of economic uncertainty, it’s SMART to maximize the efficiency of every one of your resources. Workholding technology that allows you to go from O.D. to I.D. to 3-jaw clamping in a matter of seconds without readjustment can maximize the production—and the profits—of your existing machines. Now that is WORKING SMARTER.

MANDO G211
Segmented mandrel for gear cutting

- Segmented mandrel with slim interference contour
- Rigid radial clamping with pull-back effect
- Large clamping range and vibration dampening due to vulcanized clamping bushings
- In-stock standard segmented clamping bushings
- Three end-stop levels
- Integrated flushing channels

1.800.281.5734
Germantown, WI USA
www.hainbuchamerica.com
LIEBHERR
BOOTH 3413

Based on the proven LGG 280 generating machine, Liebherr is presenting the larger LGG 400 M model at Motion + Power Technology Expo. Furthermore, Liebherr will showcase its line of gear measuring machines.

The LGG 400 M has been developed with an eye towards aerospace and job shop customers. It fits into the same footprint as its little sister, the LGG 280, but has grown in height. With a different housing and a column extension, it is capable of machining long shafts because the travel of the main and counter column has been extended.

“Our users can utilize a variety of grinding heads for internal and external gears,” says Oliver Kraft, Manager Development and Design of Gear Cutting Machines at Liebherr-Verzahntechnik GmbH. “They can perform generating grinding with high productivity on workpieces up to 280 millimeter in diameter or profile grinding on even larger components up to 400 millimeters. This means even greater flexibility than its sister machine.”

Long shafts with small diameters have come into demand, required by customers in the aerospace and jobs shop industries—often for short runs. Liebherr offers an optional crane for optimal handling of large parts. “We have ergonomically adapted the machines overall,” Kraft explains. “Due to the height, we have incorporated fold-out stair steps so workers are better able to reach the working area. Large viewing windows provide the operator with the best possible overview of the working area and the process.”

For the first time, Liebherr will be presenting its extended product portfolio in the US. The WGT series of measuring technology closed the gap in the closed-loop sector. The four-axis measuring devices are equipped with high-precision mechanic and electronics, which are controlled by intelligent and user-friendly software. The combination of granite guides and air cushioning creates maximum precision with wear-free mechanics. In addition to the gear inspection machine options available as standard, customer-specific solutions are also available, such as extending the travel range on the Z-axis, longer tailstocks to accommodate long shafts, and rotary tables adapted to the payload. Liebherr will exhibit the gear measuring machine WGT 280.

www.liebherr.com

LOUIS BÉLET
BOOTH 3033

Facing a demand from the watchmaking world for gear cutting solutions, Louis Bélet started producing tools with special profiles in the late 1980s. Currently, the profiling sector at Louis Bélet consists of several dozen machines, allowing customer requests to be met within very short lead times, even for special profiles!

“Today’s world is moving in the direction of miniaturization. Coming from the watchmaking world, Louis Bélet is ideally positioned to face these challenges, both in terms of dimension of course, but also in terms of lead time and quality,” Pierre Falbriard, R&D manager at Louis Bélet, said.

“Markets such as medical, connectivity, aeronautics and automotive are facing this megatrend on a daily basis and Louis Bélet can give them the necessary expertise in the field of cutting tools,” Hervé Baour, international BDM at Louis Bélet, said.

Louis Bélet’s know-how allows them to produce the highest quality tools for cutting gears exceeding 2500 DP, 25 being the largest dimension currently achievable.

They will also present a lecture on the theme of micro-skiving. Of course, power-skiving is a proven technology, but for a fine toothing, no solution was available on the market so far.

The product expertise offered by this company of 150 employees doesn’t just cover gear cutting tools. Louis Bélet also markets more traditional precision cutting tools such as drills, mills or shape tools, with the same quest for perfection and precision.

www.lbsa.ch

MACHINE TOOL BUILDERS
BOOTH 3407

Originally established in 1995 as a service organization, MTB has since evolved into a world class machinery rebuilder, and has begun to move towards the new machinery business.

As a technology driven firm, the staff of MTB offers a wide array of experience in mechanical and electrical engineering, electronic controls, and software design. This knowledge is coupled with an eye for innovation and a genuine desire to provide the service you need when you need it.

MTB represents Burri grinding and dressing machines, Donner+Pfister measurement and gear grinding products, Senjo-Seiki deburring and chamfering machines, and Diablo Furnaces (stop by their booth at the co-located ASM Heat Treat show in booth #1318).

www.machinetoolbuilders.com

MCINNES ROLLED RINGS
BOOTH 2922

McInnes Rolled Rings specializes in seamless rolled rings from 4”–144” diameter and forged discs up to 54” diameter in carbon, alloy and stainless steel. Their ISO 9001, AS9100 and ABS certified plant in Erie, PA combines the latest in ring rolling technology with experienced people, aimed at providing the best value and the fastest deliveries in the industry.

www.mcinnesrolledrings.com

MESYS
BOOTH 3933

Mesys will show new features of its shaft system calculation version 07/2019. The fully coupled system calculation has new features in its FEA integration which allows elastic gear bodies and elastic
bearing rings in addition to elastic housings, shafts and planet carriers. In the latest version centrifugal expansion and contact for elastic bearing rings were added.

Harmonic response can now be calculated using periodic displacements in addition to periodic forces. One use case is the calculation of dynamic gear forces based on transmission error. Another use case is considering a base excitation from the housing.

The parameter variation has a new optimization step allowing to maximize or minimize parameters based on multiple constraints. This can be used to let the software calculate maximum permissible forces for example.

The REXS data exchange format version 1.1 allows to exchange data with other CAE programs.

Bearing databases with catalog data from Schaeffler and SKF were updated, several databases for spindle bearings including internal geometry are available on request from GMN, IBC, CSC and HQW.

www.mesys.ag

MITSUBISHI HEAVY INDUSTRIES
BOOTH 4239

Mitsubishi Heavy Industries will follow the world debut of the new ZE26C at CIMT in China with the market launch of the new model in North America.

The ZE26C will respond to needs for higher speed and precision especially in the transmission systems of electric vehicles and the reduction gears used in robots. The ZE26C was developed to finish hardened and tempered gears with outer diameters up to 260 mm. Superior performance has been achieved by making improvements to the ZE-B series of widely acclaimed gear grinding machines. Specifically, the ZE26C’s grinding precision and stability have been enhanced by increasing the rigidity of the column, table and grinding wheel head, coupled with revamping of the spindle structure. In addition, by increasing cutting speed and reducing idle (non-cutting) time by roughly 50% compared to earlier models, the ZE26C boosts high-volume production capability and promotes lower running costs.

Furthermore, by expanding the maximum wheel width to 160 mm, frequency of wheel replacement is reduced and simultaneous mounting of standard and polishing grinding wheels is simplified, enabling response to a variety of in-factory needs and higher operational performance. Also, adoption of water-soluble coolant (optional) improves environmental performance while also enhancing energy savings.

The new ZE26C will be on display and perform a gear grinding demonstration (dry run). A demonstration will also be given of Mitsubishi’s Diascope monitoring system, which uses IoT technology to give visibility of real-time production status.

www.mitsubishigearcenter.com

NAGEL PRECISION
BOOTH 4308

Nagel will showcase their comprehensive line of honing, superfinishing, face grinding and deep hole drilling equipment.

Nagel has developed a new series of flexible stone superfinishers to finish inner and outer bearing races. The machines are custom designed to meet customer specifications and can be equipped with either Siemens or Allen Bradley controls. The ultra light finishing stone holder is mounted directly on a heavy duty servo oscillator and can attain oscillating speeds of up to 45 HZ. Directly coupled servo part driver can reach speeds of up to 3000 rpm. Multiple finishing heads can be mounted to achieve desired quality and output.

The key features of the new machine are: ability to change over rapidly from one part type to another and minimize non cutting idle time (part load/unload) during the machine cycle. The superfinishing heads are mounted on an X and Z servo axis for automatic positioning to accommodate part diameter and thickness change. Patent pending part drive system can handle a range of part diameters without any changeover. The new system encompasses a number of industry features to make the machine more flexible and productive.

www.nagelusa.com
GEAR TECHNOLOGY | September/October 2019

NORTON | SAINT-GOBAIN ABRASIVES

BOOTH 2607

The new Norton Xtrimium range of gear solutions is designed for high performance gear grinding in extreme, tight tolerance environments. The newly structured portfolio of gear grinding products is specifically designed by category to provide higher profile accuracy, supreme form holding and burn-free grinding in worm, profile, and bevel applications. Highlighting the new range is an innovative dual-worm wheel design that enables two operations in one grinding wheel, substantially saving time and cost.

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

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

OELHELD

BOOTH 3803

Oelheld is adding SintoGrind TC-X 630 as the new entry level product to its flagship and perennial best-selling SintoGrind series. SintoGrind TC-X 630 is made from the latest generation of GTL base oils. GTL stands for Gas to Liquid. GTL technology converts natural gas—the cleanest-burning fossil fuel—into high quality liquid products that would be otherwise be made from crude oil. GTL base oils are colorless and odorless. They contain almost none of the impurities found in crude oil, such as sulfur, aromatics and nitrogen.

SintoGrind TC-X 630 will set new standards in its product and price class. The product is designed for flute grinding, profile grinding and outside and inside diameter grinding. SintoGrind TC-X 630 works on a wide variety of materials including tungsten carbide, HSS, PCD, CBN, cermet and ceramics. SintoGrind TC-X 630 contains no hazardous elements and exhibits stable viscosity over a wide temperature spectrum.

PENTAGEAR METROLOGY LLC

BOOTH 3607

Penta Gear Metrology, a brand of Kapp-Niles, offers analytical gear inspection machines for workpieces up to 450 mm diameter, as well as a wide variety of master gears, spline gages and functional inspection equipment, including double-flank testers and gages for measuring dimension-over-pins or dimension-over-balls.

In addition, Penta Gear’s ISO 17025/ A2LA-accredited laboratory offers contract inspection services, reverse engineering and gage certification.

Ask about Penta Gear’s REPOWER program to find out how your older analytical inspection machine can be given new life.

PHILADELPHIA GEAR

BOOTH 4033

Philadelphia Gear and other experts that are a part of the Timken Power Systems team join forces to feature seven brands that combine to provide an entire industrial drivetrain solution. Drawing on a global pool of engineering expertise and technological advancements, Timken Power Systems provides end-users with a single trusted source for comprehensive electro-mechanical equipment support. From designing custom control systems to gearbox expertise to comprehensive bearing repair solutions, they can maximize your powertrain and rotating equipment’s reliability and performance.

Through a network of independently ISO-certified regional service and manufacturing centers, they focus on providing local expertise at a national level to minimize your downtime and reduce your cost of repair.

OELHELD

BOOTH 3803

Oelheld is adding SintoGrind TC-X 630 as the new entry level product to its flagship and perennial best-selling SintoGrind series. SintoGrind TC-X 630 is made from the latest generation of GTL base oils. GTL stands for Gas to Liquid. GTL technology converts natural gas—the cleanest-burning fossil fuel—into high quality liquid products that would be otherwise be made from crude oil. GTL base oils are colorless and odorless. They contain almost none of the impurities found in crude oil, such as sulfur, aromatics and nitrogen.

SintoGrind TC-X 630 will set new standards in its product and price class. The product is designed for flute grinding, profile grinding and outside and inside diameter grinding. SintoGrind TC-X 630 works on a wide variety of materials including tungsten carbide, HSS, PCD, CBN, cermet and ceramics. SintoGrind TC-X 630 contains no hazardous elements and exhibits stable viscosity over a wide temperature spectrum.

www.oelheld.com

PRESRITE

BOOTH 4200

Presrite specializes in the near-net forging of gears. Typical stock allowances range from .004” to .060” on the gear flanks. With pressures up to 6,000 tons of capacity and a state-of-the-art tech center, Presrite offers design, engineering and die-making production solutions.

www.presrite.com

PROTO MANUFACTURING

BOOTH 4328

Proto offers laboratory as well as portable and ultra-portable x-ray diffraction systems for the measurement of retained austenite and residual stress.

www.protoxrd.com

REISHAUER

BOOTH 2913

Reishauer presents a sophisticated gear grinding process monitoring system. All process data of each workpiece are recorded and remain 100% traceable.

The dressing and grinding process 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
AMORPHOLOGY

DISRUPTING TRADITIONAL GEAR PRODUCTION WITH NOVEL ALLOYS AND PROCESSES

ADVANCED GEAR PRODUCTION

Flipping the paradigm by reducing machining costs for complex gear production

POWDER & COATINGS

Proprietary coating methods give an inferior substrate hardness and corrosion resistance

Visit our booth at the largest robotic conference in the world:

IREX IN TOKYO, JAPAN

December 18th through the 21st

Talk to our technology leaders and scientists about how Amorphous Metals can improve your gear production and achieve critical metrics.

Request more information online @ www.amorphology.com
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.

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

www.reishauer.com

REM SURFACE ENGINEERING
BOOTH 4510
REM Surface Engineering, the inventor of the ISF Process, the Rapid ISF Process, the Extreme ISF Process, and the REM Process, provides surface engineering solutions for aerospace, heavy equipment and off highway and industrial gearing.

REM’s isotropic superfinishing technologies are value adding and performance enhancing improvements to conventional machining operations such as grinding and lapping. Founded in 1965 in Southington, CT by Robert Michaud, REM Surface Engineering is a family-owned company that has proudly been serving their partners and customers for over 50 years. REM Surface Engineering operates four locations in Brenham, TX, Southington, CT, Merrillville, IN and St. Neots, UK that provide products and services globally. www.remchem.com

ROTEC TOOLS LTD.
BOOTH 3131
Learn more about Affolter’s line of compact hobbing machines, including the AF110Plus, the most powerful gear hobbing center in Affolter’s GEAR line. The 7-axis AF110Plus is designed for parts up to 90 mm length and 60 mm diameter, with modules up to 1.5 mm. rotectools.com

SMT
BOOTH 4227
SMT is a globally integrated provider of mechanical transmission engineering services and software development. Over the past 16 years SMT has grown from a collective of experienced and passionate engineers into an international enterprise serving all sectors of the transmission and driveline development industry.

SMT engineers have knowledge of the full development process of automotive, industrial, aerospace, energy and marine transmissions and are able to advise on all aspects of transmission design, analysis and optimization. Having worked with leading international companies on a wide array of engineering projects, SMT can deliver fully integrated technical solutions for the design, development and manufacture of entire drivetrain, gearboxes and transmission systems.

MASTA is a complete suite of CAE software for the design, simulation & analysis of driveline systems from concept through to manufacture. www.smartmt.com

SOUTHERN GEAR
BOOTH 4228
Southern Gear is a custom precision gear and gearbox manufacturer providing quality gears to demanding industries including aerospace, defense, marine and medical. Their AS 9100- and ISO 9001-certified facilities house nearly 150 machines ready to manufacture precision gears and gearboxes including bevel, helical, spur, face, ring, internal, anti-backlash, worm and worm gears, racks, splines, sprockets and more.

Southern Gear is equipped to perform every type of machining at their plant including: turning, milling, grinding and gear cutting/grinding. Parts are manufactured in their plant, under their control and under their AS 9100 D quality system and lean manufacturing processes. Southern Gear’s total management of the entire production sequence allows them to increase efficiency and optimize quality in order supply mission-critical parts to the aerospace and other demanding industries on time and
Southern Gear’s engineers and machinists have an average of 26 years of experience, and their employees have been with the company an average of 17 years. A veteran-owned company in business for more than 60 years, Southern Gear offers a wide variety of precision gear manufacturing, from bevel to worm gears, from prototype to assembly, from aerospace to medical.

www.southerngear.com

STAR SU
BOOTH 4013

Star SU will present advanced manufacturing solutions from both machine tools and cutting tools.

Star SU will introduce their hobbing and shaping machine portfolio through the newly created company Samputensili CLC S.r.l. Star SU will interactively display the CLC 260 H and CLC 500 H — two high performance modular horizontal gear hobbing/milling machines, which can be customized for any type of gear, shaft and worms up to a total length of 5000 mm.

The new Star NXT linear CNC tool and cutter grinding machine sharpens both straight and spiral gash hob designs up to 8” OD x 10” OAL. With a small footprint and maximized grind zone, the NXT also sharpens disk, shank and helical type shaper cutters. Scudding cutters with a patented process, which totally eliminates the need for cutting oils during the grinding of gears after heat treatment with a significant reduction in the cost of consumables and a considerable improvement of environmental impact.

Star SU offers a wide variety of gear cutting tools, precision tool re-sharpening services, and advanced coatings from Oerlikon Balzers, including Alcrona Pro and Balanit Altensa, the high-speed coating solution that realizes productivity gains and efficiency.

Star SU will also feature their innovative Scudding cutters manufactured to produce gear and spline teeth for reduced cycle times and tool costs.

Also on display will be Star SU’s complete round tool offerings, including gundrills, design and build solid carbide drills, and precision reamers. Addressing the fluid power industry, they will showcase a selection of cavity/port tool solutions including one shot cavity machining.

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

www.star-su.com

and a wide range of round tools, making it a versatile tool room machine.

In addition, Star SU’s complete library of gear manufacturing machinery solutions will be available, including the Samputensili SG 160 Skygrind — the first gear dry grinding machine in the world on budget.

United Tool Supply’s booth will be full of their latest product advancements, in combination with the products that have made their business what it’s been for the last four decades. Showcased in their booth will be their Unite-A-Matic PD gauge, Surf-A-Matic surface finish gauge, and their newest product, the Roll-A-Matic PD Runout gauge. United Tool Supply’s product lines will be proudly displayed and demonstrated to show the industry what they have to offer moving into the new decade.

The company’s featured product this year, the Roll-A-Matic, is a shop hardened PD Runout Inspection gauge designed with the customer’s needs in mind. A flexible design allows United Tool Supply the ability to use customer’s existing masters and interchangeable locators to inspect multiple parts on one gauge. The gauge can be manually operated or motor-driven, with an indicator or paired with a linear gauge/LVDT probe to output the data digitally to a PC. This solution is a simple, accurate, repeatable gauge to facilitate in-process checks on the shop floor during the manufacturing process.

www.unite-a-matic.com

VIKING FORGE
BOOTH 2610

Viking Forge, LLC will display near net shaped and flashless forged gear blanks manufactured from their closed die, hot forging mechanical press lines. Producing high precision forged products from 1 to 95 lbs, 3” to 14” in diameter and up to 10” in length, Viking Forge is dedicated to using advanced technology to further the science of forging for the benefit of their customers.

Viking’s proficiency begins with engineering, where their highly skilled and experienced staff develop forging designs that meet or exceed customer expectations. 3-D CAD modeling, material flow simulation and Solid Modeling System technologies allow engineers to calculate the exacting requirements of how the steel forging process will affect the final product. These process steps reduce
multiple prototyping, controlling costs and lead times. Sales management and engineering staff will be in attendance to discuss these advantages with you.

www.viking-forge.com

WFL MILLTURN
BOOTH 4309

WFL focuses on complete machining with a full range of Millturn machines with the ability to machine complex parts up to very big components. More than twenty different machining methods can be performed.

The Millturn design concept is very robust and rigid with a massive cast iron bed. The main spindle as well as the high precision turning-boring-milling unit are extremely powerful. Gear manufacturing is all about keeping high quality demands, profile accuracy and reliability.

WFL’s can help you to transfer your traditional machining into flexible and complete machining of gears. The methods are supported by specific software cycles under the FLANX umbrella. Hobbing, skiving, profile milling, InvoMilling and gear skiving are all available. In addition, the highly sophisticated InvoMilling CAD/CAM software can be offered due to a collaboration with Sandvik Coromant. With these manufacturing methods, virtually all machining challenges for gear manufacturing can be covered. Moreover, the ability to measure the gears in the machine improves the efficiency and reduces risk of error.

Machining of parts with gear or spline features does not mean any compromise compared with conventional machining using a gear hobber. Very tight quality demands will be kept and the possibility to machine all tasks in a single set-up gives major advantages when it comes to lead-times.

www.wfl.at

GEAR TECHNOLOGY
BOOTH 3826

ASK THE EXPERT LIVE
is coming to MPT Expo 2019 in Detroit, MI.

Come and get solutions to your gear-related challenges from top experts, live and in person at MPT Expo

Gear Manufacturing, Tuesday, Oct 15, 10:30 a.m.
• Dr.-Ing. Andreas Mehr, Gear Grinding and Shaping Technology Development, Liebherr.
• Dr.-Ing. Hartmuth Muller, Head of Technology and Innovation, Klingelnberg.
• Dr.-Ing. Deniz Sari, Sales Manager Middle Europe, Samputensili
• Dr. Hermann J. Stadtfeld, VP Bevel Gear Technology and R&D, Gleason

Gear Design, Tuesday, Oct 15, 2:30 p.m.
• Charles Schultz, President Beyta Gear Services (also Gear Technology technical editor and author of Gear Talk with Chuck on the geartechnology.com blog).
• Prof. Dr.-Ing. Karsten Stahl, Director of the Gear Research Center (FZG) at the Technical University of Munich.
• Frank Uherek, Principal Engineer, Gear Engineering Software Development, Rexnord.

Lubrication, Wednesday, Oct 16, 10:30 a.m.
• Paul Conley, Chief Technologies, SKF.
• Sib Hamid, VP, Director of Operations and Corporate Director of Technology, Lubriplate.
• Dr.-Ing. Thomas Tobie, Head of the Department Load Carrying Capacity of Gears at the Gear Research Center (FZG) at the Technical University of Munich.

Bearings, Wednesday, Oct 16, 2:30 p.m.
• Mike Allega, Application Engineer Specialist, Timken.
• George Lutzow, Manager Application Engineering, SKF.
• Jitesh Modi, Engineering Director, Transmission Applications North America, Schaeffler Group USA Inc.
• Chris Napoleon, President, Napoleon Engineering Services.

www.wfl.at
Two super new products that take heat treating to a whole new dimension.

SECO/VACUUM is unveiling not one but TWO new products at the ASM Heat Treat show in October. We’re really fired up about them and we think you will be, too!

Super IQ® – The first carburizing innovation in over 3 decades!
- Modern replacement for atmosphere integral quench
- Gas carburizing with no flames and no endogas
- Turn it on, turn it off – no idling or conditioning
- Clean, cool, contained thermal cycling in vacuum
- Nominal temperature up to 2,000°F
- Integral quench using standard quench oils

4D Quench® – A leap in performance for press quenching!
- Modern alternative to press hardening
- Single piece, flow vacuum through-hardening
- Clean – no oils, no mess, no liquids disposal
- Eliminates cost of heat treat fixtures and logistics
- No bulky part handling or press maintenance
- Perfect for high volume gears/transmission parts

To learn more about these innovative new furnaces PLUS our broad array of other heat treating solutions, stop by and see us at the ASM Heat Treat Show, Booth 1207-1209 or visit us online.

www.SecoVacUSA.com
The leading machine concept for the manufacturing of complex and precise workpieces

Visit us on...

Oct. 15-17, 2019 booth 4309
WFL Oktoberfest, Oct. 16, 2019
and ...
Autania Tec Center Wixom

Register here:

WFL YouTube Channel

WFL Millturn Technologies, Inc. | Wixom, MI 48393 | 48152 West Road | Autania Tec Center | USA
Tel +1 248 347 93 90 | Fax +1 248 347 93 92 | office@wfl-usa.com | www.wfl-usa.com

WFL Millturn Technologies GmbH & Co. KG | 4030 Linz | Wahringerstraße 36 | Austria
Tel +43 732 6913-0 | Fax +43 732 6913-8172 | office@wfl.at | www.wfl.at

VISIT US AT BOOTH #4309
SHOP HARDENED SOLUTIONS

PD INSPECTION
UNITE-A-MATIC™

RUNOUT INSPECTION
ROLL-A-MATIC™

SURFACE FINISH INSPECTION
SURF-A-MATIC™

SIMPLE. ACCURATE. REPEATABLE.

UNITED TOOL SUPPLY
851 Ohio Pike - Cincinnati, Ohio 45245 - 513-752-6000
UNITE-A-MATIC.COM

VISIT US AT BOOTH #4614
MAXXOS Mandrel
The hexagonal, super-strong mandrel

- I.D. clamping mandrel for clamping diameter 18 mm to 100 mm, in stock
- High transferable torques and holding forces
- Reduced tool wear through high rigidity
- Concentric precision ≤ 0.01 mm / 0.007 mm possible
- Concentric precision ≤ 0.002 mm possible upon request
- Resistant to contamination due to its hexagonal pyramid shape

Gear manufacturers need tools returned quickly. We sharpen your perishable assets to meet or surpass original sharpening specifications... rapidly. That is what we do.

Enabling our customers to continually cut teeth since 1999.

- HOB SHARPENING
- SKIVE CUTTER SHARPENING
- COME SEE OUR SKIVE CUTTER SHARPENING MACHINE AT MPT 2019

216-642-5900
www.IndexTechnologiesInc.com

VISIT US AT BOOTH #3327

The Complete Technical Solution for Today's Gear Grinding Challenges

Learn more at http://nortonsga.us/xtrimiumgt

VISIT US AT BOOTH #2607
**Innovative Gear & Spline Measurement**

- Gages
- Master gears
- Double flank gear check
- Shaft measurement

- DÄkkS-Calibration
- VDA-5 Certificate
- Wear measurement
- Cause Analysis

- Individual design
- Stable instruments for the shop floor use
- From a single source

- Support and calculation
- Seminars
- Literature
- Software

**FRENEO GmbH**
Verzahnungstechnik I Messtechnik
90518 Altdorf - Germany
www.frengo.com

Exclusive FRENEO distributor in the U.S.: Euro-Tech Corporation
www.eurotechcorp.com

---

**Software Made in Germany**

- Calculation Software for Gearboxes
- Extended System Calculation
- Real 3D Geometry of Cylindrical & Bevel Gears
- Tooth Contact Analysis
- Free-Form Milling of Gears
- Engineering & Consulting
- Individual Software Development

**VISIT US AT BOOTH #3934**

---

**ASK-THE-EXPERT LIVE!**

This is your chance to have your questions answered in person by our live panel of experts.

**Gear Manufacturing, Tuesday, Oct 15, 10:30 a.m.**

**Gear Design, Tuesday, Oct 15, 2:30 p.m.**

**Lubrication, Wednesday, Oct 16, 10:30 a.m.**

**Bearings, Wednesday, Oct 16, 2:30 p.m.**

Can’t wait? Submit your question now! Send it by e-mail to Senior Editor Jack McGuinn (jmcguinn@geartechnology.com) and we’ll submit it to our experts.

**VISIT US AT BOOTH #3826**
The Mitsubishi ZE26C Gear Grinding Machine: Precision Gears for Precision Systems

- Optimized for Electric Vehicles & Robotics
- Greater Structural Rigidity
- Shorter Non-cutting Time
- Lower Running Costs
- Smarter Industrial IoT remote monitoring - DIASCOPE

To learn more about how the ZE26C has been optimized for the evolving needs of the industry, visit www.mitsubishigearcenter.com or contact sales at 248-669-6136.

To learn more about how the Mitsubishi ZE26C Gear Grinding Machine has been optimized for the evolving needs of the industry, visit www.mitsubishigearcenter.com or contact sales at 248-669-6136.

The Mitsubishi ZE26C Gear Grinding Machine:

- Gear Metrology
- High Speed Pump Angular Bevel
- CNC Gear Inspection
- Aero Engine Transmission Ground Straight Bevel
- Cement Mill
- Hypoid Gears
- Bevel Gearbox
- Rotary Table

- GROUND OR HARD CUT SPIRALS 0.5” to 40”
- LAPPED SPIRAL BEVELS 0.5” to 64”
- STRAIGHT BEVELS 0.5” to 74”
- REVERSE ENGINEERING

jamalgrp@bevelgearsindia.com www.bevelgearsindia.com

VISIT US AT BOOTH #4210

oelheld U.S., Inc.
1100 Wesemann Drive
West Dundee, IL 60118
Phone: 847-531-8501
Fax: 847-531-8511
Email: hutec-us@oelheld.com
www.oelheld.com

VISIT US AT BOOTH #3803
CUSTOM PRECISION GEARS
Apart from the Crowd

From Bevel to Worm Gears
Prototype to Assembly
Aerospace to Medical

SOUTHERN GEAR IS YOUR CUSTOM PRECISION GEAR SOURCE

Southern Gear
(800) 248-5152
southerngear.com

Established in 1957 | Veteran-Owned
AS9100D | ITAR Compliant | ISO 9001:2015

VISIT US AT BOOTH #3213

HIGH PRESSURE QUENCH VACUUM CARBURIZING FURNACES

IQ SERIES
Get fast, forceful gas cooling with Solar Manufacturing’s IQ series of vacuum carburizing furnaces. It’s high performance internal quench system with direct-exit, sliding radiation baffles is the least restricted gas flow path on the market for superior hardening at quench pressures up to 20 bar.

Give us a call to learn more about our vacuum furnace ingenuity.

267.384.5040
sales@solarmfg.com
solarmfg.com

THE BRIGHTEST SOLUTIONS THROUGH INGENUITY

VISIT US AT BOOTH #2013
Heat Treat Expo 2019 Booth Listings
Plan your visit with this handy guide.

HEAT TREAT 19
October 15–17
TCF CENTER (formerly the Cobo Center)
Detroit, MI
www.asminternational.org

Concessions

HTS Membership Booth

Plenary Area

Concessions

HT Education Exchange

Exhibitor Lounge/Show Office

Solutions Center

Posters

Gear Technology Advertisers in this issue

Gear Technology

Advertisers in
this issue
<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Booth#</th>
<th>Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbott Furnace Company</td>
<td><a href="http://www.abbottfurnace.com">www.abbottfurnace.com</a></td>
<td>2110</td>
<td></td>
</tr>
<tr>
<td>Accurate Sensing Technologies Pvt.Ltd.</td>
<td><a href="http://www.accuratesensors.com">www.accuratesensors.com</a></td>
<td>1328</td>
<td></td>
</tr>
<tr>
<td>ACME</td>
<td><a href="http://www.acme">www.acme</a> furnace.net</td>
<td>1519</td>
<td></td>
</tr>
<tr>
<td>Across USA</td>
<td><a href="http://www.acrosscc.com">www.acrosscc.com</a></td>
<td>704</td>
<td></td>
</tr>
<tr>
<td>Advanced Energy</td>
<td><a href="http://www.advancedenergy.com">www.advancedenergy.com</a></td>
<td>1008</td>
<td></td>
</tr>
<tr>
<td>Advanced Nitriding Solutions</td>
<td><a href="http://www.ans-ion.net">www.ans-ion.net</a></td>
<td>2023</td>
<td></td>
</tr>
<tr>
<td>Aerospace Testing &amp; Pyrometry, Inc.</td>
<td><a href="http://www.atp-cal.com">www.atp-cal.com</a></td>
<td>1922</td>
<td></td>
</tr>
<tr>
<td>AFC Holcroft</td>
<td><a href="http://www.afcholcroft.com">www.afcholcroft.com</a></td>
<td>1865</td>
<td>25</td>
</tr>
<tr>
<td>AFFRI, Inc.</td>
<td><a href="http://www.afrri.com">www.afrri.com</a></td>
<td>614</td>
<td></td>
</tr>
<tr>
<td>Air Products and Chemicals, Inc.</td>
<td><a href="http://www.airproducts.com/metal">www.airproducts.com/metal</a></td>
<td>1807</td>
<td></td>
</tr>
<tr>
<td>Airflow Sciences Corporation</td>
<td><a href="http://www.airflowsciences.com">www.airflowsciences.com</a></td>
<td>2210</td>
<td></td>
</tr>
<tr>
<td>Airgas</td>
<td><a href="http://www.airgas.com/ht">www.airgas.com/ht</a></td>
<td>1023</td>
<td></td>
</tr>
<tr>
<td>Ajax Tocco Magnethermic</td>
<td><a href="http://www.ajaxtocco.com">www.ajaxtocco.com</a></td>
<td>1415</td>
<td>62</td>
</tr>
<tr>
<td>ALD Vacuum Technologies North America, Inc.</td>
<td>ald-usa.com</td>
<td>1613</td>
<td></td>
</tr>
<tr>
<td>Allegheny Alloy</td>
<td>atimetals.com</td>
<td>1218</td>
<td></td>
</tr>
<tr>
<td>Allied High Tech Products</td>
<td><a href="http://www.alliedhightech.com">www.alliedhightech.com</a></td>
<td>803</td>
<td></td>
</tr>
<tr>
<td>Allied Mineral Products</td>
<td><a href="http://www.alliedmineral.com">www.alliedmineral.com</a></td>
<td>1022</td>
<td></td>
</tr>
<tr>
<td>Alloy Engineering Co</td>
<td><a href="http://www.alloyengineering.com">www.alloyengineering.com</a></td>
<td>614</td>
<td></td>
</tr>
<tr>
<td>Altair Engineering, Inc.</td>
<td>altair.com</td>
<td>1526</td>
<td></td>
</tr>
<tr>
<td>AMETEK</td>
<td><a href="http://www.ametek.com">www.ametek.com</a></td>
<td>908</td>
<td></td>
</tr>
<tr>
<td>Ariane Group</td>
<td><a href="http://www.ariane.group/en">www.ariane.group/en</a></td>
<td>1520</td>
<td></td>
</tr>
<tr>
<td>Astral Material Industrial Co., Ltd.</td>
<td><a href="http://www.amic.biz">www.amic.biz</a></td>
<td>508</td>
<td></td>
</tr>
<tr>
<td>Avion Manufacturing Company</td>
<td><a href="http://www.avionmfg.com">www.avionmfg.com</a></td>
<td>1013</td>
<td></td>
</tr>
<tr>
<td>Azbil North America</td>
<td>us.azbil.com</td>
<td>930</td>
<td></td>
</tr>
<tr>
<td>Blast Cleaning Technologies</td>
<td><a href="http://www.bct-us.com">www.bct-us.com</a></td>
<td>2028</td>
<td></td>
</tr>
<tr>
<td>Bloom Engineering</td>
<td><a href="http://www.bloomeng.com">www.bloomeng.com</a></td>
<td>607</td>
<td></td>
</tr>
<tr>
<td>Bodycote</td>
<td><a href="http://www.bodycote.com">www.bodycote.com</a></td>
<td>1805</td>
<td></td>
</tr>
<tr>
<td>Buehler, An ITW Company</td>
<td><a href="http://www.buehler.com">www.buehler.com</a></td>
<td>609</td>
<td></td>
</tr>
<tr>
<td>Burkert Fluid Control Systems</td>
<td><a href="http://www.burkert-usa.com">www.burkert-usa.com</a></td>
<td>628</td>
<td></td>
</tr>
<tr>
<td>Busch Vacuum and Systems</td>
<td><a href="http://www.buschusa.com">www.buschusa.com</a></td>
<td>510</td>
<td></td>
</tr>
<tr>
<td>C.C. Jensen Inc.</td>
<td><a href="http://www.ccjensen.com">www.ccjensen.com</a></td>
<td>507</td>
<td></td>
</tr>
<tr>
<td>C3 Data</td>
<td><a href="http://www.c3data.com">www.c3data.com</a></td>
<td>1126</td>
<td></td>
</tr>
<tr>
<td>Can-Eng Furnaces International Ltd.</td>
<td><a href="http://www.can-eng.com">www.can-eng.com</a></td>
<td>1103</td>
<td></td>
</tr>
<tr>
<td>Carbon Composites, Inc.</td>
<td>carboncompositesinc.com</td>
<td>508</td>
<td></td>
</tr>
<tr>
<td>CEIA USA Induction Heating Systems</td>
<td><a href="http://www.ceia-usa.com">www.ceia-usa.com</a></td>
<td>2227</td>
<td></td>
</tr>
<tr>
<td>CENOS - Simulation Software</td>
<td><a href="http://www.cenos-platform.com">www.cenos-platform.com</a></td>
<td>2126</td>
<td></td>
</tr>
<tr>
<td>CenterPoint Energy Services</td>
<td><a href="http://www.centerpointenergy.com">www.centerpointenergy.com</a></td>
<td>1623</td>
<td></td>
</tr>
<tr>
<td>CeramSource, Inc.</td>
<td><a href="http://www.ceramsource.com">www.ceramsource.com</a></td>
<td>408</td>
<td></td>
</tr>
<tr>
<td>Cleveland Electric Laboratories, Inc.</td>
<td><a href="http://www.clevelandelectriclabs.com">www.clevelandelectriclabs.com</a></td>
<td>714</td>
<td></td>
</tr>
<tr>
<td>CMI Industry Metals</td>
<td><a href="http://www.cmigroup.com">www.cmigroup.com</a></td>
<td>813</td>
<td></td>
</tr>
<tr>
<td>Contour Hardening</td>
<td><a href="http://www.contourhardening.com">www.contourhardening.com</a></td>
<td>801</td>
<td></td>
</tr>
<tr>
<td>Control Concepts Inc.</td>
<td><a href="http://www.ccipower.com">www.ccipower.com</a></td>
<td>2120</td>
<td></td>
</tr>
<tr>
<td>Cooley Wire Products</td>
<td><a href="http://www.cooleywire.com">www.cooleywire.com</a></td>
<td>1219</td>
<td></td>
</tr>
<tr>
<td>Custom Electric Manufacturing LLC</td>
<td><a href="http://www.custom-electric.com">www.custom-electric.com</a></td>
<td>806</td>
<td></td>
</tr>
<tr>
<td>Cyprium Induction</td>
<td><a href="http://www.cypriuminduction.com">www.cypriuminduction.com</a></td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>DANTE Solutions, Inc.</td>
<td>dante-solutions.com</td>
<td>1618</td>
<td></td>
</tr>
<tr>
<td>DeKalb Blower</td>
<td><a href="http://www.dekalblower.com">www.dekalblower.com</a></td>
<td>310</td>
<td></td>
</tr>
<tr>
<td>Diablo Furnaces, LLC</td>
<td><a href="http://www.diablofurnaces.com">www.diablofurnaces.com</a></td>
<td>1318</td>
<td></td>
</tr>
<tr>
<td>Double Egret Thermal Insulation Co., Ltd.</td>
<td><a href="http://www.cndoubleegret.com">www.cndoubleegret.com</a></td>
<td>2027</td>
<td></td>
</tr>
<tr>
<td>Dry Coolers Inc.</td>
<td><a href="http://www.drycoolers.com">www.drycoolers.com</a></td>
<td>1803</td>
<td></td>
</tr>
<tr>
<td>Duraloy Technologies, Inc.</td>
<td><a href="http://www.duraloy.com">www.duraloy.com</a></td>
<td>802</td>
<td></td>
</tr>
<tr>
<td>EGM USA Inc.</td>
<td><a href="http://www.ecm-usa.com">www.ecm-usa.com</a></td>
<td>2007</td>
<td>67</td>
</tr>
<tr>
<td>Edwards Vacuum</td>
<td><a href="http://www.edwardsvacuum.com">www.edwardsvacuum.com</a></td>
<td>407</td>
<td></td>
</tr>
<tr>
<td>EFD Induction</td>
<td><a href="http://www.efd-induction.com">www.efd-induction.com</a></td>
<td>1522</td>
<td></td>
</tr>
<tr>
<td>Eurotherm by Schneider Electric</td>
<td><a href="http://www.eurotherm.com">www.eurotherm.com</a></td>
<td>1213</td>
<td></td>
</tr>
<tr>
<td>Flame Treating Systems, Inc.</td>
<td><a href="http://www.flametreatingsystems.com">www.flametreatingsystems.com</a></td>
<td>1718</td>
<td></td>
</tr>
<tr>
<td>Fluke Process Instruments</td>
<td><a href="http://www.flukeprocessinstruments.com">www.flukeprocessinstruments.com</a></td>
<td>502</td>
<td></td>
</tr>
<tr>
<td>Fluxtrol Inc.</td>
<td><a href="http://www.fluxtrol.com">www.fluxtrol.com</a></td>
<td>1007</td>
<td></td>
</tr>
<tr>
<td>FURNACARE</td>
<td><a href="http://www.furnacare">www.furnacare</a></td>
<td>2022</td>
<td></td>
</tr>
<tr>
<td>Future Design Controls</td>
<td><a href="http://www.futuredesigncontrols.com">www.futuredesigncontrols.com</a></td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>Gasbarre Thermal Processing Systems</td>
<td><a href="http://www.gasbarre.com">www.gasbarre.com</a></td>
<td>2309</td>
<td></td>
</tr>
<tr>
<td>Gefran, Inc.</td>
<td><a href="http://www.gefran.com/en">www.gefran.com/en</a></td>
<td>1727</td>
<td></td>
</tr>
<tr>
<td>GeoCorp, Inc.</td>
<td><a href="http://www.geocorpinc.com">www.geocorpinc.com</a></td>
<td>1400</td>
<td></td>
</tr>
<tr>
<td>Graphite Machining, Inc.</td>
<td><a href="http://www.graphitemachininginc.com">www.graphitemachininginc.com</a></td>
<td>1015</td>
<td></td>
</tr>
<tr>
<td>Graphite Materials GmbH</td>
<td><a href="http://www.graphite-materials.com">www.graphite-materials.com</a></td>
<td>823</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Website</td>
<td>Booth#</td>
<td>Ad</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>----------------------------------------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>Graphite Metallizing Corp.</td>
<td><a href="http://www.graphalloy.com">www.graphalloy.com</a></td>
<td>1818</td>
<td></td>
</tr>
<tr>
<td>Heat Treat Central</td>
<td><a href="http://www.heatreatcentral.com">www.heatreatcentral.com</a></td>
<td>309</td>
<td></td>
</tr>
<tr>
<td>Heat Treat Furnaces, a TTX company</td>
<td><a href="http://www.txinc.com">www.txinc.com</a></td>
<td>307</td>
<td></td>
</tr>
<tr>
<td>Heat Treat Today</td>
<td><a href="http://www.heatreattoday.com">www.heatreattoday.com</a></td>
<td>2123</td>
<td></td>
</tr>
<tr>
<td>Heatbath/DuBois Chemicals</td>
<td><a href="http://www.heatbath.com">www.heatbath.com</a></td>
<td>1003</td>
<td></td>
</tr>
<tr>
<td>Heating Induction Services, Inc.</td>
<td><a href="http://www.heatinginductionservices.com">www.heatinginductionservices.com</a></td>
<td>1828</td>
<td></td>
</tr>
<tr>
<td>HEESS GmbH &amp; Co. KG</td>
<td><a href="http://www.heess.com">www.heess.com</a></td>
<td>1315</td>
<td></td>
</tr>
<tr>
<td>HEMO GmbH</td>
<td>hemo-gmbh.de</td>
<td>1128</td>
<td></td>
</tr>
<tr>
<td>High Temperature Concept</td>
<td><a href="http://www.htconcept.org">www.htconcept.org</a></td>
<td>1320</td>
<td></td>
</tr>
<tr>
<td>Hind High Vacuum Company (Pvt) Ltd.</td>
<td><a href="http://www.hhv.in">www.hhv.in</a></td>
<td>702</td>
<td></td>
</tr>
<tr>
<td>Honeywell</td>
<td><a href="http://www.honeywell.com">www.honeywell.com</a></td>
<td>928</td>
<td></td>
</tr>
<tr>
<td>Howden - Garden City Fan</td>
<td><a href="http://www.howden.com">www.howden.com</a></td>
<td>918</td>
<td></td>
</tr>
<tr>
<td>ibg NDT Systems Corporation</td>
<td><a href="http://www.ibgndt.com">www.ibgndt.com</a></td>
<td>1826</td>
<td></td>
</tr>
<tr>
<td>Idemitsu Lubricants America</td>
<td><a href="http://www.idemitsu.com">www.idemitsu.com</a></td>
<td>402</td>
<td></td>
</tr>
<tr>
<td>II-VI M Cubed Technologies, Inc.</td>
<td><a href="http://www.ii-vi.com/m-cubed">www.ii-vi.com/m-cubed</a></td>
<td>2228</td>
<td></td>
</tr>
<tr>
<td>Induction Tooling</td>
<td><a href="http://www.inductiontooling.com">www.inductiontooling.com</a></td>
<td>707</td>
<td></td>
</tr>
<tr>
<td>Inductotherm Group</td>
<td><a href="http://www.inductoheat.com">www.inductoheat.com</a></td>
<td>1600</td>
<td></td>
</tr>
<tr>
<td>Industrial Heating</td>
<td><a href="http://www.industrialheating.com">www.industrialheating.com</a></td>
<td>2026</td>
<td></td>
</tr>
<tr>
<td>Industrial Heating Equipment Association</td>
<td><a href="http://www.ihaa.org">www.ihaa.org</a></td>
<td>314</td>
<td></td>
</tr>
<tr>
<td>INEX Incorporated</td>
<td><a href="http://www.inexinc.net">www.inexinc.net</a></td>
<td>1418</td>
<td></td>
</tr>
<tr>
<td>Inland Vacuum Industries, Inc.</td>
<td><a href="http://www.inlandvacuum.com">www.inlandvacuum.com</a></td>
<td>818</td>
<td></td>
</tr>
<tr>
<td>Innova Techno Products (P) Ltd</td>
<td><a href="http://www.innovatechnoproducts.net">www.innovatechnoproducts.net</a></td>
<td>2326</td>
<td></td>
</tr>
<tr>
<td>International Thermal Systems LLC</td>
<td><a href="http://www.internationalthermalsystems.com">www.internationalthermalsystems.com</a></td>
<td>922</td>
<td></td>
</tr>
<tr>
<td>Ion Heat S.A.S</td>
<td><a href="http://www.ionheat.com">www.ionheat.com</a></td>
<td>1019</td>
<td></td>
</tr>
<tr>
<td>IPS Ceramics USA</td>
<td><a href="http://www.ipsceramics.com">www.ipsceramics.com</a></td>
<td>410</td>
<td></td>
</tr>
<tr>
<td>Jansen Inc.</td>
<td>jansenusa.com</td>
<td>2200</td>
<td>Inside Back Cover</td>
</tr>
<tr>
<td>ITC - International Technical Ceramics</td>
<td><a href="http://www.itccoatings.com">www.itccoatings.com</a></td>
<td>1919</td>
<td></td>
</tr>
<tr>
<td>Jackson Transformer</td>
<td><a href="http://www.jacksontransformer.com">www.jacksontransformer.com</a></td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>JGEF / Tempering &amp; Nitriding Furnace</td>
<td><a href="http://www.jgeffurnace.com">www.jgeffurnace.com</a></td>
<td>1922</td>
<td></td>
</tr>
<tr>
<td>JUMO Process Control, Inc.</td>
<td><a href="http://www.jumousa.com">www.jumousa.com</a></td>
<td>1726</td>
<td></td>
</tr>
<tr>
<td>Kanthal AB</td>
<td><a href="http://www.kanthal.com">www.kanthal.com</a></td>
<td>414</td>
<td></td>
</tr>
<tr>
<td>King Tester Corporation</td>
<td><a href="http://www.kingtester.com">www.kingtester.com</a></td>
<td>413</td>
<td></td>
</tr>
<tr>
<td>Kowalski Heat Treating Company</td>
<td><a href="http://www.khheat.com">www.khheat.com</a></td>
<td>1118</td>
<td></td>
</tr>
<tr>
<td>L&amp;L Special Furnace Co., Inc.</td>
<td><a href="http://www.lffurnace.com">www.lffurnace.com</a></td>
<td>1518</td>
<td></td>
</tr>
<tr>
<td>Laserline Inc.</td>
<td><a href="http://www.laserline.com">www.laserline.com</a></td>
<td>2308</td>
<td></td>
</tr>
<tr>
<td>LEKO Corporation</td>
<td><a href="http://www.leko.com">www.leko.com</a></td>
<td>1101</td>
<td></td>
</tr>
<tr>
<td>Leybold USA, Inc.</td>
<td><a href="http://www.leybold.com">www.leybold.com</a></td>
<td>2019</td>
<td></td>
</tr>
<tr>
<td>Lindberg/MPH</td>
<td><a href="http://www.lindbergmph.com">www.lindbergmph.com</a></td>
<td>1819</td>
<td></td>
</tr>
<tr>
<td>Mager Scientific, Inc.</td>
<td><a href="http://www.magersci.com">www.magersci.com</a></td>
<td>1620</td>
<td></td>
</tr>
<tr>
<td>McDaniel Advanced Ceramic Technologies</td>
<td><a href="http://www.mcdanielceramics.com">www.mcdanielceramics.com</a></td>
<td>1108</td>
<td></td>
</tr>
<tr>
<td>McLaughlin Services LLC</td>
<td><a href="http://www.mclaughlinsvc.com">www.mclaughlinsvc.com</a></td>
<td>1113</td>
<td></td>
</tr>
<tr>
<td>Mersen USA Greenville-MI Corp.</td>
<td><a href="http://www.graphite-eng.com">www.graphite-eng.com</a></td>
<td>815</td>
<td></td>
</tr>
<tr>
<td>Messer</td>
<td><a href="http://www.messer-us.com">www.messer-us.com</a></td>
<td>1227</td>
<td></td>
</tr>
<tr>
<td>Metal Treating Institute</td>
<td><a href="http://www.heatreat.net">www.heatreat.net</a></td>
<td>1527</td>
<td></td>
</tr>
<tr>
<td>Metallurgical High Vacuum Corp</td>
<td>www METHVAC.COM</td>
<td>2307</td>
<td></td>
</tr>
<tr>
<td>MPF Products Inc.</td>
<td>mpfi.com</td>
<td>914</td>
<td></td>
</tr>
<tr>
<td>Nabertherm Inc.</td>
<td><a href="http://www.nabertherm.com">www.nabertherm.com</a></td>
<td>1220</td>
<td></td>
</tr>
<tr>
<td>Nel Hydrogen</td>
<td><a href="http://www.protononsite.com">www.protononsite.com</a></td>
<td>1215</td>
<td></td>
</tr>
<tr>
<td>Nippon Grease Co, Ltd.</td>
<td><a href="http://www.nippon-grease.co.jp/en">www.nippon-grease.co.jp/en</a></td>
<td>315</td>
<td></td>
</tr>
<tr>
<td>Nitrex Metal Inc.</td>
<td><a href="http://www.nitrex.com">www.nitrex.com</a></td>
<td>1918</td>
<td></td>
</tr>
<tr>
<td>NK Carbon Group</td>
<td><a href="http://www.carbongroup.de">www.carbongroup.de</a></td>
<td>1226</td>
<td></td>
</tr>
<tr>
<td>Nortake Co., Inc.</td>
<td><a href="http://www.nortake-elec.com">www.nortake-elec.com</a></td>
<td>2328</td>
<td></td>
</tr>
<tr>
<td>North American Cronite</td>
<td><a href="http://www.safe-cronite.com">www.safe-cronite.com</a></td>
<td>2207</td>
<td></td>
</tr>
<tr>
<td>Oslård Engineering Corporation</td>
<td>combustion911.com</td>
<td>1222</td>
<td></td>
</tr>
<tr>
<td>Optris Infrared Sensing, LLC</td>
<td><a href="http://www.optiris.com">www.optiris.com</a></td>
<td>1422</td>
<td></td>
</tr>
<tr>
<td>PACE Technologies</td>
<td><a href="http://www.metallographic.com">www.metallographic.com</a></td>
<td>1419</td>
<td></td>
</tr>
<tr>
<td>Park Thermal International</td>
<td><a href="http://www.parkthermal.com">www.parkthermal.com</a></td>
<td>1410</td>
<td></td>
</tr>
<tr>
<td>Performance Review Institute</td>
<td><a href="http://www.contractwithpri.com">www.contractwithpri.com</a></td>
<td>820</td>
<td></td>
</tr>
<tr>
<td>Pfeiffer Vacuum Inc.</td>
<td><a href="http://www.pfeiffer-vacuum.com">www.pfeiffer-vacuum.com</a></td>
<td>601</td>
<td></td>
</tr>
<tr>
<td>PhoenixTM</td>
<td><a href="http://www.phoenixtm.com">www.phoenixtm.com</a></td>
<td>713</td>
<td></td>
</tr>
<tr>
<td>Praxair, Inc.</td>
<td><a href="http://www.praxair.com">www.praxair.com</a></td>
<td>2103</td>
<td></td>
</tr>
<tr>
<td>Premier Furnace Specialists / Beavermatic</td>
<td><a href="http://www.premierfurnace.com">www.premierfurnace.com</a></td>
<td>1405</td>
<td></td>
</tr>
<tr>
<td>Proceq USA, Inc.</td>
<td><a href="http://www.proceq.com">www.proceq.com</a></td>
<td>923</td>
<td></td>
</tr>
<tr>
<td>Pro-Tech Company Inc.</td>
<td><a href="http://www.protechcompanyinc.com">www.protechcompanyinc.com</a></td>
<td>809</td>
<td></td>
</tr>
<tr>
<td>Protection Controls, Inc.</td>
<td><a href="http://www.protectioncontrolsinc.com">www.protectioncontrolsinc.com</a></td>
<td>913</td>
<td></td>
</tr>
</tbody>
</table>
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.
<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Booth#</th>
<th>Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVA Industrial Vacuum Systems GmbH</td>
<td><a href="http://www.pvatepla-ivs.com">www.pvatepla-ivs.com</a></td>
<td>819</td>
<td></td>
</tr>
<tr>
<td>Pyromaitre Inc.</td>
<td><a href="http://www.pyromaitreonvens.com">www.pyromaitreonvens.com</a></td>
<td>1223</td>
<td></td>
</tr>
<tr>
<td>Pyromation / Schlemmer</td>
<td><a href="http://www.pyromationovens.com">www.pyromationovens.com</a></td>
<td>1327</td>
<td></td>
</tr>
<tr>
<td>Qual-Fab, Inc.</td>
<td><a href="http://www.qual-fab.net">www.qual-fab.net</a></td>
<td>1923</td>
<td></td>
</tr>
<tr>
<td>Quintus Technologies</td>
<td>quintustechnologies.com</td>
<td>403</td>
<td></td>
</tr>
<tr>
<td>Rock Valley Oil &amp; Chemical Co.</td>
<td><a href="http://www.rockvalleyoil.com">www.rockvalleyoil.com</a></td>
<td>622</td>
<td></td>
</tr>
<tr>
<td>Rohde GmbH</td>
<td><a href="http://www.rohdetherm.de">www.rohdetherm.de</a></td>
<td>409</td>
<td></td>
</tr>
<tr>
<td>Rolled Alloys</td>
<td><a href="http://www.rolledalloys.com">www.rolledalloys.com</a></td>
<td>903</td>
<td></td>
</tr>
<tr>
<td>RoMan Manufacturing</td>
<td><a href="http://www.romanmfg.com">www.romanmfg.com</a></td>
<td>313</td>
<td></td>
</tr>
<tr>
<td>SBS Corporation</td>
<td><a href="http://www.sbscorporation.com">www.sbscorporation.com</a></td>
<td>1920</td>
<td></td>
</tr>
<tr>
<td>Schunk Carbon Technology, LLC</td>
<td><a href="http://www.schunkgraphite.com">www.schunkgraphite.com</a></td>
<td>613</td>
<td></td>
</tr>
<tr>
<td>Scientific Forming Technologies Corp.</td>
<td><a href="http://www.deform.com">www.deform.com</a></td>
<td>2226</td>
<td></td>
</tr>
<tr>
<td>Seco Vacuum Technologies</td>
<td><a href="http://www.secovacusa.com">www.secovacusa.com</a></td>
<td>1207</td>
<td>43</td>
</tr>
<tr>
<td>Secco/Warwick Corp.</td>
<td><a href="http://www.secowarwick.com">www.secowarwick.com</a></td>
<td>1209</td>
<td></td>
</tr>
<tr>
<td>SGL Group - The Carbon Company</td>
<td><a href="http://www.sglgroup.com">www.sglgroup.com</a></td>
<td>2018</td>
<td></td>
</tr>
<tr>
<td>Siemens Industry, Inc.</td>
<td>usa.siemens.com/processanalytics</td>
<td>513</td>
<td></td>
</tr>
<tr>
<td>Signature Vacuum Systems</td>
<td><a href="http://www.signaturevacuum.com">www.signaturevacuum.com</a></td>
<td>701</td>
<td></td>
</tr>
<tr>
<td>SIMPLEX METALS LTD</td>
<td><a href="http://www.simplexmetalsltd.ca">www.simplexmetalsltd.ca</a></td>
<td>2128</td>
<td></td>
</tr>
<tr>
<td>Sinosteel Advanced Materials (Zhejiang) Co., Ltd.</td>
<td>en.sinosteel.com</td>
<td>1428</td>
<td></td>
</tr>
<tr>
<td>SKAKO Vibration A/S</td>
<td><a href="http://www.skako.com">www.skako.com</a></td>
<td>1426</td>
<td></td>
</tr>
<tr>
<td>SMS-Elotherm</td>
<td><a href="http://www.techinduction.com">www.techinduction.com</a></td>
<td>404</td>
<td></td>
</tr>
<tr>
<td>Solar Manufacturing</td>
<td><a href="http://www.solarmfg.com">www.solarmfg.com</a></td>
<td>2013</td>
<td>69</td>
</tr>
<tr>
<td>South-Tek Systems</td>
<td><a href="http://www.southteksystems.com">www.southteksystems.com</a></td>
<td>1723</td>
<td></td>
</tr>
<tr>
<td>Stand Energy Corporation</td>
<td><a href="http://www.standeenergy.com">www.standeenergy.com</a></td>
<td>1627</td>
<td></td>
</tr>
<tr>
<td>Steeltech, Ltd.</td>
<td>steeltetchtd.com</td>
<td>722</td>
<td></td>
</tr>
<tr>
<td>Struers Inc.</td>
<td><a href="http://www.struers.com">www.struers.com</a></td>
<td>1608</td>
<td></td>
</tr>
<tr>
<td>Sun-Tec Corporation</td>
<td><a href="http://www.sunteccorp.com">www.sunteccorp.com</a></td>
<td>901</td>
<td></td>
</tr>
<tr>
<td>Super Systems</td>
<td><a href="http://www.supersystems.com">www.supersystems.com</a></td>
<td>1407</td>
<td></td>
</tr>
<tr>
<td>Surface Combustion</td>
<td><a href="http://www.surfacecombustion.com">www.surfacecombustion.com</a></td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>Taylor - Winfield Technologies</td>
<td>inductionheating-tw.com</td>
<td>1018</td>
<td></td>
</tr>
</tbody>
</table>

**RESIDUAL STRESS MEASUREMENT**

Laboratory, Portable, Ultra Portable X-Ray Diffraction Systems

**TECHNOLOGY THAT DELIVERS ACCURATE RESULTS**

Ensure your parts are of the highest quality. Our methods are time-tested and proven to be extremely accurate and reliable.

1-734-946-0974 info@protoxrd.com

www.protoxrd.com

[www.geartechnology.com]
<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Booth#</th>
<th>Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Televac/The Fredericks Company</td>
<td><a href="http://www.televac.com">www.televac.com</a></td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>Tenova Inc.</td>
<td><a href="http://www.tenovacare.com">www.tenovacare.com</a></td>
<td>1510</td>
<td></td>
</tr>
<tr>
<td>The David Round Company</td>
<td><a href="http://www.davidround.com">www.davidround.com</a></td>
<td>1813</td>
<td></td>
</tr>
<tr>
<td>Thermal Care Inc.</td>
<td><a href="http://www.thermalcare.com">www.thermalcare.com</a></td>
<td>1313</td>
<td></td>
</tr>
<tr>
<td>Thermal Processing</td>
<td><a href="http://www.thermalprocessing.com">www.thermalprocessing.com</a></td>
<td>2119</td>
<td></td>
</tr>
<tr>
<td>Thermcraft, Inc.</td>
<td><a href="http://www.thermcraftinc.com">www.thermcraftinc.com</a></td>
<td>1427</td>
<td></td>
</tr>
<tr>
<td>Thermo-Cal Software Inc.</td>
<td><a href="http://www.thermocal.com">www.thermocal.com</a></td>
<td>1110</td>
<td></td>
</tr>
<tr>
<td>Titan Metallurgy</td>
<td><a href="http://www.titanmetallurgy.com">www.titanmetallurgy.com</a></td>
<td>1123</td>
<td></td>
</tr>
<tr>
<td>TOYO TANSO USA</td>
<td><a href="http://www.ttu.com">www.ttu.com</a></td>
<td>604</td>
<td></td>
</tr>
<tr>
<td>Trumpf Huettinger, Inc.</td>
<td><a href="http://www.trumpf.com">www.trumpf.com</a></td>
<td>603</td>
<td></td>
</tr>
<tr>
<td>Tucker Induction Systems</td>
<td><a href="http://www.tuckerinductionssystems.com">www.tuckerinductionssystems.com</a></td>
<td>1001</td>
<td></td>
</tr>
<tr>
<td>Ultraflex Power Technologies</td>
<td>ultraflexpower.com</td>
<td>1626</td>
<td></td>
</tr>
<tr>
<td>United Process Controls</td>
<td><a href="http://www.group-upc.com">www.group-upc.com</a></td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Unitherm Furnace, LLC</td>
<td>unithermfurnace.com</td>
<td>826</td>
<td></td>
</tr>
<tr>
<td>Vac Aero International Inc.</td>
<td><a href="http://www.vacaero.com">www.vacaero.com</a></td>
<td>1010</td>
<td></td>
</tr>
<tr>
<td>Vacuum Pump Services Corp.</td>
<td>vacpumpservices.com</td>
<td>1023</td>
<td></td>
</tr>
<tr>
<td>Verichek Technical Services, Inc.</td>
<td>verichek.net</td>
<td>1026</td>
<td></td>
</tr>
<tr>
<td>Wickert Hydraulic Presses USA</td>
<td><a href="http://www.wickert-usa.com">www.wickert-usa.com</a></td>
<td>915</td>
<td></td>
</tr>
<tr>
<td>Williams Industrial Service</td>
<td><a href="http://www.wisfurnaces.com">www.wisfurnaces.com</a></td>
<td>1119</td>
<td></td>
</tr>
<tr>
<td>Wirco Inc.</td>
<td><a href="http://www.wirco.com">www.wirco.com</a></td>
<td>303</td>
<td></td>
</tr>
<tr>
<td>Wisconsin Oven</td>
<td><a href="http://www.wisoven.com">www.wisoven.com</a></td>
<td>1620</td>
<td></td>
</tr>
<tr>
<td>WS Thermal Process Technology Inc.</td>
<td><a href="http://www.flox.com">www.flox.com</a></td>
<td>2118</td>
<td></td>
</tr>
<tr>
<td>Xinghua Tongbu Casting Co., Ltd.</td>
<td><a href="http://www.top-casting.cn">www.top-casting.cn</a></td>
<td>926</td>
<td></td>
</tr>
<tr>
<td>Yokogawa</td>
<td><a href="http://www.yokogawa.com">www.yokogawa.com</a></td>
<td>2327</td>
<td></td>
</tr>
<tr>
<td>York Wire &amp; Cable, Inc.</td>
<td><a href="http://www.yorkwire.com">www.yorkwire.com</a></td>
<td>515</td>
<td></td>
</tr>
<tr>
<td>ZIRCAR Ceramics, Inc.</td>
<td><a href="http://www.zircarceramics.com">www.zircarceramics.com</a></td>
<td>1827</td>
<td></td>
</tr>
<tr>
<td>Zircar Refractory Composites, Inc.</td>
<td><a href="http://www.zrci.com">www.zrci.com</a></td>
<td>2122</td>
<td></td>
</tr>
</tbody>
</table>
The Power of One$^2$

Your Objective:
One face in perfect alignment with another. For infinity.

No problems. No distress. No delays.
That’s the same objective you have for choosing your gear producer. Circle Gear’s objective is to engage with every customer’s objectives.

- One to 1000 gears
- Customer designed or reverse engineered
- Gearbox repair, rebuild or redesign
- OEM or end-users
- ISO 9001:2015 Certified

1501 S. 55th Court, Cicero, IL 60804
(800) 637-9335
(708) 652-1000 / Fax: (708) 652-1100
sales@circlegear.com
www.circlegear.com

Spiral and Straight Bevel Gears (Cut, Ground or Lapped) • Spur Gears • Helical Gears • Long Shafts • Herringbone Gears • Involute and Straight Sided Splines • Internal Gears • Worm and Worm Gears • Racks • Sprockets • ISO Certified

Partnering with QualityReducer to provide Gearbox repair, rebuilding and reverse-engineering.
Fellows

Gear Shaping
Gear Hobbing
Surface Grinding
Vertical Grinding
Speciality Machines

Remanufactured Fellows 10-4
Available with Electronic Guide

Standard Features
Fanuc 0i-F CNC Control
4 Axis CNC
Conversational Programming
19.5” Touch Screen Monitor
Easy-Automate Enclosure

Optional Equipment
Electronic Helical Guide
CNC Back-Off
Programmable 5th & 6th Axis
Standard & Custom Automation
Hydraulic Fixture Clamping
Quick Change Tooling

MACHINESALES@BOURN-KOCH.COM
815-965-4013
www.bourn-koch.com

MOTION + POWER
TECHNOLOGY EXPO
EXHIBITOR
Booth #3813
At Presite, our experience, innovation and expertise, as well as the people behind it all, ensure that you get the best, most accurate net and near-net forgings. From presses up to 6,000 tons of capacity, to our state-of-the-art Tech Center, we can offer design, engineering, die-making and production solutions.
We’ve Got You Covered...

BENZ OIL, INC. EST. 1898     benz.com

BENZ GRIND
MULTI GRIND
E GRIND

ADVANCING LUBRICATION...

GOTTA GET BACK IN TIME...

It may not be as impressive as a DeLorean, but if time travel is your thing, we have you covered at www.geartechnology.com.

Today, our user-friendly archive (1984 to present) is now available online with an optimized search engine that allows subscribers to locate specific articles using keywords and phrases.

We’ve created a database where subscribers can peruse more than thirty-five years of gear manufacturing articles without leaving their desks.

In an era where content is king, let Gear Technology be your destination for the past, present and future of gear manufacturing.


CATTINI NORTH AMERICA
Leading Italian gear manufacturer now proud to be serving the Americas!

HEAVY DUTY SHAFTS FEATURING HARD GEAR FINISHING

• Learn why many multi-national heavy-duty vehicle and machinery OEMs have been choosing Cattini for years.
• Not just a supplier, Cattini has earned partner status with many customers.

CATTINI NORTH AMERICA CORP.
Your reliable Partner
717-262-2120
1690 Opportunity Ave., Chambersburg PA, 17201

Contact us at www.CattiniNA.com
Introducing the NEW GEARBOX GENERATION
Licensing Available

The 2 CHANNEL TRANSMISSION combines a differential with a CVT

NO MORE SWITCHING GEARS!
• Cheaper to build
• Motor running - all the time at the speed of maximum efficiency
• Very high torque at low speed
• Less pollution

The new gearbox generation opens the door to new markets.
Cars • Farm machinery • Trucks • Pumping stations • Wind turbines and many more.
2ChannelTransmission.com
sixal@mindspring.com

Visit Us at MPT Expo Booth #4401
Processing Ability Module: 0.3~12, Maximum O.D: 400 mm
Grinding Ability Module: 1~10, Maximum O.D: 300 mm
Gear Accuracy AGMA: 8~12 / JIS B 1704: 0~4
Design Software Gleason CAGE / Gleason GEMS / Klingelnberg KIMOS
CNC Machines Cutting Gleason Phoenix II 280HC, Phoenix II 275HC
Klingelnberg Oerlikon C15, Oerlikon C27
Lapping Gleason 600HTL / Klingelnberg L60
Grinding Gleason 275G / Klingelnberg G27
Inspection Gleason 475GMM / Klingelnberg P40
Gear Tester Klingelnberg T60

YAGER GEAR ENTERPRISE CO., LTD.
NO. 57, SHIGU LN., GUOZHONG RD., DALI DIST.,
TAICHUNG CITY, 41260 TAIWAN.
TEL: +886-4-24076223 FAX: +886-4-24076218
Website: www.yagergear.com  E-mail: service@yagergear.com

SHAPING THE FUTURE OF INDUCTION

Induction Heat Treating Solutions
Your Global Source for Service, Support & Manufacturing

- Scanners
- Single Shot
- Lift & Rotate
- CHT
- Tooth by Tooth
- Part Development
- Power Supplies
- Parts & Service
- Installation & Construction

24 / 7 Customer Service: 800-547-1527

www.AjaxTocco.com
Hungry for More?

Everything you need to be a world-class gear manufacturer — the suppliers, the technical information and the market intelligence — can be found online.

• The GT Library includes a complete archive of back issues and articles, 1984-today
• Directory of suppliers of machine tools, services and tooling
• Product and Industry News updated daily
• Exclusive online content in our e-mail newsletters
• Calendar of upcoming events
• Comprehensive search feature helps you find what you’re looking for — fast!

www.geartechology.com
The Additive Advantage
How 3-D Printing is Changing the Powder Metal Performance Game

Matthew Jaster, Senior Editor

A study released in the 1995 September/October issue of *Gear Technology* examined the advantages of powder metallurgy for new and existing gear applications. “The Beginner’s Guide to Powder Metal Gears,” written by George Shturtz at Carbon City Products, Inc., explored why PM deserved serious consideration for gear design in areas like automotive, hand tools, outdoor power equipment and office machinery applications.

It’s a fascinating read — particularly in 2019 — when you compare the role PM plays today in gear manufacturing versus its potential back in 1995. And while the Metal Powder Industries Federation (MPIF) has championed the technology — offering technical papers on powder metal since the mid 1940’s — additive manufacturing has given PM even greater visibility in recent years pushing its potential from prototyping into the production environment.

Matt Sand, president at 3DEO, said that metal additive manufacturing was always outshined by plastic 3-D-printing because the process of using powder metal is very complex. Some powder metals need to be handled in careful environmental conditions to prevent explosions and some processes require sintering in order to achieve final part density.

“Currently, metal additive manufacturing is used mainly for prototyping and one-off production of complex parts in industries such as aerospace and medical devices. However, companies like 3DEO are working hard to create new metal AM processes that are optimized for high-volume serial production,” he added.

The Potential of 3-D-Printed Components
As 3-D-printing machines continue to increase their capabilities, PM components have the potential to become more than just one-off, customized solutions.

According to Tommy Lynch, senior applications engineer, additive manufacturing at Xometry, powder bed fusion metal systems have evolved to become more productive. Powder handling is becoming more user-friendly, and Lynch is seeing more systems emerge that have dual or quad laser setups that can increase build speed and through-put on smaller parts.

Lynch said metal binder jetting is also going through a revitalization stage with new players in the technology. Over the next few years, this technology could have a stronger foothold for making production metal parts with similar results as metal injection molding.

Concerning the potential of 3-D-printed powder metal components, Lynch believes that compared to traditional manufacturing methods the biggest advantage will be the speed of iteration.
“Engineers now have the flexibility to design, instantly quote, order, and have parts within a week. In addition, there may be cost savings by avoiding steep setup charges that typically occur with traditional methods such as CNC machining or metal casting,” Lynch said.

For laser powder bed fusion, like direct metal laser sintering or selective laser melting, the ability to use the same process for both prototyping and production has provided a strategic advantage in part validation and revision releases. Lynch has seen many examples of Xometry customers solving challenges with their metal casting supply chain by moving to direct-printed metal options. Parts produced also have the benefit of being fully-dense and ready-to-machine.

Additionally, Sand said that 3-D-printed metal components benefit from advanced designs and complex geometries such as internal cooling channels. These components can benefit from increased durability, reduced cost, shorter lead time and improved functionality.

Alex Crease, application engineer at Markforged, said that 3-D-printing applications have changed since the advent of high-strength metal parts and low-cost adoption. Take Markforged’s Metal X, a metal 3-D printer, for example, as it introduces a safe and cost-effective method of producing parts quickly out of a variety of metals. The machine extrudes bound metal powder layer by layer to construct a part. Once built, it’s sintered in a furnace, where the binder melts away and the final metal part solidifies.

“Additive technologies like the Metal X demonstrate that 3-D-printing can efficiently produce parts that can withstand the rigors and strain of the modern factory, but it also signals that such quality and effectiveness aren’t just reserved for the largest manufacturers with the deepest pockets. The 3-D-printing landscape has further evolved with the introduction of artificial intelligence (AI), giving manufacturers the opportunity to make 3-D-printing more accurate and reliable.

### Regarding Gear Production

While PM components come in all shapes and sizes, the readers of this magazine would probably be most intrigued by their future potential in gear manufacturing.

“Gears are very difficult due to the tight tolerances and high demands on the components,” Sand said. “Most metal
3-D-printing technologies are NOT able to hit these component requirements in production quantities.

3DEO’s Intelligent Layering process starts with a layer of metal powder that is then sprayed with a proprietary binder. A cutting tool is then used to cut out the 2-D design of one dimension of the part. This process continues layer by layer until the part is built. The green part is then sintered in a furnace to melt the binder and achieve final part density. 3DEO’s process is able to achieve a superior surface finish which reduces post-processing.

“This is particularly beneficial for gears because gears have a complex shape with tiny grooves that may be hard to polish. In addition, gears require tight tolerances because the gears must fit together perfectly to function,” Sand said.

On the polymer side, Lynch said there are significant advances in material science which include being able to print in epoxy and urethane materials through the Carbon DLS platform. Both polymer and metal powder bed fusion technologies tend to work well for medium to larger gears; and laser sintering and multi-jet fusion are great examples of this.

“There are still surface finish and resolution issues on finer features and thin gaps. Process tolerance, materials, and as-built surface finish should all be considerations when choosing additive for geared components,” Lynch said.

The challenge of producing gears with additive manufacturing is two-fold; machines need to print with high enough precision to minimize backlash in the gear teeth, and the materials the machines print have to withstand torque transmission through the teeth. Plastic 3-D printers that have dominated the industry don’t have the strength or the resolution to print effective gear teeth. While metal 3-D-printers have the material strength to do it, metal 3-D-printers, until now, were not affordable, according to Crease.

“The Metal X offers a cost-effective solution for creating metal parts in a variety of metals, including stainless steel and tool steels. Since producing gears often requires some amount of tooling and overhead, like extrusion dies, broaches, and more, additive manufacturing has the potential to reduce some of those overhead costs to make both prototyping and production more efficient. Functional prototypes and small-scale production parts, like gears and similar components, can be created without worry over tooling or overhead costs,” Crease said.

Once manufacturers are ready for larger scale production, Crease said they can use the Metal X to create the tooling and workholding needed to make gears and other components at scale. This allows gear manufacturers to iterate quickly through designs, optimizing both the gear design and its tooling design, all while keeping costs low.

Markforged’s Blacksmith, the first AI-powered software that makes additive manufacturing machines “self-aware,” allows users to automatically adjust programming to ensure every part is produced as designed. Blacksmith AI software connects additive manufacturing equipment to inspection equipment. This means that parts can be 3-D scanned and their information can be relayed back to the machines making them, which in turn update their settings to make the next part more precise. This closes the loop between manufacturing and inspection to make 3-D-printed parts more accurate and repeatable.

“Markforged’s Blacksmith, has the potential to improve part precision and repeatability to ensure manufacturers receive accurate print gears or gear tooling with ‘adaptive manufacturing.’ Through 3-D scanning, this data is compared to the original design which AI then learns from and adapts the process settings to produce a more accurate final part. Ultimately, Blacksmith will produce the right part the first time and every time, and manufacturers can ensure that printers are hitting the necessary tolerances for gear components and can reduce the number of design iterations needed before a production run,” Crease said.

**Know Your Limits**

Additive manufacturing has its own set of unique limitations. According to Lynch, this is primarily around internal stresses generated during the build process. Support structure is an absolute need in most cases, and post-processing adds additional challenges as well as surface inconsistencies.

“Educating and building reasonable expectations for our customers is a large part of working with metal printing,” Lynch said. “Size and costs can also be prohibitive. Although this technology can scale, it is best optimized when a full build tray is utilized for an array of small pieces.”

The greatest challenge with utilizing metal 3-D printing is the lack of quality control within the industry. “3-D-printing is mainly used for prototyping because when used for
high-volume production, most technologies fail to achieve repeatability and typically have problems with degrading processes,” Sand said.

Cresce agrees that the number one challenge isn’t the technology itself, but education in the industry around it. “When vendors introduce a breakthrough, new ways to make parts, it’s naturally going to take time for everyone to understand the process and how it can be leveraged to improve and change their business,” he said.

**A Focus on Heat Treat and Surface Finish**

Heat treating, specifically for stainless steel alloys, is basically controlled heating and cooling cycle(s) to obtain specific conditions or properties. Depending on a heat-treating condition, it is possible to increase hardness and tensile strength of a part and/or improve ductility and machinability. The condition is usually defined by the application and working environment of the part, according to Sand.

“Finishing processes such as media blasting improve the surface quality, as well as properties like surface hardness and fatigue resistance. Blasting also helps with removing contamination and providing a uniform surface appearance,” he added.

Lynch added that heat treating is essential for many printed metal components to stress relieve the parts before removing from its supports and build plate. Post heat treating is available as well for hardening materials in built components. Typically parts are bead blast or shot-peened to remove any excess material on surfaces. There are abrasive and non-abrasive methods of surface smoothing, but each has trade-offs.

Just like with traditional metals, 3-D-printed metals can be heat-treated to certain temperatures to achieve different material properties, so the traditional processing methods for gears can carry over into modern technologies like 3-D-printing. “Smooth, precise surfaces on gear teeth allow the gears to mesh consistently without any slop or noise, which is why surface prep is so important. Any inconsistencies in the surfaces of the
gear teeth make the gear less efficient: it becomes more likely to jam, and more power is needed to transmit forces through the teeth. Similarly, more backlash and slop will be introduced into the system if the gears are manufactured less precisely. So having a consistent, clean surface improves the performance of the gear and makes it more efficient. Parts printed on Markforged’s Metal X can be cleaned up just like their traditional metal counterparts, making it easy to post-process if very high precision is needed,” Crease said.

Taking Initiative

So where is the technology heading today?

Sand said it’s not trivial to move from prototyping to production. Additive manufacturing is great for rapid prototyping, but achieving the repeatability necessary for serial production is complicated. The reason being is that additive manufacturing lacks a standardized method of production. With additive manufacturing, there are hundreds of variables to control that can affect the outcome of a print. Each printer, operator, and even layer is independent of the other and can create serious problems with the predictability of performance.

“3DEO started with the idea of production in mind, so all or our systems have been developed around this. As we grow and take on larger orders, we continually discover how much additive manufacturing processes lack standardization in quality and process controls. As a result, we have to develop our own systems in order to compete with traditional manufacturing,” Sand said.

3DEO has a dedicated R&D team that continues to develop and improve the Intelligent Layering technology. We are currently working on expanding our available materials to others such as titanium and tungsten carbide.

Xometry is able to instantly price and provides lead times for seven 3-D printing technologies as well as traditional machining, sheet metal, and molding (courtesy of Xometry).

Printing is only the first step of a multi-stage process when 3-D-printing metals. The best way to conceptualize the part is as a near-net-shape, meaning that additional processing is likely necessary to achieve specific tolerances or surface finishes. A great surrogate is that of metal casting, where the shape is made then typically post-machined.

“Simplicity and reliability are key for additive manufacturing, which is why we developed the full additive ecosystem – from software to printers to materials. This tactic allows us to fine-tune every part of the process to give our customers the best user experience and reliability. We even launched Blacksmith to ensure customers can tell if they’ve printed in-spec parts. It’s essential to align each part of the process under one group because one weak link will produce a poor result. For example, if a customer uses an inferior material, they’ll have an inferior final part, no matter how high-quality the printer is,” Crease said.

The Future of 3-D-Printed, PM Gears

Sand believes the future is bright for gear manufacturing, especially when it comes to lower volume production runs. 3DEO offers metal 3-D-printing technology in production today, but there are undoubtedly many other new, up-and-coming technologies that will make significant inroads in gear fabrication.

Lynch said that resolution and surface finish will continue to improve from direct-printed results. It may not be the case that powder bed fusion will be the primary way metal parts are additively manufactured.
“With new hybridizations of processes, both additive-to-additive, and additive-to-subtractive, there will be greater leveraging of strengths between processes. For example, growing a part and in-situ tuning of feature sets may be commonplace; pairing this with model-based definitions (MBD or PMI) will complement the blend of design intent, fabrication, and real-world implementation,” Lynch said.

The capabilities of additive manufacturing technology are increasing at an incredible rate, especially with tolerancing and dimensional precision, according to Crease.

“Ten to 15 years from now, we expect to produce gears and energy transmission systems ranging from precision nanodrives and micro motors to extremely large-scale gears (such as mill and pulley gearing) all from a variety of 3-D printers,” Crease said. “Additionally, the removal of current limitations in designs of teeth and grooves from subtractive manufacturing will create more possibilities for all new engagement and drive methods that were never considered before.”

For more information:
Markforged
Phone: (617) 666-1935
https://3d.markforged.com

3DEO
Phone: (844) 496-3825
www.3deo.co

Xometry
Phone: (240) 252-1138
www.xometry.com

For more information or a quote, call 1-855-WE-HEAT-IT or visit solaratm.com

Vacuum Heat Treating Services
We know high quality gears and components are vital to performance. Our leading edge vacuum technology and expertise provides precise control and repeatability for consistently superior parts.

• Low Pressure Vacuum Carburizing (LPVC)
• Vacuum Gas Nitriding
• Vacuum Stress Relieving
• High Pressure Gas Quenching (HPGQ)

Advantages
• Uniformity of case depths
• Minimized distortion
• No IGO (Intergranular Oxidation)
• Parts returned clean, free of soot – eliminating downstream cleaning processes
Influence of Thermal Distortion on Spur Gear Tooth Contact

Dr. Jon Larrañaga, Dr. Ibai Ulacia, Aurea Iñurritegi, Dr. Aitor Arana, Jon German, and Julen Elizegi

Introduction
The increase of efficiency in automotive gear transmissions has been a key subject of research in the past decade (Ref. 1); to this aim, dip-lubricated gearboxes have been designed with minimized oil levels in search of reduced churning power losses (Ref. 2) and maximum power-to-weight ratios. However, when such gears’ running conditions reach the highest pitch line velocities and torques, bulk temperatures increase rapidly, resulting in reduced oil film thickness, higher surface shear stresses and an increased number of asperity contacts—all of which may lead to a premature failure of the gear pair. Moreover, in such cases, not only high temperatures are reached but also significant temperature gradients are found between pinion and gear. Figure 1 shows a sample of the aforementioned operating case. As can be seen, the optimal conditions lie between a relative immersion depth of $H/D = 0.1$ to $0.25$, where power losses are minimal. However, with these oil levels the temperature difference between pinion and gear reach $20^\circ$C to $30^\circ$C because the small size of the pinion results in a lower convection heat transfer due to the reduced oil-lubricated area and its increased rotational speed (with respect to that of the gear) increases the amount of heat flowing inwards, resulting in a higher bulk temperature of the pinion. This phenomenon leads to relative pitch deviations and thermally induced profile distortions (Ref. 3).

Several experimental results regarding the effects of thermal distortion on the gear mesh can be found in literature — primarily related to turbo-gears running at high pitch line velocities (close to 100 m/s) (Refs. 4–6) — where the differential thermal effects are known to cause large variations of contact and root stresses (Ref. 7). At lower tangential speeds, only thermal effects of plastic gears have been analyzed in scientific literature (Refs. 8–9) because the material properties are temperature-dependent and the increased thermal expansion coefficient causes significant profile distortion. Nevertheless, plastic gears do not reach the bulk temperature levels of their steel counterparts (Ref. 10) and, therefore, metallic gears may also show appreciable geometry distortion when they are subject to operating conditions such as those shown (Fig. 1).

In the present work, predicted steady-state temperature distributions from a thermal-lumped parameter model developed by the authors in (Ref. 11) are used as inputs for a 2-D finite element model. Geometry distortion and tooth contact parameters in the transverse plane are numerically computed where load distribution, transmission error and available backlash are studied. Narrow face width spur gears with $b/d < 0.5$, running at high speeds and low oil levels are analyzed, and it will be shown that even with thermally favorable operating conditions with high immersion depths, profile deviations are appreciable. The results of the study will allow setting the limits of design backlash to avoid gear jamming and to size the initial profile modifications to reach the desired contact behavior at operating temperatures.

Thermo-Mechanical Model
The thermo-mechanical model developed in the current work is a combination of a simple thermal-lumped parameter model of the gear pair (Ref. 11) and a 2-D finite element model (FEM) (Ref. 12). The former allows calculating thermal gradients in the gear body as well as the temperature differences between pinion and gear; while the latter is used to compute geometry distortion and perform the loaded tooth contact analysis (LTCA).

Thermal-lumped parameter model. Unlike other thermal network models in gear literature that represent the complete...
gearbox, the thermal network model developed herein focuses on the temperature field of the gear pair. The main underlying assumption is that it is possible to compute the steady-state temperature distribution within the solids, considering only the heat flux coming from the gear mesh and the shaft, as well as the steady-state temperatures of the surrounding fluids (oil and air inside the gearbox).

As it can be seen (Fig. 2), pinion and gear are discretized radially and each individual control volume is linked to its neighbors by means of thermal resistances. Circumferential thermal gradients within the gear body are neglected and therefore pure radial conduction is considered. This means that the control volumes are represented as annulus, where conduction resistances are computed from the classical one-dimensional cylindrical approach. The relative immersion depth being different for the pinion and gear, some of individual annulus are permanently in contact with the oil sump, while others only exchange heat with the oil-air mixture inside the gearbox. Therefore, convective heat transfer resistance between the external surfaces of the gear and the surrounding fluid depend on the local Nusselt number, \( N_u \), which is evaluated considering the thermo-physical properties of the fluid at the boundary layer temperature. Heat exchange due to radiation is neglected because the temperature levels of the elements inside the gearbox are not high (usually below 200°C).

Two heat sources are considered: i) power losses from the gear mesh; and ii) heat from the bearings and sealings. The former is described in detail (Ref. 11), while the latter is computed from classical equations in gear literature (Ref. 13) where only a third of the total power loss is introduced in the gear axis nodes; the remaining two thirds are assumed to be dissipated through the housing and oil bath. If constant, steady-state oil/air temperatures are considered, it is not necessary to compute churning and windage power losses because the heat generated within the fluid no longer increases its bulk temperature.

Finally, the solution of the model is given by the system of equations assembled in matrix form in Equation 1, in which \( C \) is the capacity matrix; \( K \) is the conductivity matrix (where \( K_{ij} = R_{ij}^{-1} \)); \( Q \) is the heat input vector; \( \Theta \) is the temperature vector; \( t \) denotes time; and the superimposed dot indicates time differentiation. In order to avoid instabilities due to non-linearities in fluid properties and convection coefficients, the Picard iteration method is used to solve the initial value problem.

\[
C(\Theta, t) \times \dot{\Theta} + K(\Theta, t) \times \Theta = Q(t)
\] (1)

The resulting radial temperature distribution of pinion and gear is loaded in a 2-D finite element model which computes the thermal growth of each point of the mesh following Equations (2) and (3).

\[
r_i'(x) = r_i(x) + \Delta r_i(\Theta)
\] (2)

\[
\Delta r_i(\Theta) = \alpha L \sum_{i=1}^{n} (r_{i+1} - r_i) \left( \frac{T_i + T_{i+1}}{2} - T_0 \right)
\] (3)

**Finite element model.** A thermo-mechanical quasi-static and two-dimensional model of a gear pair is developed to analyze the effect of the thermal distortion on gear mesh behavior — namely, load distribution and transmission error. The numerical models are automatically generated using a custom gear mesh generator and the FEM models are calculated using MSC.Marc solver.

The gear and pinion mesh are generated following the methodology used by Litvin (Ref. 14). This methodology is characterized by defining a greater density of elements in the teeth than in the body of the gear (Fig. 3). Additionally, a progressive mesh density (i.e. — bias factor) has been determined from the symmetry axis of the tooth to the contact area (Ref. 15). A four-node, isoparametric, arbitrary quadrilateral element for plane stress applications is used (element type 3 of the MSC.Marc software (Ref. 16)).

The numerical model considers two load cases: in the first
step, the temperature of the gears as computed by the lumped thermal network model are introduced and then thermal growth is computed. In a second step, the expanded gears rotate and the contact between pinion and gear is computed. The rotation is applied in the pinion and the torque in the gear, both counter-clockwise. Rigid connectors are introduced between the point representing the gear axis centerline and the body, which are also used to apply the rotation and torque boundary conditions (Fig. 3). As it has been described by the authors in a previous work (Ref. 12), the complete gear was modelled in order to minimize the effect of boundary conditions in the results.

**Case study.** With the aim of studying the influence of thermally induced geometry distortions on contact behavior, a reference gear pair with identical teeth geometry has been selected. Such gears are characterized by having the same length of approach and recess, as well as the same thickness along the tooth height (i.e. same manufacturing profile shift coefficients $x_i$, ensuring that they have the same bending and rotational stiffness at any point). With this approach, any difference in contact behavior can be easily identified from the horizontal and vertical displacements in the corresponding diagrams.

Table 1 summarizes the geometrical characteristics of the gear set under consideration. Five different torque levels are applied—from 100 Nm to 500 Nm at two different pitch line velocities—10 m/s (2,000 rpm) and 20 m/s (4,000 rpm). The gears are lubricated with FVA3A mineral oil which is an ISO VG100 oil with 4% Anglamol EP additive. The numerical simulations consider oil levels from H/D = 0.5 to 0.1 at a constant oil sump temperature of 90°C. The material selected for the gears is a 16MnCr5 steel, 206 GPa Young modulus, 0.3 Poisson coefficient, 7,830 kg/m$^3$ and a thermal expansion coefficient of 12.5 μm/m K.

**Results**

First, resulting temperatures from the thermal network model are summarized and then thermally distorted geometry will be presented. Loaded tooth contact analysis results will be displayed at the end where the influence of different parameters

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Geometry parameters of the spur gearset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>Value</td>
</tr>
<tr>
<td>Number of teeth</td>
<td>$z_{1,2}$ [-]</td>
</tr>
<tr>
<td>Normal module</td>
<td>$m_n$ [mm]</td>
</tr>
<tr>
<td>Normal pressure angle</td>
<td>$\alpha_n$ [°]</td>
</tr>
<tr>
<td>Face width</td>
<td>$b$ [mm]</td>
</tr>
<tr>
<td>Profile shift coefficient</td>
<td>$x_{1,2}$ [-]</td>
</tr>
<tr>
<td>Operating center distance</td>
<td>$a_o$ [mm]</td>
</tr>
<tr>
<td>Reference profile acc. ISO 53</td>
<td>[-]</td>
</tr>
<tr>
<td>Tolerance field acc. DIN 3967</td>
<td>[-]</td>
</tr>
</tbody>
</table>

![Figure 3](image-url) Mesh detail and boundary conditions of the numerical model.

![Figure 4](image-url) Predicted temperatures and gradients for different input powers and immersion depths.
Temperature distribution. The different combinations of torque, speed and immersion depth result in bulk temperatures in the range between 90°C to 160°C. No appreciable thermal gradient has been found between pinion and gear because the speed ratio is 1 and the oil level covers the same area in both gears; therefore, the convection heat transfer is identical, which explains the absence of temperature differences.

In order to simulate unfavorable thermal conditions, two additional situations have been studied: i) idler gears with additional heat inputs from multiple meshes; and ii) reduction gear units. Figure 4 presents the results of the latter with $z_1 = 20$ and $z_2 = 30$, while the rest of the parameters are maintained. As it can be seen, significant temperature gradients exist at the highest input powers and lowest immersion depths.

Thermally induced geometry distortion. Figure 5 depicts the degree of distortion of the gears described in Table 1 with respect to the original geometry manufactured at 20°C. Distorted geometry at the oil sump temperature of 80°C is calculated along with the geometry change at a sufficiently high temperature, 140°C. In both cases, it is seen that a constant temperature increase of the gear (without temperature gradients in the direction of the radius), increases the tip diameter, reducing the manufacturing allowance that approaches zero. However, the difference at the root is not that important.

Such a difference between the tip and the root indicates that a considerable profile slope deviation exists. This is explained by the thermally induced base diameter increase, $f_b$, which is interrelated to the pressure angle deviation, $f_\alpha$, by means of the following equation.

$$f_b = f_\alpha \cdot d_b \cdot \tan(\alpha)$$

Furthermore, profile form errors are also present because the diagram on the right (Fig. 5) shows a slight curvature that deviates from the mean shape of the profile. However, such differences seem to be strictly located in the root region and they will not be addressed in the current paper. Finally, tip diameter increase is also shown, which may act on the length of the line of action and the contact ratio. All of these parameters are further analyzed in the next sections.

Loaded tooth contact analysis without thermal effects. In order to understand the effects of thermally induced geometry distortions on contact parameters, the reference calculations with variable torque (and ambient temperature) are presented (Fig. 6). Loaded tooth contact analysis shows the normal behavior under load, with a non-dimensional load sharing factor, $R$, between 0.4 and 0.6. Significant contact outside the theoretically defined phase of mesh is also observed, where the simulated start/end of the active profile takes place 1.5 degrees before/after expected. On the other hand, loaded transmission error (Fig. 6b) shows an increasing peak-to-peak value with torque, but also decreasing mean values — indicating that the driven gear lags behind its theoretical value due to the increased tooth deflection.

Moreover, both Figures 6a and 6b show a symmetrical

![Figure 5](image1.png) Profile geometry distortion at different operating temperatures.

![Figure 6](image2.png) Influence of torque on load distribution and transmission error.
behavior with respect to the pitch point, C, indicating that both geometries are identical. That is to say, the length of approach equals the length of recess. Table 1 also shows that no design profile shift has been considered and the same tolerance field is applied to both gears, resulting in equal manufacturing profile shift coefficients $X_E = -0.0309$. Therefore, pinion and gear are geometrically identical and, as a result, have the same stiffness.

**Influence of temperature increase on LTCA.** In the same way as torque, temperature increase also extends the length of the path of contact. Tip diameter is increased proportionally to temperature and therefore the start of the active profile comes earlier and the end of it arrives later. In general terms, the trend of temperature increase is comparable to that of load. Figure 7a depicts this phenomena at a constant torque of 400 Nm and variable temperature (in the range of the numerically predicted values). However, as it can be observed (Fig. 7b) the influence of temperature on the length of the line of action is lower than that of torque. An increase of 100 Nm extends the path of contact 2%, while a 100°C increase implies approximately 1%.

If the shape of the thermally affected load distribution diagram (Fig. 7a) is compared to that of load (Fig. 6a), it is seen that temperature increase does not influence the symmetry. Thermal expansion affects pinion and gear shape in the same manner and therefore there is no geometrical difference; hence, no stiffness difference either.

On the other hand, the increase of temperature affects transmission error appreciably (Fig. 8a). The reduction of the mean level of transmission error is fully explained by the reduction of the available backlash angle (Fig. 8b). For instance, at 300 Nm the decrease of the backlash angle from 20°C to 140°C is 0.0527 degrees, which corresponds to the mean step between both curves at the same operating temperatures (Fig. 8a).

**Influence of temperature gradient on LTCA.** In order to analyze the effect of the temperature gradient, the pinion temperature is maintained constant at 140°C, while gear temperature decreases. This case, with different temperatures for identical gears, represents multi-mesh transmissions where a gear could be engaged with multiple others and consequently the

---

**Figure 7**  Influence of temperature increase on load distribution at $T = 400$ Nm.

**Figure 8**  Influence of temperature increase on transmission error at $T = 300$ Nm.
temperature of the former would be higher than the rest.

When a temperature gradient exists, the thermal expansion affects in a different manner on the gear and the pinion; therefore, the load distribution and the transmission error are no longer symmetrical. Figure 9 shows the influence of temperature gradient between pinion and gear on the load distribution and transmission error.

The asymmetrical behavior of the load distribution and transmission error slightly increases as the temperature gradient rises. Additionally, it is noticed an increase of the overall transmission error while in the double tooth contact region (between points A–B and D–E), transmission error shows an increasing slope. The increase in transmission error is explained by the differences in the profile deviations of the pinion and the gear caused by different temperatures.

**Influence of gear ratio.** Dissimilar gear pairs compose most gear transmissions; therefore, the temperature levels reached in each body are also different. Figure 10 shows the load distribution and the transmission error of a gear pair with a reduction factor of 1.5.

First, the case of no temperature gradient is analyzed (140°C) in order to account for the effects of the gear size. In this case the increase of the temperature produces a larger expansion on the gear than on the pinion, inducing an asymmetrical load distribution. Similar load distribution is observed when identical gears are subjected to thermal gradients, as has been seen in the previous section. If the thermal expansion of the pinion is larger than the gear's, the load distribution decreases in the approach double contact region and is increased in the recess double contact part.

However, when temperature gradients are introduced in a reduction gear unit, the load distribution asymmetry is compensated (Fig.10a). This effect is fully explained with the compensation of pinion and gear thermal expansions. The pinion has a smaller size than the gear, but larger temperature, thus

---

**Figure 9** Influence of temperature gradient between pinion and gear on load distribution and transmission error at $T = 300\text{Nm}$ and $\Theta_1 = 140^\circ \text{C}$.

**Figure 10** Influence of temperature gradient between pinion and gear on load distribution and transmission error at $T = 300\text{Nm}$ and $\Theta_1 = 140^\circ \text{C}$; case of reduction unit.
balancing the difference on thermal expansion and its effects.

Regarding the effects of thermal gradients of reduction transmissions on the transmission error, an increase of the transmission error is observed when the temperature gradients are higher (Fig. 10b). In this case, the decrease of the temperature on the gear increases the backlash while the transmission error increases.

Discussion

From the observation of Figures 6–10, it can be concluded that the most significant phenomena involved in the thermally and mechanically loaded gear behavior with respect to the simply loaded case is the reduction of transmission error; this is due to the available backlash angle decrease and the shift in the load distribution diagram when thermal gradients or relative pitch errors are present. However, in the preceding simulations load has been kept constant while varying temperature and their influence have not been interrelated.

**Combined elastic and thermal deflections.** In general, in cases where there is a differential base pitch increase, the geometry distortion is partially offset by elastic tooth deformations. However, when thermal loading is such that the expansion in the direction of the line of action is larger than the elastic deformation, load distribution can be significantly affected. This situation may affect mean tooth stress level and the position of the maximum value.

Figure 11 shows an example of such a situation. When the pinion drives the gear, the existence of torque reduces the base pitch of the pinion proportionally to the deflection of the loaded pinion tooth, which increases the base pitch of the gear by an amount equal to its deflection. The sum of both deflections determines the load distribution, and therefore tooth stresses. However, when thermal effects are considered, the existence of a temperature differential increases the base pitch of both the pinion and the gear proportionally to the tooth expansion. As a consequence, the load distribution diagram is altered beforehand. If thermally induced deformations are as large as elastic deformations, the load distribution diagram turns symmetrical because both phenomena compensate each other. Figure 11a shows the tooth root stress levels when thermal distortions are larger than elastic deformations, while Figure 11b shows compensated deflections. At 100 Nm the distortion of the bending stress diagram for a temperature difference of 30°C is as large as 30% in the recess, while at 500 Nm it barely represents 5%.

It is interesting to note that in both cases the stress difference between the isothermal case and that with maximum temperature gradient in the recess path of contact is approximately equal. This happens because in both cases the thermally induced pitch error is equal, as it is a function of the temperature gradient and not the torque. Therefore the additional deflection that the gears must overcome in both cases is the same, and the local load difference is almost equal — resulting in the same stress differential.

**Design recommendations for enhanced contact behavior.** In order to compensate the dissimilar root bending stresses (Fig. 11a), profile modifications need to be applied. To this aim, the amount of deviation at the operating temperature is computed and represented (Fig. 12). It is observed that pitch deviations increase proportionally to temperature, while profile slope decreases — both of which are the expected behaviors. For a pinion temperature of 140°C and a gear at 110°C, pitch differentials are 13 μm and 17 μm, respectively and the profile slope decrease corresponds to 27 μm and 20 μm. Therefore pinion and gear are applied to these modifications at ambient temperature to enhance contact behavior at steady-state operating conditions (assuming that the generated heat is not affected and the steady-state bulk temperature is the same).

![Figure 11 Influence of combined thermal and mechanical loads on root stresses at Θ = 140°C.](image1)

Figure 11 Influence of combined thermal and mechanical loads on root stresses at Θ = 140°C.

![Figure 12 Profile deviations as a function of temperature and corresponding modifications.](image2)

Figure 12 Profile deviations as a function of temperature and corresponding modifications.
Figure 13 shows the contact parameter comparison between the reference state at ambient temperature, the thermally distorted one, and the corrected geometry. As can be seen (Fig. 13a), the load distribution has been improved but a significant difference of up to 10% is still present, indicating that profile form errors may not be negligible. On the other hand, it is shown (Fig. 13b) that the initial transmission error levels are recovered with small differences due to the aforementioned form errors.

Conclusions

In this paper the effects of thermally induced geometry distortions on load distribution and transmission error have been analyzed. A thermal-lumped parameter model accounting for radial temperature distribution has been coupled to a two-dimensional finite element model. Analytically predicted temperatures have been loaded on the FEM model to compute geometry distortion, and tooth contact analysis has been carried out. The results show that at high input powers and low oil levels, temperature differences arise between pinion and gear, resulting in pitch errors and profile slope deviations. Such profile distortions affect load distribution — especially at low loads and high temperatures — leading to a non-symmetrical diagram that affects bending stress levels. Transmission error is fundamentally influenced by the backlash angle decrease shifting the mean level towards zero. Profile modifications have been proposed and it has been shown that mechanical and thermal deviations can be predicted and compensated at the manufacturing stage.

For more information.
Questions or comments regarding this paper? Contact Dr. Jon Larrañaga at jlarranaga@mondragon.edu.

References


Dr. Ing. Jon Larrañaga is a professor and researcher at the group of Structural Mechanics and Design in the department of Mechanical and Industrial Production of Mondragon Unibertsitatea since 2011. His main research expertise is in the field of mechanical design, simulation and experimental validation of mechanical components (gears, bearings, spline couplings, ball-screws) regarding performance, durability and/or NVH. Also among his studies was a post-doctoral stay at Deakin University (Australia). He has supervised 2 Ph.D. theses (currently supervising 5 Ph.D. students) and he has published 10 journal papers, 3 patents and more than 30 contributions in national and international conferences. Larrañaga has participated in 35 research projects funded from both industry and public administrations.

Dr. Ing. Ibai Ulacia is a professor and researcher at the group of Structural Mechanics and Design in Mondragon Unibertsitatea since 2009. During his Ph.D. he was a visiting research scholar at the University of Waterloo in Canada and also at HZG in Germany. He is currently coordinating research activities in the field of Mechanical Design (DMLab), focused on the numerical simulation and experimental validation of mechanical components (gears, bearings, spline couplings, ball-screws) regarding performance, durability and/or NVH. He has supervised 9 Ph.D. theses (currently supervising 5) and more than 35 bachelor and master theses. He has published 2 book chapters, 31 journal papers (cited 644 times), 2 patents and more than 70 conference contributions (4 keynote or invited talks). Ulacia has also participated in more than 35 research projects funded by both industry and public administrations.

Aurea Iñurritegi is a research assistant at the group of Structural Mechanics and Design (DMLab) in the department of Mechanical and Industrial Production of Mondragon Unibertsitatea. She holds a double-engineering degree from Mondragon Unibertsitatea in Spain and Ecole Centrale de Nantes in France, as well as a Master in Industrial Engineering from Mondragon Unibertsitatea. She graduated in 2018, with the final master thesis in the multi-body simulation of a bogie gearbox, in ALSTOM. She started her Ph.D. thesis in 2019 in the field of high misalignments spline couplings. Iñurritegi has published 1 conference paper and co-authored 3 more papers.

Dr. Ing. Àitor Arana is a professor and researcher at the group of Structural Mechanics and Design in the department of Mechanical and Industrial Production of Mondragon Unibertsitatea since 2008. He holds a double engineering degree from Mondragon Unibertsitatea in Spain and Ecole Centrale de Nantes in France and a Master of Research on Applied Sciences from the latter. He has recently finished his Ph.D. thesis in the field of thermo-mechanical behavior of gear transmissions, dealing with the influence of thermal distortion on gear geometry and tooth contact. His main research expertise is in the field of mechanical design, tribology and analytical modeling of mechanical components (gears, bearings, spline couplings, ball-screws) regarding performance, durability and/or NVH. Arana has published 3 journal papers, 2 patents and 17 conference contributions, and has participated in 16 research projects funded by industry and public administrations.

Jon German is a research assistant at the group of Structural Mechanics and Design (DMLab) in the department of Mechanical and Industrial Production of Mondragon Unibertsitatea. He holds a Degree in Mechanical Engineering from Mondragon Unibertsitatea. He graduated in 2018, with the final undergraduate thesis in the numerical-experimental correlation of the thermomechanical behavior in spur gears. He started a Master in Industrial Engineering from Mondragon Unibertsitatea in 2019, and has co-authored 1 paper.

Julen Elizegi is a research assistant at the group of Structural Mechanics and Design (DMLab) in the department of Mechanical and Industrial Production of Mondragon Unibertsitatea. He holds a Master in Industrial Engineering from Mondragon Unibertsitatea. He graduated in 2017, with the final master thesis in the optimization of a crane gearbox. He started his Ph.D. thesis in 2018 in the field of fatigue failures in gears. He has published 1 conference paper and co-authored 2 more papers.
**Design Parameters for Spline Connections**

Dr. Hermann J. Stadtfeld

**Introduction**

Splines are machine elements that connect a shaft with a rotor. Next to transmitting torque, the spline might also be utilized to center the rotor to the shaft. It is interesting that the spline’s tooth profiles are involutes, although the involute profile does not contribute to the torque transmission, nor is it linked to the centering function. The reason for the involute profile is the fact that most external splines are manufactured by hobbing with a standard straight-sided, symmetric hob tooth profile that is fast and delivers good accuracy results. The internal spline has to be manufactured with shaping or broaching, using an involute cutting tooth profile. The nomenclature and parameters of a typical spline connection are presented (Fig. 1). The spline connection in Figure 1 is neither centering on the flanks nor on its major or minor diameters.

The exception to the involute profiles is the parallel straight profile spline that requires a planning operation for the external member and a single tooth shaping or broaching of the internal member. Splines can be organized into 2 main categories and 4 sub-categories that are defined by national and international standards; an overview is given (Fig. 2).

Studying the literature teaches that many large OEM’s pick the design proposals, the tolerances and function features for one particular spline design from several standards. Here it will be proposed to use metric units for all calculations, applying the addendum/dedendum recommendation by DIN and following the ANSI guideline for side fit and major diameter fit. In order to eliminate the confusion that the design by picking dimensions and tolerances from different standards might cause, the following sections present a firm guideline for each step of the design, tolerancing and cutting tool definition.

**The Different Spline Functions and the Required Fits**

If a splined shaft that is, for example, the output of a transmission drive with a rotor that is mounted on its own bearings, then the function of the spline is not the centering of the rotor but merely torque transmission. In this case, a centering function would just cause the transfer of misalignment and runout between shaft and rotor, which leads to vibration and bearing wear. The described connection should have backlash between the flanks and clearance between the top of the internal and external teeth and their adjacent roots, and use a profile fit with backlash (Fig. 3).

If a splined shaft is connected with the internal spline, for example — at the output of a transmission — and if the shaft is long in relation to its diameter, then a flank-centered fit as shown (Fig. 4) is preferred. In order for correct flank centering, the backlash between the internal spline teeth and the shaft spline teeth must be zero. To achieve such a transitional fit, the tolerances according to ISO 7H (shaft spline) and 7n (internal spline) are recommended.

In a case where a rotor like a sprocket is radially centered by the spline connection, then major diameter transition fit (or interference fit) according to ISO (outside shaft diameter tolerance H7 and major internal diameter tolerance n7 (or H7/p7 for a press fit) can be used (Fig. 5). The profiles can be made with backlash or as transition or interference fit (see tolerance recommendations in connection with Figs. 3 and 4). The decision regarding the flank fit depends on the operation schedule.
<table>
<thead>
<tr>
<th>Involute Splines with Pressure Angle</th>
<th>Spline Categories</th>
<th>Parallel Straight Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha = 30^\circ, 37.5^\circ, 45^\circ )</td>
<td>( \alpha = 30^\circ, 37.5^\circ, 45^\circ )</td>
<td>( \alpha = 20^\circ, 30^\circ, 37.5^\circ, 45^\circ )</td>
</tr>
<tr>
<td>Addendum Formula see Standard</td>
<td>Addendum = 0.45-m Dedendum = 0.55-m Broaching Dedendum = 0.60-m Hobbing</td>
<td>Addendum and Dedendum Definition lean towards DIN &amp; ISO</td>
</tr>
<tr>
<td>Min space width equal max tooth thickness, in case of interference fit increase internal spline tooth thickness</td>
<td>ISO “H” tolerance for external shaft diameter. For internal major diameter use “a to h” for clearance fit, use “h to p” for a gentle fit and “p to z” for press fit</td>
<td>Regarding fit lean towards DIN &amp; ISO</td>
</tr>
</tbody>
</table>

Root fillet radii with either profile side fit or backlash and always clearance at the major and minor diameter

Flat root with sharp fillet corners with major diameter fit, backlash and clearance at minor diameter (DIN-ISO also covers a minor diameter fit)

Flat root with sharp fillet corners with either profile side fit or backlash and always clearance at major and minor diameter

Figure 2  Overview of different spline categories [1 through 7].

Figure 3  Not centering connection.

Figure 4  Flank centered connection.
The parallel straight-sided spline has straight-sided teeth on the spline shaft and straight-sided slots on the internal spine. To calculate addendum and dedendum, the formulas either from the ANSI or the ISO standard can be used. In a metric calculation like that shown before, the ISO tolerance recommendations are appropriate for diameters and tooth thickness versus slot width. An example for a straight-sided spline is shown (Fig. 6).

The effective pressure angle can be calculated from the triangle in Figure 6, using the reference diameter as hypotenuse and the tooth thickness as the opposite side. The straight-sided spline according to AGMA has checks at the root fillets (Fig. 6). There is no particular preference in the standards regarding diameter fit or flank fit. Also, for the parallel-sided spline it is common to either use a major diameter fit with clearance on the flanks or a major diameter fit with a gentle fit or press fit on the flanks. Flank fit without major diameter fit is uncommon because a radial misalignment due to a press fit is more likely than is the case of splines with non-parallel flanks.

**Defining Spline Dimensions**

The example spline (Fig. 7) transmits the torque of a sprocket to the splined shaft (or vice versa) and centers the sprocket radially. The example sprocket spline has metric dimensions. Although it is proposed in this article to use metric dimensions for all calculations, later, for the search of a suitable standard hob, the module can be converted into diametral pitch in order to find the closest hob — either in the metric or in the imperial system.

The tooth depth is calculated using the difference between major and minor diameter divided by two:

\[
\text{Depth} = \frac{d_{\text{major}} - d_{\text{minor}}}{2} = 2 \text{ mm}
\]

The tooth proportions addendum and dedendum relate the depth to the still-unknown module:

\[
\text{Depth} = h_K + h_F = 0.45\cdot m + 0.60\cdot m
\]

This relationship allows to calculate a module of:

\[
m = \text{Depth}/1.05 = 1.905
\]

With the known module it is now possible to calculate addendum and dedendum:

- Reference addendum: \( h_K = 0.45\cdot m = 0.857 \text{ mm} \)
- Reference dedendum: \( h_F = 0.60\cdot m = 1.143 \text{ mm} \)

Both dimensions, \( h_K \) and \( h_F \), are reference values that split the tooth depth into the reference addendum and the reference dedendum. This means that neither of the values is related to the pitch circle. The pitch diameter is calculated like for a standard spur gear by multiplying the module with the number of teeth:

\[
d_0 = m\cdot z = 22.857 \text{ mm}
\]

It can be recognized that the pitch diameter is smaller than the minor diameter of the spline. Because the spline is not a meshing gear member, there is no working pitch diameter and the meaning of the pitch diameter is primarily important for the choice of the hob cutter and/or the broach. However, it is
meaningful to calculate a reference diameter that separates the reference addendum and the reference dedendum:

\[ d_{\text{Ref}} = d_{\text{Minor}} + 2 \times h_F = 26.286 \text{ mm} \]

The difference between the pitch diameter and the reference diameter can now be used to calculate the profile shift, which is:

\[ x \times m = (d_0 - d_{\text{Ref}})/2 \]

or:

\[ x = (d_0 - d_{\text{Ref}})/(2 \times m) = -0.9 \]

The initially calculated module of 1.905 mm will not allow utilizing a standard broach for the internal sprocket spline. If the module is now rounded to a number from the DIN/ISO table of preferred modules, then the rounding to 2.0 mm is proposed.

Rounded module: \( m_{\text{final}} = 2.0 \text{ mm} \)

This module rounding is without any tangible consequence if the spline shaft, as well as the sprocket spline, are together in the design and manufacturing planning stage. If the sprocket design is done for an aftermarket purpose, and has to fit on an OEM shaft spline, then the working pressure angle at the reference diameter might show some mismatch. In the present case the rounding was only small and pressure angle mismatch will be within an acceptable tolerance.

With the new, rounded module the previously calculated addendum and dedendum values have to be preserved. However, the original factors for the calculation of addendum and dedendum (\( h_K = 0.45 \times m \) and \( h_F = 0.60 \times m \)) have changed by the module rounding. This fact is not relevant, because the \( mm \)-value of the sum of addendum and dedendum remain the same, as well as the top-root clearance.

After the module rounding, the pitch diameter and the profile shift factor have to be recalculated:

\[ d_{\text{final}} = m_{\text{final}} \times z = 24.00 \text{ mm} \]

\[ x_{\text{final}} \times m_{\text{final}} = (d_{\text{final}} - d_{\text{Ref}})/2 \]

\[ x_{\text{final}} = x_{\text{Internal}} = (d_{\text{final}} - d_{\text{Ref}})/(2 \times m_{\text{final}}) = -0.572 \]

The spline set always has a V0 profile shift relation which means:

\[ x_{\text{Internal}} + x_{\text{External}} = 0 \]

and

\[ x_{\text{External}} = -x_{\text{Internal}} = +0.572 \]

Defining the Spline Pressure Angle

If the splines are being designed, then one of the preferred pressure angles from the standards should be used. ANSI and DIN offer the choice between 30°, 37.5° and 45°. In the JIS standard also a pressure angle of 20° is proposed.

If the spline is designed for an aftermarket product (for example the sprocket shown Fig. 7), then a simple measurement — preferably on a CMM or with a Vernier caliper as shown (Fig. 8) — can be conducted to obtain a first pressure angle estimation. If the aftermarket product is the sprocket (not the shaft), then it would be desirable to obtain the measurement explained in Figure 8 on the spline shaft.

The measurement results are used together with the depth of the spline tooth to calculate the approximated pressure angle:

\[ \alpha_{\text{approx}} = \arctan\left[2 \times \text{Depth}/(t_1 - t_2)\right] \]

For the example in Figures 6 and 7 with a topland \( t_2 = 2.60 \text{ mm} \), a root width \( t_1 = 7.30 \text{ mm} \), and a depth of 2.0 mm the
approximated pressure angle is:
\[ \alpha_{\text{approx}} = \arctan\left[2.0 / (7.30 - 2.60)\right] = 40.39^\circ \]

The approximated angle is between the preferred angle 37.5° and 45° from the standards. The difference from 45° is 4.61° and the difference from 37.5° is only 2.89°. The decision therefore is 37.5°.

\[ \alpha_{\text{external}} = \alpha_{\text{internal}} = 37.5° \]

37.5° is a popular pressure angle for splines, which also indicates that the result of measurement and calculation is realistic. It is recommended that the major diameter of the sprocket is equal to the outside diameter of the spline shaft to assure a major diameter fit. If the sprocket is the transmission output of a unidirectional unit, then the flanks can receive a small backlash (e.g. — sprocket spline tooth thickness tolerance ISO 7H and shaft spline tooth thickness tolerance 7f). If sprocket and spline have to transmit torque in frequently changing directions, then a transition fit or a press fit of the spline teeth is recommended (sprocket ISO 7H, shaft ISO 7n).

The tolerance of the major diameter of the internal spline should be selected as a transition fit; for example, ISO H7 (the outside diameter of the spline shaft should be ISO j7).

**Defining Tool and Cutting Parameters**

The tool for the spline shaft can be a standard ISO spline hob cutter module 2.0 with a pressure angle of 37.5° and sharp corners at the hob teeth. Due to the profile shift of \( x_{\text{external}} = +0.572 \), the hob cutter must be retracted from the theoretical position by \( x_{\text{external}} \times m = 1.144 \) mm away from the shaft.

The tool for the internal spline can be a standard ISO spline shaper cutter, for example, with 8 teeth. The center distance between shaper cutter and internal spline is:

Center Distance: \[ d_0 = 2 - x_{\text{m}} - dx_{\text{external}} / 2 \]

A profile shift of the shaper cutter \( x \) might be required with the low number of cutter teeth, and is therefore considered in the center distance formula.

**Summary**

This article provides a guideline for the selection of a suitable standard in connection with the kind of spline to be designed and manufactured. Some basic formulae have been explained, together with a strategy on how to find standard tooling by calculating an appropriate profile shift factor for the spline to be designed. If an aftermarket part like a sprocket should be matched to an existing spline shaft, then the dimensions of major and minor diameter can be found on the shaft. Addendum and dedendum have to consider the recommended top root clearance (on the not-centering top root combination). If those facts are all taken into consideration, then it is not important to know if the mating, existing shaft was manufactured with an English standard hob and the sprocket is manufactured with a metric standard hob; this is as long as both members use the appropriate profile shift, which will assure that the reference diameters of shaft and internal spline are identical. Also, a simple method for determining the pressure angle of an existing spline has been presented. The result was compared to the ANSI and ISO table of recommended spline pressure angles which allowed a mature choice of the closest value.

The final section of the article aids in the selection of a hob cutter for the shaft and a shaper cutter for the internal spline. For the correct setup of the manufacturing machine the calculation of the center distances between work and tool was presented.

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

---

**References**


---

**Dr. Hermann J. Stadtfeld** is the Vice President of Bevel Gear References 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 2006 as Vice President R&D he received 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.
A Precise Prediction of the Tooth Root Stresses for Involute External Gears with Any Fillet Geometry under Consideration of the Exact Meshing Condition

Tobias Paucker, Michael Otto and Karsten Stahl

Introduction
An efficient design with high power density characterizes a modern transmission, which leads, in many ways, to optimized constructions. Reaching a high utilization of material strength requires an exact prediction of occurring stress under given load carrying capacity to guarantee sufficient endurance.

Practically applied standardized methods to evaluate the load carrying capacity (AGMA 2101 (Ref. 1), DIN 3990 (Ref. 3), ISO 6336 (Ref. 4)) contain formulas to calculate the tooth root stress of standard profiles. At the same time, optimized profiles are designed that use more and more reserves of load carrying capacity (e.g. — optimized fillets, special tooth profile). Widely available FEM-calculations provide precise stress results, but are still laborious to apply for tooth contact analysis. Detailed, but fast and easy to use calculation methods are necessary to evaluate different types of tooth profiles in consideration of freely designed fillets. In addition, a more detailed analysis of standard tooth root profiles is required to increase power density. Also in many cases, expecting the maximum load and critical root stress at the tangent point of 30° (DIN3990 (Ref.3), ISO 6336 Ref.4)) or the Lewis-Parabola (AGMA (Ref. 1) is not always right (Ref. 2.)

This paper shows a method to calculate the occurring tooth root stress for involute, external gears with any form of fillets very precisely within a few seconds. The following parameter variation uses a 2-D boundary element model to receive the notch stresses of the fillets. These calculated stresses are linked to a high-quality analytical tooth contact analysis to consider the exact relations of the gear mesh. This algorithm is implemented in the FVA software RIKOR (Refs. 5–6). The introduced model also allows a calculation of the occurring tension and compression stresses along the whole fillet for different mesh positions.

Calculation Method
The following section describes the calculation method that extends the standardized method of ISO 6336 (Ref.4).

Declaration of supporting points. Initially, a declaration of the supporting points of the tooth flank and the field of action is necessary to describe the calculation method.

Figure 1 shows a definition of these supporting points for the plain normal section, and the plain longitudinal view of the tooth flank — including the root.

To illustrate the form of the fillet, it is most suitable to use a normal section of the tooth. For a spur gear, the normal and transverse sections are the same, located in a plane. But the normal section of a helical is curved in a 3-D area. To represent the actual fillet form precisely, a plain normal section is used. For later valuation, the plain normal section of the contour is indexed with a number of supporting points \( k \) (amount \( = n_{ppt} \)). At every point \( k \) of the contour, it is possible to define a number of supporting points \( l \) (amount \( = n_{dpt} \)) in normal direction to the inside of the gear material. For the analytical model, the tooth width is discretized in a number of supporting points \( i \) (amount \( = n_{tpt} \)). The mesh width is also discretized in a certain amount of supporting points \( j \) (amount \( = n_{mpt} \)), as it is not always the same size as the tooth width.

Figure 1 also shows the definition of a local coordinate system \((x,y,z)\).

Influence function \( \beta_5 \) of tooth root bending moment. To consider the tooth width and the bending lever, which varies in its longitudinal direction for helical gears, an influence function \( \beta_5 \) is introduced that is based on investigations of Umezawa (Ref. 8).

This function describes the impact of a local tooth force at \( j \) to the bending moment, which occurs in \( i \) (compare to Eq.1).
When solving this function for a certain amount of supporting points and combining it with the local bending lever, a precise analytical calculation of the local bending moment (helical gears) is given.

\[
\beta_{F_i,j} = \left( e^{-0.5 \left( \frac{(z-p_i)}{\sigma_i \beta_F} \right)^2} \right) \left( \frac{h_j}{h_F} \right) + S_{i,j} + S_{h,j}
\]

**Tooth root bending moment** \( M_i \). While solving the influence function \( \beta_F \) for every discretized load on the contact line, the local tooth root bending moment \( M_i \) can be solved at every supporting point \( i \) (compare to Eq. 2). The local bending lever \( h_j \) is referenced to the boundary point of the 30°-tangent and the fillet. This method also allows the consideration of the exact load distribution.

\[
M_i = \sum_{j=1}^{n_{MPT}} \beta_{F_i,j} \cdot h_j \cdot p_j
\]

**Local stress correction factor** \( Y_{S,j,k,l} \). To allow the calculation of local stress correction factors for any fillet forms, it is convenient to use a numerical method. A 2-D numerical method is adequate to fulfill this requirement, while it also calculates very fast. Within this paper, a 2-D boundary element method (BEM) is used (Ref. 5).

The local stress correction factor \( Y_{S,j,k,l} \) calculates for every location of the acting force \( j \), along the fillet \( k \), and also in normal direction to the inside of the gear \( l \) (surface tension also possible). It correlates to the quotient of a local tooth root stress at the investigated location and the reference bending stress at the equivalent beam (bending lever of acting force to the 30°-tangent) (compare to Eq. 4).

This reference is necessary for this calculation method, but does not influence the calculation accuracy. A reference to every other tangent is possible as only the distribution between local stress correction factor and root bending moment would change, while their product would stay the same. The reference of the local stress correction factor is a certain load acting point \( j \). Therefore, the stress-increasing effect of the fillet is constant along the mesh width for a certain load acting position.

\[
Y_{S,j,k,l} = \frac{\sigma_{S,j,k,l}}{\sigma_{S,ref}}
\]

**Figure 2** Illustration of the influence function \( \beta_F \), local bending lever \( h_j \), and a certain load distribution \( p_j \).
Local tooth root stress $\sigma_{i,k,l}$. With exchanging the standardized stress correction factor with the local and numerical determined stress correction factor, it is possible to calculate a local tooth root stress at any location of the fillet (Eq. 5). This method also allows the prediction of the location of the highest occurring root stresses. With the requirement of very low calculation time, it would also be convenient to use this algorithm for optimizations. Within this paper it is used to compare the results to the standardized approach of ISO 6336 (Ref. 4).

$$\sigma_{i,k,l} = \frac{1}{W_b} \cdot \sum_{j=1}^{nMPT} \beta_{Fj} \cdot h_{Fj} \cdot p_{Fj} \cdot Y_{Sj,k,l}$$

Equation 5: Calculation of the local tooth root stress $\sigma_{i,k,l}$ at supporting point $i$, profile point $k$ and depth point $l$ with the exact load distribution $p_{Fj}$ and the local stress correction factor $Y_{Sj,k,l}$

Parameter Variation and Results
The calculation method, introduced above, allows doing extensive parameter variations and studies and comparing the results to, e.g., standardized methods. In the following, a parameter study is shown, which investigates different trochoid fillet geometries and compares them to the corresponding results of ISO 6336 (Ref. 4). The variations are made with very stiff shafts and bearings, as the influence of these machine elements are not in focus for these calculations. The influence of the mesh stiffness is considered for these calculations.

Varied parameters. There are different possibilities to change the fillet geometry. The presented calculation study shows a variation of the profile shift $x$ ($-1 \leq x \leq 1$) and the tooth height $h_x$ (influences contact ratio $-1 \leq \varepsilon_x \leq 1$). A different tooth height leads to changing contact ratio and, therefore, a variation of the critical contact line that is responsible for the maximum tooth root stress. The sum of profile shift is zero for every case to keep
the same center distance. The plane normal sections of the different investigated tooth contours are shown (Fig. 3), while the focus of the calculations lies on the pinion (\(z = 42\)).

Table 1 shows the 3-D model with the geometrical data of the gears, and Table 2 shows the tool data for gear 1 of this model.

**Influence of the contact ratio.** Figure 4 shows the relation of the maximum tooth root stress according to ISO 6336 (Ref. 4) to the maximum tooth root stress according to Equation 5. A result above one means that the calculation according to ISO 6336 (Ref. 4) gives higher results as the local method of this paper. A main result is that for increasing contact ratios, the standardized method calculates very safely. Schinagl (Ref. 7) investigates the influences of the profile and contact ratio within his dissertation, while his results support this consideration.

**Location of maximum tooth root bending stress.** The method also allows an investigation of the location of the maximum occurring stress. The reference stress of the corresponding beam is at the 30°-tangent. Figure 5 shows the location (in ° of the tangent) of the maximum tooth root stress, depending on the profile shift and the contact ratio (critical contact line). With an increasing profile shift, the radius of the fillet decreases. The critical tension stress gets shifted nearer to the center of the tooth root fillet, which may lead to a more critical alternating load.

**Further Calculation Possibilities**
The discussed geometries of the variation are focusing on trochoid fillet geometries. Of course, the numerical method is not restricted to certain root geometries. Therefore, there are different calculations imaginable that are introduced in the following section. The pros and cons of each fillet geometry — especially of optimized forms — are not discussed.

**Calculation of grinding notches.** For case hardened gears, it is common to manufacture them with a certain amount of protuberance and finish the gears with a grinding process after hardening. An unfavorable behavior can be the occurrence of grinding notches. To evaluate these fillets forms there are different approaches, such as the investigations of grinding notches by Wirth (Ref. 9). To determine an exact or even measured contour, the approaches, which only describe the notches or protuberances analytically, are not promising. More productive is an investigation of the exact fillet form with numerical methods. Figure 6 shows a nominal contour compared to one with a grinding notch. An important point is to be able to evaluate these kinds of manufacturing deviations and to be able to react in an adequate amount of time without having to run extensive tests. Figure 8 shows a calculation of a gear with a grinding notch (normal section of the contour and tangential stresses); the 3-D illustration is shown for one tooth within Figure 9.
Calculation of asymmetric root geometries. The critical tooth root stress according to DIN 3990 (Ref. 3) and ISO 6336 (Ref. 4) is represented as a tension at the side of the acting load. Therefore, it is possible to reduce the radius of the tooth root at the compression side in order to allow a wider radius at the side of the tension. An example of such an asymmetric root contour is shown (Fig. 7). To evaluate this sort of optimization it is possible to use the introduced algorithm. The distribution of the root stresses can be seen (Fig. 10) for a load acting at both sides.

Conclusion
This paper introduces an algorithm to calculate precisely and quickly the local tooth root stress for involute external gears with any fillet geometry, and under consideration of the exact meshing condition. The formulas for this method and an extensive variation are introduced that show deviations between the simpler standardized approach and the presented local approach. A main result is that the standardized method according to ISO 6336 (Ref. 4) calculates the occurring maximum tension stress very safely for high contact ratios. By using this method the material utilization can be increased by up to 50%. The location of the maximum tooth stress deviates significantly for different profile shifts. Furthermore, examples of calculations for any root geometries are shown. On the one hand, with optimized fillet forms it is possible to decrease the occurring stresses up to 30%. On the other hand, an evaluation of manufacturing deviations is possible without test runs. All examples are calculated without the influences of shafts and bearings, which would lead to more unequal load sharing.

Future investigations should also cover these influences, as an unequal load sharing does not lead to an unequal stress distribution within the same amount. In addition, the introduced algorithm is suitable for root optimizations with any fillet geometry. To discuss and exercise this fact, further investigations are necessary.

For more information. Questions or comments regarding this paper? Contact Tobias Paucker at paucker@fzg.mw.tum.de.

References

Tobias Paucker works as a Research Associate at the Gear Research Centre (FZG) at the Technical University of Munich.

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

Prof. Dr. Karsten Stahl is Chair, Machine Elements, Mechanical Engineering, at TUM. He leads and conducts research in the area of mechanical drive systems, with particular interest in investigating the load capacity, efficiency and dynamics of all gears types. His other areas of interest include applications in automotive engineering such as synchronization systems and multi-disc clutches. Stahl has developed methods for analysis that have been incorporated into international standards, together with the component strength values derived by means of these methods. He studied mechanical engineering at TUM and performed his doctoral studies from 1994 to 2000 in the Machine Elements Department. In 2001, he joined BMW as a development engineer, then as the manager of gear development in Dingolfing. In 2006 he transferred to the MINI plant in Oxford where he was initially quality manager for transmissions, then quality manager for powertrains and suspensions. In 2009 he took over responsibility for the initial development and innovation management of powertrain and vehicle dynamics systems at BMW in Munich. Stahl has been a full professor in the Machine Elements Department since 2011.
Octave LaBath
1941–2019

Octave LaBath, 77, of Blue Ash, Ohio, and former vice president of engineering at Cincinnati Gearing Systems Inc., died Thursday, August 8, 2019. LaBath was an active AGMA member, a member of ASME and president of Gear Consulting Services. He held a patent of a gearbox in wind turbines and worked on the LCAC for the U.S. Navy.

LaBath was active on nine AGMA technical committees at various points since the 1970s. He was the Chairman of the ISO TC 60, a member of the Technical Division Executive Committee (TDEC) and received the TDEC Award in 1982, Chairman of AGMA’s Epicyclic Enclosed Drives Committee — where he led the completion of ANSI/AGMA 6123, Design Manual for Epicyclic Gear Drives — and published three papers through AGMA (AGMA 209.12, AGMA 209.15, and 02FTM10).

“We are saddened to hear about Octave as he was a great engineer that did so much for AGMA and the gear industry,” said Amir Aboutaleb, vice president, technical division, AGMA. “He was a true steward for the development of standards and welcoming all who wanted to be a part of the process. His technical expertise, kind demeanor and willingness to include all committee members will be remembered.”

Many members of AGMA attribute their participation in technical committees to LaBath, whom encouraged them to get involved.

“Octave was one of the rare individuals in the gear industry who always took the time to recognize new committee members and their contributions to standards development,” said Frank Uherek, principal engineer, Rexnord Gear Group. “He explained the background of the myriad of “rules of thumb” that gear engineers use to produce their designs.

LaBath was not only an important member of the AGMA technical committees but he really stood out as a leader amongst his peers, including those he worked with.

“Octave was a true gear engineer with an exceptional personality,” said Tom Miller, chief engineer, Cincinnati Gearing Systems Inc. “He loved gears and gearboxes and even in retirement was always eager to teach or learn more about gears. There will never be another Octave; he will be greatly missed.”

LaBath attended the University of Cincinnati in the College of Engineering. After his freshman year in 1960, he started a co-op job with the Cincinnati Gear Company. His first work section was in the shop as a machinist assistant setting up and producing pump gear blanks on an Acme Gridley four-bar feed machine. He learned to use micrometers to measure the outside diameters and face widths, depth mics to measure the hub lengths, and bore gages to measure the size in the bore.

His next job was assisting in setting up and manufacturing bevel gear blanks on a Cleveland automatic screw machine. Here, they made the blanks from a single bar stock fed automatically into the screw machine. He learned how to measure the face and back angles on the blanks.

LaBath worked in various shop departments — cut off saws; turning; hobbing; shaping; shaving; burring; shaft grinding; bore grinding; milling machine; and inspection.

Two years into his job at Cincinnati Gearing Systems, LaBath went into the office as an assistant to the vice president of engineering. He calculated the set-up for the gear inspection machines using a Friden mechanical calculator. He used mathematical tables in an Illinois Tool small booklet for the trigonometric and involute functions.

During his final year of co-op work, LaBath designed a gearbox that reduced the speed of a hydraulic motor that used pump gears in the motor. This included designing the housing, selecting the bearings and seals, and testing the assembly. The unit was a vertical design with splash lubrication.

While at UC, LaBath joined the student section of ASME. He ended up being a 40-year lifetime member of ASME. He graduated with a BSME degree in 1964 and joined Cincinnati Gear full-time as a project engineer. At the urging of a colleague, he decided to continue his education at night school. In fact, when he took an advanced machine design class, the teacher actually had LaBath and other students teach the section on gear design.

It was in the master’s program that LaBath was introduced to computers. His work included the design, assembly, and testing of the various designs. He retired from the Cincinnati Gear Company in 2001 as — ironically enough — vice president of engineering. Learn more about Octave LaBath here:

Mahr
OPENS CUSTOMER CENTER IN WIXOM, MICHIGAN
MATTHEW JASTER, SENIOR EDITOR

Mahr Inc., a global manufacturer of precision measurement equipment and solutions, recently celebrated the grand opening of its new Midwest Regional Customer Center. Located in the Detroit area in Wixom, MI, the facility features an extensive demonstration area, fully equipped with the very latest machines, systems and precision gages from the Mahr portfolio. Furthermore, the site has been specified to provide training and conference spaces, together with office spaces for the Mahr team.

"It’s been a fantastic team effort to get this off the ground," said Brett Green, CEO and president, Mahr Inc. during the ribbon-cutting ceremony. "A lot of people here and in the wider Mahr world have come together on this project and we’re delighted to have everything ready and on display so our customers can bring their measurement challenges here and let Mahr help solve their problems."

"The grand opening was a great opportunity for me to come by and celebrate with our Mahr family. The state of Michigan has a very long and proud history of manufacturing. In a recent article in Global Trade Magazine, Michigan was ranked as one of the top ten states for tech-driven manufacturing. It’s my great pleasure to declare Mahr’s Detroit-area Customer Center in Wixom officially open," said Carl Mahr, member of the Mahr family and supervisory board.

According to Pat Nugent, vice president of product management at Mahr, Wixom was chosen as the location for Mahr’s second Midwest customer center because it’s in the heart of the automotive manufacturing industry and is a key area of focus for Mahr’s business.

"Mahr’s strategy for the Americas is to bring its expertise closer to customers, so a local presence in this automotive and manufacturing industry hotspot is important to grow the Mahr brand in Michigan and beyond. Furthermore, the location in Alpha Tech Park specifically is ideal because of its easy access off the interstate," Nugent said.

Given the prevalence of gears in automotive manufacturing, Mahr expects gear metrology to be an important area of focus at the Wixom facility.

“As surface finish on gears is becoming increasingly important, the Wixom facility currently includes a dedicated and automated gear surface finish machine. A gear can be placed on this machine and the user simply inputs its basic parameters, and the tool will automatically measure the gear’s surface finish. Furthermore, there are numerous hand tools currently at our Wixom facility that are used in gear measurement.”

Nugent said that the MarShaft SCOPE 600 plus 3-D, an optical and tactile shaft measuring machine for gears and camshafts, should be in Wixom soon and they expect the GMX universal gear measuring machine to be available in the future as well.

“The MarShaft SCOPE, GMX universal gear measuring machine and surface measurement machine are all made to measure a gear simply by inputting the parameters into the software, and then it automatically calculates how it has to move around to get around the gear and in between the teeth and make all the measurements — they are all very easy to operate.

We ultimately expect all products to be represented in the Wixom facility,” Nugent added.

Gear inspection training and education at this facility will be a key area of focus.

“We’ve built a dedicated training facility adjacent to the product demo room to provide training for all products. It was designed this way so that any product can be moved into the training room very easily, at any time," Nugent said. “Additionally, we expect to offer our full suite of Mahr Academy classes at Wixom. We began conducting MarSurf and MarForm classes this year, and MarGear is coming next year. (www.mahr.com)

Adam Gimpert
DISCUSSES HELIOS NAME CHANGE

Helios Gear Products Business Manager Adam Gimpert recently discussed the name-change from Koepfer America to Helios in an industry Q&A:

Q: Helios is a new name in the gear manufacturing industry. What do you do?
A: The name is relatively new, but our company has supplied machines and tools to the industry for over 30 years as Koepfer America. As of January 1, 2019, our name changed to Helios Gear Products.

Q: What spurred the name change?
A: The confluence of three forces convinced us it was the right time for a name-change. Firstly, our company has grown to offer manufacturers several solutions for machines and tools. We directly represent several OEMs (original equipment manufacturers), including ourselves, and many consumable tool OEMs. A neutral brand like “Helios” allows us to more equally
represent all our partner OEMs.
Secondly, in 2018, our key OEM partner announced a new hobbing solution well suited for the direct and Tier 1 automotive sectors. We have structured our company to serve job shops and similar small manufacturing operations, so the alignment between our group and this new hobbing machine required an evolution of our organization.

Lastly and thirdly, YG Tech, OEM of the Hera line of gear hobbing equipment, needed new representatives in North America. After visiting the YG Tech factory and vetting their machine tool solutions, we knew that working together would bring a great hobbing solution to market. With the Hera line, we can now offer gear manufacturers three empowering forces: affordability, quality, and from-stock delivery—all with our proven, reliable technical assistance.

Q: Does this mean that Koeper is gone?
A: “Koeper” is owned by the EMAG Group, and here in the United States, Helios Gear Products will continue to be the technical service provider for legacy Koeper equipment, which includes models such as 300, 200, 160, 180, 173, 153, and others. We proudly continue to serve our existing Koeper customers with our proven technical support and new affordable technologies.

Q: For technical assistance on Koeper equipment, should customers contact Helios?
A: Absolutely! We are EMAG Koeper GmbH’s technical service partner for all “K-type” machinery. In simple terms, if the machine is a Koeper Model 300, 200, 160, 180, 173, 153, or similar, Helios is the go-to company for technical assistance and domestically stocked parts.

Q: Why is Helios and YG Tech such a great combination?
A: The Hera machines from YG Tech offer world-class technology, such as Fanuc CNC, direct-drive torque motors, hardened and ground linear rails, and unified automation systems that our existing customers will expect and find familiar. YG Tech is a multi-generational family-owned business echoed by today’s leadership at Helios, and YG Tech has built gear machines since 1963 and other machine tools since the early 20th century. With Helios’s expertise and reputation in the North American gear manufacturing industry, the Helios Hera line offers manufacturers a new, affordable, high-quality, high-technology, reliable option for gear hobbing in the 21st century.

Q: What does “Helios” mean?
A: For our team, Helios means equipping manufacturers with machines and tools to make profitable gears. For others, Helios is the god of the sun in Greek mythology, We liked the sun symbolism, and “Helios” is not tied to any one brand that we represent. We strive to “shed light” on the path to profitable production for gear manufacturers, so they can compete in the global arena.

Q: What are Helios’s main product offerings?
A: Machines and tools for gear manufacturers: We supply hobbing equipment for gears up to about 30 inches in diameter, and on the other end, we have hobbing equipment that comfortably handles gears smaller than a baby’s little finger. Our deburring and chamfering machines are a growing segment of our products, and we also supply abrasive tools for generating grinding, form grinding, bevel gear grinding, and more. Cutting tools, of course, are an important part of our offerings: carbide and HSS hobs, milling cutters, and shaper cutters. Lastly, manufacturers also rely on us for hob sharpening and contract inspection work.

Depending on the hobbing solution required, our hobbing machines are built by ourselves, Monnier + Zahner, or YG Tech, and our deburring and chamfering machines are built by Tecnomacchine.

Q: Will Helios continue to offer used equipment?
A: We certainly will continue to offer cost-conscious solutions. Manufacturers looking for budget-friendly machines should consider our used and re-controlled (“K-Repowered”) options, which we offer with warranties and backed by our Helios technical support. Our stock is always changing, so manufacturers should give us a call or visit our website for the latest.

Q: Is there anything else you’d like to add about the future of Helios?
A: We continue to work on being a leading supplier of gear manufacturing solutions. Part of that effort is our sales partnership with Kapp Technologies of Boulder, CO. Combined, our engineers and sales teams offer manufacturers a new, affordable, high-quality resource for hobbing, grinding, deburring, and inspection solutions. Manufacturers know that working with either Helios or Kapp will open doors for productive and profitable gear manufacturing for the future. (www.heliosgearproducts.com)
**October 16–23—K 2019** Düsseldorf Exhibition Center, Düsseldorf, Germany. Over 3,000 exhibitors from 60 nations will be on-hand at this trade fair for plastics and rubber. Four topics have been chosen for K 2019 by the academics and experts from the K 2019 Innovation Group: Plastics for Sustainable Development & Circular Economy, Digitization and the Plastics Industry 4.0, System Integration: Functionality through Material, Process and Design, and Young Talents in the Industry. K 2019 is the performance barometer for the entire industry and its global marketplace for innovations. For eight days, the “Who’s Who” of the entire plastics and rubber world will meet here to demonstrate the industry’s capabilities, discuss current trends and set the course for the future. For more information, visit www.k-online.com.

**October 22–24—SouthTec 2019** TD Convention Center, Greenville, S.C. South-Tec draws manufacturing suppliers, distributors and equipment builders from across North America and around the world—bringing them together in Greenville, South Carolina. With hundreds of exhibiting companies, attendees can find all the latest technologies and services—plus the experts who build them—ready to demonstrate solutions that can help them grow their business. Visitors can make side-by-side comparisons, discover integrated equipment, hear about industry trends and forecasts, and leverage their purchasing power. For more information, visit www.southteconline.com.

**October 30–31 —Advanced Engineering 2019** Birmingham, United Kingdom. Advanced Engineering continues to build even further upon its position as the UK’s largest annual gathering of OEMs and engineering supply chain professionals. Advanced Engineering provides a platform for knowledge transfer and business discussions across: R & D, design, test, measurement & inspection, raw materials & processing, manufacturing, production and automation. The 2019 edition features co-located shows such as Aero Engineering, Composites Engineering, Automotive Engineering, Performance Metals, Connected Manufacturing and Medical Device Engineering. Lab Innovations is the UK’s only show dedicated to the entire laboratory industry. 150+ exhibitors will showcase laboratory equipment, laboratory technology, analytical equipment, life science supplies and much more to thousands of laboratory managers, laboratory technicians and procurement managers. For more information, visit https://www.easyfairs.com/advanced-engineering-2019/advanced-engineering-2019/.

**November 6–8—AGMA Gear Failure Analysis (Fall)** St. Louis, Missouri. Explore gear failure analysis in this hands-on seminar where students not only see slides of failed gears but can hold and examine those same field samples close up. Experience the use of a microscope and take your own contact pattern from field samples. Gear engineers, users, researchers, maintenance technicians, lubricant experts, and managers should consider attending. Instructors include Rod Budny (RBB Engineering) and Andy Milburn (Milburn Engineering, Inc.). For more information, visit www.AGMA.org.

**November 19–21—Power-Gen International 2019** New Orleans, Louisiana. Power-Gen International provides comprehensive coverage of the trends, technologies and issues facing the generation sector. Displaying a wide variety of products and services, Power-Gen International represents a horizontal look at the industry with key emphasis on new solutions and innovations for the future. Topics include plant performance, cyber security, energy storage, flexible generation and more. Learn more at www.power-gen.com.

**November 19–22—Formnext 2019** Frankfurt, Germany. Formnext is more than an exhibition and conference. It’s an entire platform for companies from the world of additive manufacturing. Here, a veritable who’s-who from the realms of design and product development, industrial tooling, production solutions, quality management, and measurement technology comes together with leading providers in basic materials and component construction. It will also explore clever ways in which AM can be integrated into process chains in industrial production. In addition, top international speakers and other experts will be on hand to engage conference attendees in in-depth discussions at the highest technical level. For more information, visit https://formnext.mesago.com/events/en.html.

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

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

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

Study the routes of key market players including:

Dr Oliver Blume,
Chairman of the Executive Board
Porsche AG, Dr Ing. h.c. F. Porsche AG,
Germany

Christian Levin,
Chief Operating Officer,
TRATON Group, Sweden

Ruiping Wang,
Vice President of Geely
Auto Group, Zhejiang Geely
Auto Group, China

www.drivetrain-symposium.world/de
GEAR TOOLING FOR SALE

Gleason Index Plates & Cams for Models 606, 607, 608, 609, 610, 19, 109,
Gleason Cams for Models #2, #102 & #645
Gleason Dressers arms for Model 27 & 463
Gleason Dresser cams for Model 17, 27 & 463
Gleason Model 104 Cutter Bodies, with Blades
Gleason Wheel Mounts for Model 17/27
Gleason 40 & 45 Degree Dresser Blocks
Gleason Model 37 Planer Cams
Gleason Model 645 Cams

Looking For:
Gleason 2A/102 Cams
Gleason Model 6 Testers
Gleason 529 & 537 Quench Presses
michael@GoldsteinGearMachinery.com
**FREE SUBSCRIPTION**

**RESPONSE REQUIRED**

☐ **YES** I want to receive/continue to receive *Gear Technology*

☐ **NO** Thanks anyway, but I don’t need the world’s best publication on gear engineering and manufacturing.

Name __________________________  JobTitle _________________________

Signature __________________________ Date ________________

How would you like to receive *Gear Technology?*

☐ PRINT version (Verify mailing info below)

☐ DIGITAL Version (E-mail required)

☐ BOTH Print AND Digital (E-mail required)

E-mail ___________________________________*

How are you involved with GEARS?

☐ My company MAKES GEARS (20)

☐ 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? _______________________

*Your PRIVACY is important to us. You get to CHOOSE how we use your personal information. The next e-mail we send you will have clear instructions.*

MAILING INFORMATION

NAME: ____________________________

JOB TITLE: ________________________

COMPANY: ________________________

ADDRESS:

☐ Check if this is a home address

CITY: ____________________________

STATE/Province: _________________

ZIP/Postal Code: _________________

PHONE: ________________________

FAX: ____________________________

Put your business card here to make it easier!

Mail to: 1840 Jarvis Ave., Elk Grove Village, IL 60007 USA

or

FAX to 1-847-437-6618

SCAN to: subscribe@geartechnology.com
If somebody’s going to throw a million dollars and five years towards constructing a single clock, you’d figure a project of that scale might come with its own building just to house it. But bucking expectations, the Corpus Clock fits comfortably in a display case on a street corner. You could walk right past it on Corpus Christi College’s campus and barely even blink, much less guess the clock’s cost.

That’s hardly the only way the Corpus Clock bucks convention. A grasshopper escapement clock with a literal grasshopper statue from hell carved on top, it tells time without the use of hands. Instead, the clock’s gold-plated face has a number of blue LED backlights and dozens of little doors in it. As each second, minute or hour ticks by, the corresponding doors flip open to allow the backlight to shine through. Instead of watching the second hand tick by, you can watch these blue lights orbit around the clock’s surface. One quirk, however, is that it doesn’t tell time precisely. It’s only accurate once every five minutes.

And perhaps wildest of all, this entire contraption works through almost purely mechanical means. It would have been incredibly easy to do things the other way around — to just slap those little LED lights all over the clock’s surface like a carnival game and have them light up one at a time. But instead, the Corpus Clock goes the extra mile, creating the same effect with its more complicated system of opening doors and lights. And it would have been almost as easy to just have those doors run on electrical means, but only the light itself is powered by a single motor. Everything else is pure mechanical work.

And all of it is built up around one of the world’s largest grasshopper escapements, which is on full display. In yet another one of the Corpus Clock’s many quirks, its guts are openly exposed — everything from the escapement to the escape wheel it interacts with are right on the face of the clock for any curious onlooker to study.

The glamour doesn’t stop with the clock’s lavish design, however. There was also a consequential amount of pageantry surrounding it. Professor Stephen Hawking was a guest of honor at the clock’s unveiling. It’s been dubbed “The Strangest Clock in the World.” TIME had an even more glowing name for it: the 48th best invention of 2008.

Though perhaps not the most rigorous timekeeper, the Corpus Clock is a work of art, both in mechanical ingenuity and in aesthetic form. And like a lot of art, it has an intended message. Its designer, John Taylor, had a lot of different things to say about his creation, but he often focused on that grasshopper on top.

The Chronophage, it’s called. Time Eater. Striding forward against the turning of the escape wheel, each step marking a second, and opening and closing its jaw repeatedly, devouring time itself as the seconds and minutes tick past. And beneath it, a line from the Bible: “the world passeth away, and the lust thereof.” Taylor said that he intended the clock to be “terrifying,” to fit the image of time as a voracious, unfriendly creature.

And such a thing is just hanging out on a street corner. A work of art, ambitious in both its engineering and its intended artistic meaning, with a hundred interesting little facts about it, just chilling on the street. To the casual observer just looking at it, most of Corpus Clock’s groundbreaking facets are almost invisible despite literally being worn on the outside of its frame, but once you do a little research, it makes sense how this could be a million dollar clock.
We’re more than a manufacturer.
When you partner with Ipsen, you get the support and resources of an entire team dedicated to your success.

Ipsen Customer Service (ICS)
Provides comprehensive aftermarket support and services for any brand of atmosphere or vacuum heat-treating system.

Marketing
Assists with co-promoting your new furnace or retrofit through press releases, testimonials, videos and professional photography.

Project Management
Manages every project and operates as the centralized point of contact, ensuring your furnace or retrofit is completed on time, within budget and to the highest quality standards.

Quality Control (QC)
Complies with the requirements of ISO 9001:2015 for the design, manufacturing, inspection and testing of all heat-treating equipment.
With the VIPER 500 MFM, KLINGELNBERG enters the market with a pioneering technological achievement and even deeper immerses into the field of cycloidal gears – and thus into the world of robotics. Thanks to an outstanding technology, the VIPER 500 MFM in many cases eliminates the need for the time-consuming and costly pairing of components. In combination with our precision measuring centers and the Closed Loop concept, Klingelnberg now offers a complete system that makes manufacturing high-precision cycloidal gears an easy task!