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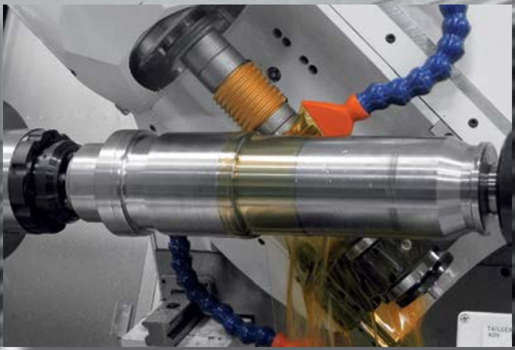

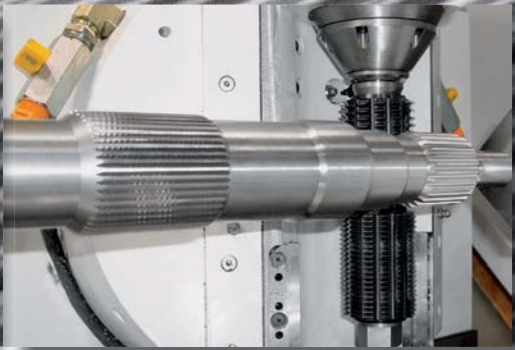

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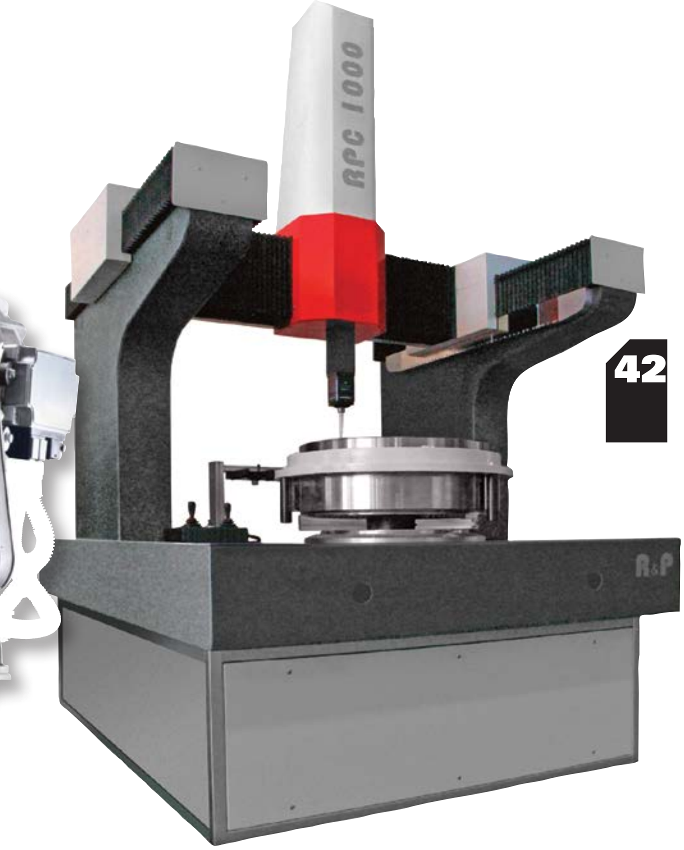

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departments

Photo by David Ropinski

Intelligence in Production.

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Chicago, Il. - USA
September 8-13, 2014
North Hall,
Booth N-6930

Generating grinding machine
LGG 180/LGG 280
- A single-table solution for gear grinding of workpieces up to Ø 180 mm, or up to Ø 280 mm, and workpiece lengths up to 500 mm
- Extremely fast load/unload times of 4 seconds, chip-to-chip, with a single-table
- New Palletizing Cell LPC 3400

Gear hobbing machine LCH 180 two
- Multi-cut strategy with roll/press deburr-chamfering
- Primary hobbing time is done in parallel to the load/unload, and roll/press deburr-chamfering, between two cuts – on two work-tables

Gear hobbing machine LC 180 Chamfer Cut
- High chamfer quality with one-cut hobbing strategy
- Primary hobbing time is done in parallel to chamfering in a second machining position

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LIEBHERR
The Group

THE GEAR INDUSTRY'S INFORMATION SOURCE

www.geartechnology.com

Our latest video featured on the *Gear Technology* homepage comes courtesy of **Slone Gear**. This video shows a new way to measure tooth thickness on internal parts using a span micrometer. The gage is set to a master and then placed over several teeth. The Slone Gear software will calculate the tooth thickness/dimension under pins. For more information, visit *www.youtube.com/watch?v=r3ARM7bLf_8*.

Unsung Heroes

Gear Technology blogger Charles D. Schultz recently wrote about the unsung go-to guys and gals that go unnoticed in most gear shops. Read this post (The Invisibles: People Who Keep Shops Running) and others at *www.geartechnology.com/blog/*.

IMTS 2014

Gear Technology will continue to feature the latest product and industry news items related to IMTS 2014 taking place September 8-13 at McCormick Place in Chicago. All the new technologies, products and can't miss events will be available on our website as well as Twitter and LinkedIn.

E-Newsletter:

Sandvik Coromant, along with technology partners Star SU, Höfler, DMG Mori, Mazak, Okuma, Carl Zeiss, Zoller, Nikken CNC Rotary Table and WFL, hosted a gear event in Schaumburg, Illinois. Read the recap in our recent E-Newsletter here: *www.geartechnology.com/newsletter/0614/sandvik.htm*

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No Excuse is Good Enough

Publisher & Editor-in-Chief
Michael Goldstein

Might some of you may be tempted to skip IMTS this year? Business is just so-so. You can't afford to be away from the shop. It will be a waste of time because you don't have the budget for new machine tools or new technology anyway. You've cut back on travel expenses. It's your wife's birthday.

Maybe the last excuse is valid, but the others bear closer examination.

Most of you already know that IMTS often presents a unique buying opportunity, because every machine tool manufacturer is there in the same place, and each of them is forced to compete for your attention and your business. This highly competitive environment can result in good pricing if you're in the market to buy.

But even if you're not shopping for new technology, IMTS has a lot to offer. It's not just about buying machine tools, cutting tools and automation. It's about learning how the latest processes and technologies can best be put to use. You can be sure that the newest technology will be on display. You can also be sure that there will be plenty of experts on hand to help you understand how it can help you become more productive, efficient or profitable.

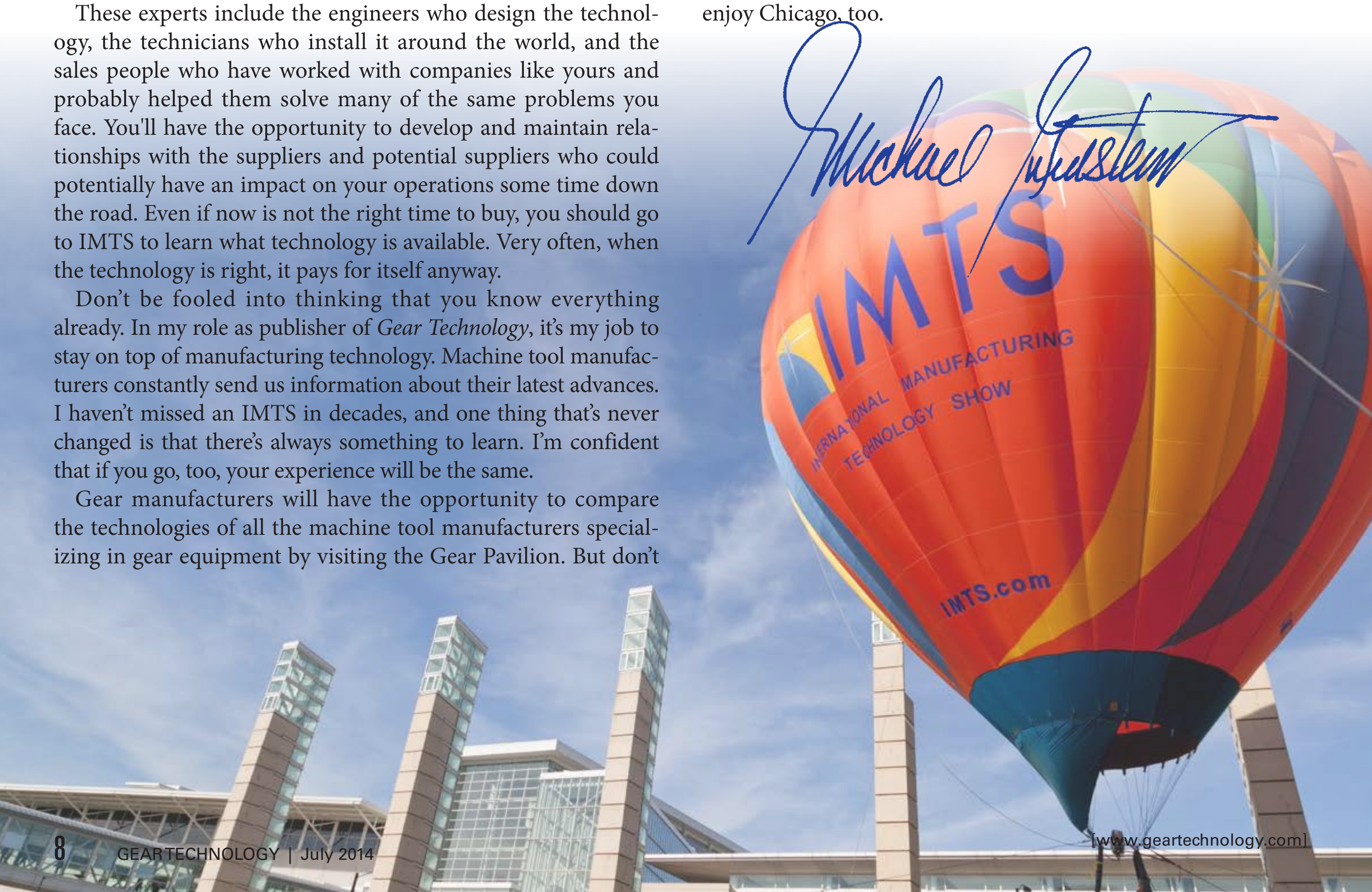
These experts include the engineers who design the technology, the technicians who install it around the world, and the sales people who have worked with companies like yours and probably helped them solve many of the same problems you face. You'll have the opportunity to develop and maintain relationships with the suppliers and potential suppliers who could potentially have an impact on your operations some time down the road. Even if now is not the right time to buy, you should go to IMTS to learn what technology is available. Very often, when the technology is right, it pays for itself anyway.

Don't be fooled into thinking that you know everything already. In my role as publisher of *Gear Technology*, it's my job to stay on top of manufacturing technology. Machine tool manufacturers constantly send us information about their latest advances. I haven't missed an IMTS in decades, and one thing that's never changed is that there's always something to learn. I'm confident that if you go, too, your experience will be the same.

Gear manufacturers will have the opportunity to compare the technologies of all the machine tool manufacturers specializing in gear equipment by visiting the Gear Pavilion. But don't stop there, because the non-gear equipment can often be just as important to your operations, especially with today's multitasking machines. Or maybe you'll need to visit the Quality Assurance pavilion to learn how you can better streamline your inspection operations. The point is, every conceivable manufacturing operation is covered at IMTS, and no matter what you consider your specialty, there may be opportunities to expand your capabilities or increase your productivity that you haven't even considered.

If you look at our Product News section this issue, you'll see a lot of examples of new technology that will be exhibited at IMTS. We're saving some of the best new products for our August IMTS issue, but take a look beginning on page 10 to get an idea of the breadth and depth of technologies that will be on display.

Then, stop making excuses and book your ticket for Chicago. IMTS only comes once every two years, and 100,000 visitors per show can't be wrong. No excuse is good enough. In fact, even if it *is* your wife's birthday, bring her along. She'll probably enjoy Chicago, too.



Index Traub

OFFERS PROCESS RELIABILITY AT IMTS 2014

The new Index G220 Turn-Mill Center includes a motorized five-axis milling spindle and a tool turret with Y-axis, providing maximum machining flexibility for turning and milling complex parts in a single setup. Index will demonstrate the machine at IMTS 2014, Booth S-8136. The G220 provides a distance of 1,280 mm between the main and counter spindle and a maximum turning length of 1,000 mm. Operators have easy access to the main and counter spindles, the turret and the motorized milling spindle, as well as the operating panel.

The fluid-cooled, identical main and counter spindles feature a clearance of 65 mm (chuck up to max. 250 mm diameter), and provide power of 20/24 kW, a torque of 135/190 Nm and a maximum speed of 5,000 rpm. A tool turret is located in the lower part of the machine, can accommodate VDI 25 and VDI 30 tool mountings in 18 or 12 stations, all of which can be equipped with individually driven tools (power 6 kW, torque 18 Nm, speed 7,200 rpm).

The G220's fluid-cooled, five-axis motorized milling spindle (with power of 11 kW, torque of 30 Nm and speed up to 18,000 rpm) comes equipped with hydrostatic bearings in the Y and B axes. The stable circular guide further ensures excellent rigidity and damping. The Y-axis features a +/-80 mm stroke. The B-axis, driven directly by a torque motor, has a swivel range of -35 to +215 degrees. With a large travel distance in the X-direction, machining at up to 30 mm below the turning center height is possible.

The motorized milling spindle operates using a one- or optionally two-row tool chain magazine, which features space for 70 or 140 tools (HSK-A40). The double-row tool magazine enables setup during machining time. The compact machine features a CNC-controlled programmable gantry-type removal unit for finished workpieces. It can unload remnants from the main spindle as well as finished parts from the counter spindle.

The G220 is equipped with the latest generation of the Index C200 SL controller. Based on the Siemens Sinumerik 840D sl (solution line), it features an 18.5 inch touchscreen.

Additionally, the new Traub TNL42 automatic lathe will have its North American debut at IMTS 2014, Booth S-8136. Developed for high production precision turning, the new 42-mm TNK42 fixed headstock automatic lathe adds to the series of CNC fixed/sliding headstock automatic lathes, the TNL18 and TNL32. The new machine is for production of turned parts up to 250 mm in length and of geometrically complex workpieces in large and medium volumes.

With two tool turrets, a main spindle with C-axis and 42 mm bar capacity (7,000 rpm, max. 29 kW and 65 Nm) and a swivel counter spindle with C-axis for extensive rear end machining, the TNK42 offers high production rates with only 5.5 m^2 footprint (without bar loader). The vertical design of the machine permits unobstructed chip flow and better ergonomics for setup operations. The stable, vertical cast machine bed is mounted on a heavy cast iron machine base, providing excellent damping properties for high-precision cutting.

The upper tool turret has 10 stations with slide travels of 140 mm in × and 300 mm in the Z axis. All stations in the upper turret can be equipped with live tool holders. Turret indexing is accomplished with an NC rotary axis with a direct measuring system, avoiding the need for any mechanical lock, thereby allowing fast positioning of the turrets at any angle. This way, multiple tools can be assigned to each station, so that the upper tool carrier can be equipped with up to 20 tools.

The standard built-in Y-axis for the two turrets is formed by the interpolated movement of the CNC turret indexing H-axis and simultaneously the C-axis of the work spindle as well as the X-axis of the tool carrier. Through this combined motion along with the powerful tool drives (with max. 5 kW/8 Nm/12,000 rpm), the TNK42 provides a large Y-travel for all turrets, e.g., to mill surfaces and grooves on workpieces or to drill axis-parallel, off-center holes. Traub has also reduced idle time with its innovative optional "Dual Drive" system for the upper turret, where two separate drive trains are used to ramp up the speed for the next tool while still cutting with the current tool. This means the new tool is indexed to the machining position at full speed, reducing secondary processing times and extending the service life of the live tool holders.

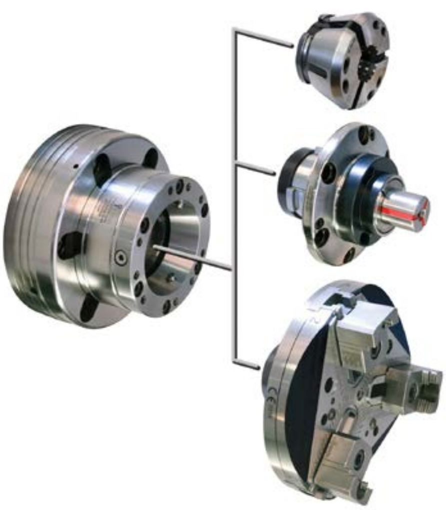
Apart from its function as a lower tool turret with 9 stations and identical functionality as the upper tool turret, the lower cross-slide serves as a swivel counter-spindle for rear-end machining of workpieces. The swivel movement of the counter spindle is achieved through the CNC turret indexing axis (H-axis), thereby providing a counter spindle with a C-axis that can be moved in three axes (X/H/Z), allowing unrestricted counter spindle machining at 7,000 rpm (max. 12 kW and 22.5 Nm) and 42 mm spindle clearance.

For more information:
Index Traub
Phone: (317) 770-6300
www.indextraub.com

Hainbuch America

PRESENTS TWO QUICK CHANGEOVER SYSTEMS AT IMTS

The centroteX System allows changeover of any workholding device on a machine within five minutes while maintaining accuracies, eliminating the need for an operator to indicate the workholding system during changeovers and dramatically decreasing machine downtime. This system has a common flange plate that is fitted to the machine spindle along with a bayonet mount on the drawtube. The sub plate with chuck or fixture is then coupled to this interface, rotated 15 degrees and locked via quick connect fasteners. The centroteX System



can be mounted on any CNC machine and with most any workholding or fixture device, allowing manufacturers to schedule production scenarios according to their customer needs and not according to the workholding set-up on the machines. .

The second quick change system is Hainbuch's Spanntop Modular Chuck System. This system utilizes Hainbuch's original 10-second collet change for OD clamping What if you want to change over from OD clamping to precise ID clamping, without changing the clamping device? Not a problem with the Mando Adapt mandrel. Place the mandrel in the mounted clamping device and tighten three screws to lock the mandrel in the clamping device for extreme rigidity and precision. For rotating products, concentricity of 0.005 mm between taper and mandrel taper can be achieved. For stationary clamping devices, repeatability of 0.003 mm is possible. This can be accomplished without adjusting.

New to the Hainbuch modular system is the Jaw Module, which is small and flexible; can be quickly changed and covers a large clamping range. The result is a quick-change clamping solution for all situations. The new Jaw Module completes the circle of modularity and gives a new clamping dimension that opens up even more possibilities for users. All this with less weight and a smaller interference contour. In short: ID clamping, OD clamping and 3-jaw clamping all-in-one. Hainbuch America will be at Booth W-2413 in the Tooling & Workholding Systems Pavilion.

For more information:
Hainbuch America
Phone: (414) 358-9550
www.hainbuchamerica.com

Sunnen Products

OFFERS HEAVY-DUTY BORE GAGES

Sunnen (Booth N-700) GR-2245/2241 bore gages combine rugged design with precise, reliable measurement to 0.0001" for heavy-duty large-part machining. Standard models are capable of checking bore diameters from 2" (50.8 mm) to 12" (300 mm) and bore lengths up to 24" (600 mm) with appropriate attachments, while special-order models can measure bores up to 65" (1650 mm) long. GR-2245/2241 gages are suitable for energy industry components, such as flow meter tubes, liner hangers, drill pipe, mud pump liners and sucker rod pump barrels. Available with analog dial readout or electronic indicators, the gages feature long wearing, replaceable carbide gaging points to withstand extreme wear conditions with rough workpieces or abrasive materials. The gages feature patented wear-proof ball cranks for long-term repeatability and retractable or non-retractable gaging points. Models with retractable gaging points prevent scratching of the bore during removal. The gages are designed with a dust/water protection level of IP42 or IP53, and a specially designed shock shield protects the dial from hand heat and jarring to ensure reliable readings.

The gages use adjustable centralizers to ensure proper positioning over the entire diameter range, resulting in accu-

Siemens Industry, Inc.

INCREASES CNC TECHNOLOGY AT IMTS

With the introduction of the 808 at IMTS in 2012, Siemens brought power, flexibility and reliable performance to the job shop. Already accepted as an OEM component by numerous mill and lathe builders, the 808 provides job shops the unique opportunity to apply advanced CNC power to their existing machines, breathing "new life into old iron," as the saying goes. The 808 rounds out the growing family of CNC models from Siemens, which now spans the range from the most basic three-axis machines to most advanced five-axis machining centers, with full robotic integration, secondary ops management and transfer line capability, all on a single control, the 840D. This and other Siemens innovative products will be on hand at IMTS 2014 at Booth E-5010.

For more information:
Siemens Industry, Inc.
Phone: (800) 743-6367
www.siemens.com

rate centering action, even if the gage is tilted off the bore axis. A simple twist adjusts gaging tension, allowing the head to go smoothly in and out of any size bore. A right-angle attachment is available for conditions where the gage is difficult to read or total gage height is an issue. Blind-hole probes allow measurements to within 0.5" (13 mm) of the bottom the blind bore.

Standard dial-equipped gages read out in tenths (0.0001"/0.002 mm), and models with five-tenths read outs (0.0005"/0.010 mm) are also available.

Gages with electronic indicators are accurate to ±0.00012 in. (±0.003 mm) with 0.00005 in. (0.001 mm) resolution, and provide the ability to perform scaling calculations, judge tolerance, hold data and perform general comparison measurements. Operators can easily toggle between inches and metric measurement readouts. A data output cable enables direct transfer of bore measurements to a computer, making the gages ideal for fast SPC data collection at multiple points in a bore during long production runs. Gages can be preset with upper and lower tolerance limits for GO/±NG judgments, which are then displayed in full-size characters.

The electronic indicator displays the spindle's absolute position via an absolute linear encoder capable of relocating the origin, even after the power is turned off, for quick-start, multi-point measurement. The positive/negative count resulting from the spindle's up-and-down movement can be toggled, and the indicator face can be rotated 330 degrees, for easy reading at virtually any angle. Battery life, under normal use, is approximately 5,000 hours.

All gages come packed in sturdy, custom-fitted boxes with all tools and wrenches required for setup and adjustment.

For more information:
Sunnen Products Company
Phone: (314) 781-2100
www.sunnen.com

Walter USA LLC

EXPANDS CUTTING TOOL TECHNOLOGY

Walter will showcase several new technologies in Booth W-1700 at IMTS 2014. The exhibit will feature the new Walter Blaxx F5055 slitting cutter, the latest addition to its Blaxx family of high-performance milling cutters. The mill incorporates similar technology to the Walter Cut SX grooving system, which is based on self-gripping, form-locking indexable inserts that provide ideal cutting force for the tool. The SX parting and grooving system also features coolant supply through the tool for optimum cooling of the cutting edge for all monoblock tools in the SX system.

Also featured will be Walter's expansion to its range of tough, reliable and long-life standard solid carbide deep-hole drills with the introduction of Walter Titex X•treme D40 and the X•treme D50 drills, which provide 40xD and 50xD drilling depths respectively. Walter's XD technology (XD stands for extremely deep) enables holes to be drilled in one operation without pecking, in steel, cast iron or non-ferrous metals. The display will also include New Tiger•tec Silver high performance cutting material with new positive rake 7° and 11° geometries for steel machining along with new geometries for cast iron machining will also be on hand. The new geometries include a classic flat top with a stepped plateau, as well as a robust geometry for maximum process reliability, even for interrupted cuts.

Further, the company will feature its new range of Walter counter-boring and precision boring tools for diverse machining applications. The new line has been expanded with Capto adaptors in addition to the existing NCT and ScrewFit adaptor program.

New Prototyp Prototex Eco Plus from Walter, also on display, is a versatile through-hole tap that delivers superior performance and tool life. Designed for through-hole threads up to 3.5xD, it can be used on steel, stainless steel, and cast iron and non-ferrous metals such as aluminum and copper.

The exhibit will also highlight Walter Xpress and Walter Multiply. Walter Xpress is an incredibly fast ordering and delivery system for high-quality special tools. Walter Multiply is a multi-level networked and customized program that assists users in the optimization of tool selection from planning, manufacturing, maintenance, logistics and training. A variety of cutting fluids and coolants available from Walter, including its newest low foaming options, will also be displayed.

For more information:
Walter USA LLC
Phone: (800) 945-5554
www.walter-tools.com

Jenoptik

OFFERS VERSATILE MOBILE SURFACE MEASUREMENT SYSTEM

The Jenoptik W10 mobile surface roughness measuring system (IMTS 2014 Booth E-5545) is ideally suited for measurements on the production line or machining cell. The new instrument's remote measuring capability brings the measurement lab to the shop floor. Light and compact in design, easy to operate with long-lasting battery power, the W10 is simple to use. Operation is intuitive through the easy to understand graphic user interface. More than 800 measurements with one battery charge guarantee a high level of reliability even during frequent use. Measuring results may be quickly printed out on the integrated printer—wirelessly via Bluetooth technology. Capable of checking more than 40 roughness and waviness parameters using an extensive array of probes and accessories, the new W10 can match the performance of more expensive stationary systems with its accuracy and precision.

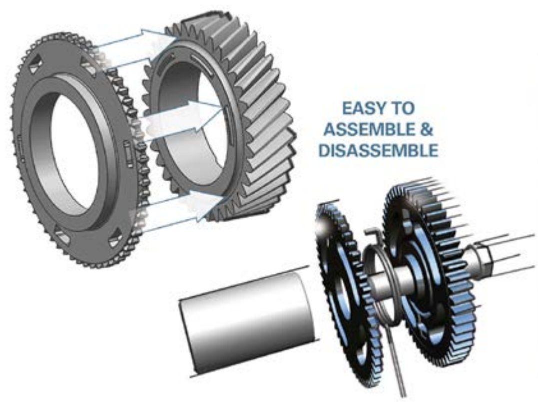
The new Jenoptik W10 is ergonomically designed, with the device easily fitting into the user's hand making it simple to precisely position on the workpiece. The wireless device can be used for transverse probing, overhead measurement, mobile measurement on small shafts, perpendicular measurement, and is equipped with tripod legs to adapt to small workpiece height. An integrated V-groove securely positions small shaft type parts on the unit for measuring.

The W10 is capable of tracking eight separate measurement programs, including one for device verification, up to 100 separate profiles, with a total storage capacity of up to 10,000 completed measurements. The integrated click wheel allows the operator to intuitively select device functions. In conjunction with the large color display with graphic interface, this makes operation of the W10 simple and transparent, delivering easy to see results and tolerance evaluations. The roughness probes and measuring instrument electronics are calibrated independently from each other at the factory.

For more information:
Jenoptik Industrial Metrology
Phone: (248) 853-5888
www.jenoptik.com

GKN Sinter Metals

OFFERS POWDER METAL ALTERNATIVES



GKN Sinter Metals is a developmental partner of the automotive industry, producing the widest range of sintered drivetrain components from metal powder worldwide. Powder metal production processes are environmentally friendly, producing safe and quiet-running components with a long service life — the engineers at GKN Sinter Metals see these products as the future trend of gearbox design.

GKN's TechCenter at Radevormwald, Germany, is supporting this trend. For many years, the engineers at the TechCenter have been working to optimize manual and automatic gearboxes with universities and renowned research institutions, like the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, that specialize in materials science and drivetrain technologies

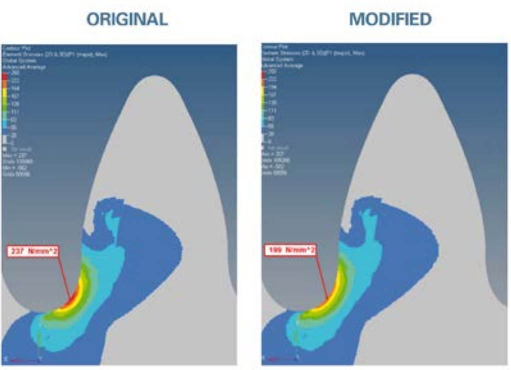
During the VDI Drivetrain Congress, held from June 24-25 in Friedrichshafen, Germany, GKN presented its product portfolio, field-tested gear developments and technological trends such as lightweight design.

Antonio Casellas, vice president of GKN Sinter Metals Global Product Management, said, "Powder metallurgy is a pioneering technology. It offers a variety of process options with specially designed metal powders to meet the increasing demands of the various drivetrain applications. Powder metal offers new possibilities in geometry, such as undercuts, 'green-in-green' technology or helical gears to innovate gearbox design."

Four examples of GKN technology include:

Conventional compaction. Conventional compaction of selected metal powders on GKN developed powder presses using 'closed-loop' technology ensures densities above 7.2 g/cc with a homogeneous material structure. The 'closed-loop' method developed by GKN allows geometries such as undercuts or the innovative 'green-in-green' technology. The surface density is further improved by a subsequent sizing operation.

Warm compaction. Utilizing warm compaction, a technology developed by GKN, a density of more than 7.35 g/cc is achieved. The powder has been engineered to be compacted in heated tooling. Again, the 'closed-loop' process is used.



Selective rolling. Rolling of selected functional surfaces serves to achieve full density in highly stressed contact areas of the drivetrain component. Helical gears can be provided with a heavy-duty surface area and an elastic core with a supporting strength to optimize application performance.

Powder forging. Due to its outstanding design flexibility and excellent performance with good geometrical precision, powder forging is an ideal technology for producing drivetrain components because a nearly full density is achieved across the entire volume of the part. In this process, a PM part having a compact density of approximately 7.0 g/cc is fed directly from sintering into a forging press. It is then brought to full density by hot forging.

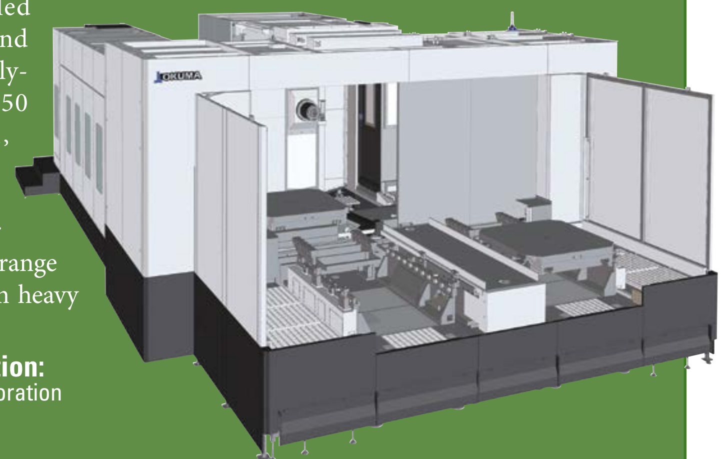
Powder forged synchronizer rings and passenger car connecting rods represent a selection of high volume components that GKN produces for drivetrain applications. An extension to this technology is the development of powder forged gearbox components with helical teeth. The various processes described here represent only a small selection of our technological and economic solutions. These are complemented by our extensive experience in the development of metal powders, powder presses, compaction tooling, sintering and heat treatment for advanced drivetrain applications.

For more information:
GKN Sinter Metals
Phone: +(44) 1527 517715
www.gkn.com

Okuma

DEMONSTRATES SPEED AND POWER WITH MA-12500H MACHINING CENTER

Okuma's MA-12500H horizontal machining center will be on display for the first time at the 2014 International Manufacturing Technology Show (IMTS), Booth S-8500. The hallmark of this machine is its ability to provide a good balance of speed and cutting power for machining of aluminum alloys, cast iron and difficult-to-machine materials. This makes it well suited for large part aerospace machining. The MA-12500H is so fast and powerful, it's the machine of choice for building lathes at the Okuma DS1 plant in Oguchi, Japan. Built on an integral bed and base, and designed with reinforcing ribs for increased stability and load carrying capacity, the MA-12500H incorporates Okuma's exclusive Thermo-Friendly Concept to achieve unparalleled thermal stability and accuracy. Standardly-equipped with a 50 taper 6,000 rpm, 60/50 horsepower spindle, it is also available with either a 12,000 rpm wide range spindle or 4,500 rpm heavy duty spindle.



For more information:
Okuma America Corporation
Phone: (704) 504-6324
www.okuma.com

Zeiss

CONTURA OFFERS ADDITIONAL MEASURING RANGES

The latest generation of the successful Zeiss Contura is now entering the market. Zeiss introduced the coordinate measuring machine at the Control show in Stuttgart, Germany. This system provides a platform for flexible, reliable and uncompromising quality assurance. It is even more precise than its predecessor and offers a large package of optical sensors on top of additional measuring ranges. Zeiss Calypso reference software and a highly tuned overall system enable Zeiss Contura to maintain its place as the standard in its class.

Like no other Zeiss coordinate measuring machine, Zeiss Contura has made high-performance measuring technology available to the masses. The latest generation will continue on this proven path. A reliable measuring system is the result of the interaction of its components: design, sensors, software and service. "With Zeiss Contura, customers receive a well-balanced system and thus a guarantee for stable, reproducible precision. Put simply: results you can rely on," says Andrzej Grzesiak from Zeiss Industrial Metrology business group. Thanks to its robust design, Zeiss Contura. can also be used near production. The latest and most powerful scanning sensors from Zeiss are available for the machine.

Tailored sensors

In tune with the various customer requirements, sensors are available in the direkt, RDS and aktiv versions. With the Zeiss Vast XXT probe, the direct model enables scanning. This configuration is ideal for small workpieces, for

which a small single or star stylus is sufficient. Scanning makes it possible to efficiently and precisely measure the form in addition to the size and location. For parts with different angular positions, the RDS sensor model is the right choice. The RDS articulating probe holder can be freely positioned in 2.5 degree increments, resulting in more than 20,000 possible positions. Thanks to the RDS-CAA, the data from every single position can be mathematically calculated in just a few minutes. "This drastically improves the utilization level of the machine and results in additional possibilities to immediately measure even complex angular positions," states Grzesiak. Its sensor interface permits the flexible use of contact and optical sensors, including the new Zeiss LineScan sensor. It enables the fast optical measurement of features.

The active configuration is recommended when long styli are needed for measurements deep inside a part or for additional demands on precision and speed. The Zeiss Vast XTR gold and Vast XT gold premium probes are available. This active regulation enables highly accurate measurements with very long, heavy stylus systems. "Active scanning is a unique value added by Zeiss," emphasizes Grzesiak. navigator technology from Zeiss, which enables a tangential approach without a stop & go, as well as circular or helical scanning, results in added productivity.

Choice of measuring ranges

Another new feature is the range of measuring volumes. The Zeiss Contura family has eight different sizes starting with a measuring volume of 700 × 700 × 600 mm up to 1200 × 2400 × 1000 millimeters. From a design standpoint, Zeiss Contura is based on proven features: its efficient, highly precise air bearings are an in-house development. Zeiss AirSaver can also be integrated for additional savings. This technology reduces compressed air consumption by up to 60 percent depending on how it is used.

For more information:
Zeiss Industrial Metrology
Phone: (800) 327-9735
www.zeiss.com/metrology

Seco Tools

HIGHLIGHTS MILLING, TURNING AND THREADING AT IMTS 2014

Seco Tools, LLC (Booth W-1564) will unveil several new milling, turning, threading and tool holding products that were developed with material advancements in mind, including a square shoulder cutter that enhances side-milling operations, a multi-edge system that meets the industry's demand for narrow cutting-edge grooving and parting-off tools, an insert that provides high-performance threads in a single pass, and toolholders with special vibration damping capabilities.

Milling

Seco will spotlight several milling insert grades including the new MS2050 that utilizes an advanced coating technique and substrate to bring enhanced process reliability and higher cutting data to applications involving titanium alloys. The special PVD coating on the MS2050 not only strengthens the insert's wear resistance but also eliminates reaction with the workpiece material for increased cutting speeds and tool life and a lower cost per part. MS2050 is available in a variety of positive geometries for square shoulder milling, face milling, copy milling and high-feed milling.

With its four cutting edges and innovative cutter design, the new Square T4-08 shoulder milling solution that will be on display at IMTS balances economy and performance when machining cast iron and steel. Made for roughing and semi-finishing operations, the Square T4-08 brings smooth cutting action and good surface finish to slotting and contouring applications. The tangential mounting of the tool's inserts increases the surface area of contact between the inserts and cutter body, resulting in increased rigidity and machining stability. Additionally, such a mounting design directs the cutting forces to the thickest part of the inserts, providing highly robust milling performance and

increased metal removal rates with small diameters.

IMTS attendees will also see the latest in flexible, cost-effective modern end-mill design by way of the Minimaster Plus replaceable milling tip system. Engineered with speed, precision and complete versatility in mind, the system offers a large selection of inserts and shanks for a multitude of tough milling applications, including those that involve steel, stainless steel, cast iron and aluminum materials. Most recently, Seco made this system even more adaptable by adding internal coolant capability to all three of the diameter sizes of its new high-feed milling heads.

As more manufacturers opt for stronger, lighter composite materials instead of steel to reduce the weight of the parts they produce, Seco has developed dedicated tooling for the rapidly growing use of this material. Among those products are the Jabro JC840 and JC845. The JC840 double helix end mill cutter effectively machines laminated materials by directing its cutting forces inward and toward the component filler material during slotting and side milling operations. The JC845 solid end mill reduces delamination, pressure build up and heat in the cutting zone when slotting and side milling carbon fiber reinforced plastics.

Turning

Regarding advanced turning inserts for different materials, Seco will exhibit its Duratomic-coated TK1001 and TK2001 carbide grades that bring exceptional wear resistance and faster cutting speeds to cast iron applications as well as the TP1030 cermet grade that maintains tight tolerances and high surface finish in high-volume threading operations involving steels and stainless steels. From its Secomax line, the company will highlight CBN010, an uncoated PCBN grade that has high resistance to edge chipping when cutting hardened steels, and CBN060K for turning case hardened steels within the application area defined by H10 – H20 ISO designations.

Seco's X4 multi-edge system meets the industry's demand for narrow cutting-

edge grooving and parting off tools. At IMTS, attendees will see how the company has added smaller shanks to the short reach system so that it can accommodate an even broader range of machining applications such as Swiss parts. Overall, the X4 consists of indexable tangential inserts with three-dimensional chipbreakers and a highly stable clamp design. These strong, dependable system components achieve high accuracy, repeatability, productivity and surface quality in external grooving and parting-off operations involving small parts, slim bars and tubes made from a wide variety of common materials.

Threading

The new Thread Chaser inserts that Seco will have on display at IMTS incorporate multi-tooth patterns to allow push and pull threading of OD and ID features with one or two passes. The inserts incorporate precise thread patterns that quickly and reliably generate high-accuracy, consistently perfect thread pitches. Through-coolant holes and chip formers direct high-pressure coolant precisely to the cutting edge to optimize chip formation, provide efficient chip evacuation and extend tool life. These inserts will provide substantial value to manufacturers working with pipes and couplings made from a wide range of material hardnesses for the oil and gas industry.

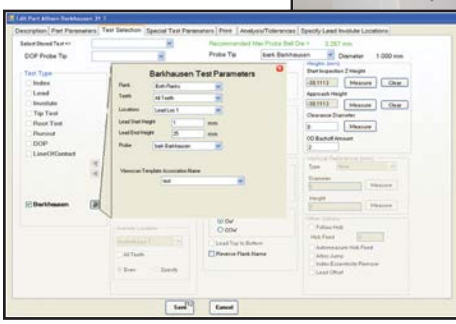
For more information:
Seco Tools
Phone: (248) 528-5200
www.secotools.com

No Compromising on Quality at Allison Transmission

Gleason 350GMS helps put higher quality, more reliable gears into its next-generation TC10 automatic transmission.

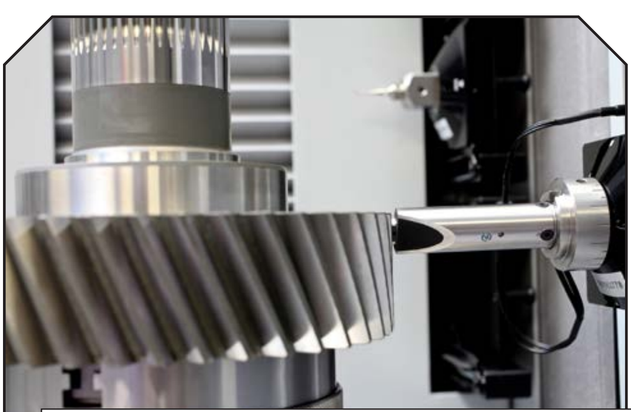
In the past, Class 8 tractor operators have been forced to sacrifice vehicle drivability and transmission reliability and performance just to squeeze a few precious extra miles out of a tank of gas. For many, those days are now coming to an end, thanks to Allison Transmission's all-new TC10 automatic transmission, which delivers 5% more fuel economy than their current manual or automated manual tractors. The TC10 also provides smooth, seamless acceleration and the peace of mind that comes with a 5-year, 750,000-mile warranty.

Allison conducts a typical Barkhausen inspection on the Gleason 350GMS, using simple step-by-step programming steps in the familiar *GAMA Windows* environment.



High quality transmission gears produced in Allison's ultra-modern Plant 16 at their Indianapolis, IN global headquarters play a significant role in the TC10 performance story. For example, in the past a finish profile grinding operation after heat treat would have been considered the exception rather than the rule for gears of this type. Now, grinding is a requirement for many of the 20 gears found in this countershaft 10-speed transmission. But with profile grinding comes the potential for grinding burn — the often unpredictable thermal damage that can occur to a hardened gear during grinding. Grinding burn can cause re-tempering and the creation of a softer microstructure that ultimately causes high tensile stresses and a gear that wears prematurely or fails catastrophically—a condition that Allison is keen to detect, but not through the traditional nital etching method.

Making the case for Barkhausen. In the early stages of the TC10 project, Allison Transmission decided to take a different approach to the detection of grinding burn and other surface damage that can result from case hardening and even parts handling – a method that today is paying significant dividends in gear quality and performance, according to Ann Wilkerson, Allison Transmission manufacturing engineer.



A standard Barkhausen inspection on this Allison helical gear consists of two traces per tooth flank, four teeth evenly spaced 90 degrees apart – 16 total traces.

"While a number of the TC10 ground gears are purchased, we do have one particularly challenging helical gear with very high tolerance requirements that we decided to produce from forgings in-house, including a final finish grinding operation where the potential for grind burn exists," explains Wilkerson. "Neither installing a nital etching line nor outsourcing the gear for nital etching were options from a cost and delivery standpoint, and because of our concerns about the process itself. Fortunately, the Gleason GMS gear inspection solution allows us to perform not only the typical gear checks required in our day-to-day prototyping and production work, but also Barkhausen and surface finish measurement. Through the use of the GMS and Barkhausen, we've had considerable success in refining our grinding and dressing cycles to minimize grind burn — not to mention detecting evidence of grind burn that would not have shown up with nital etching."

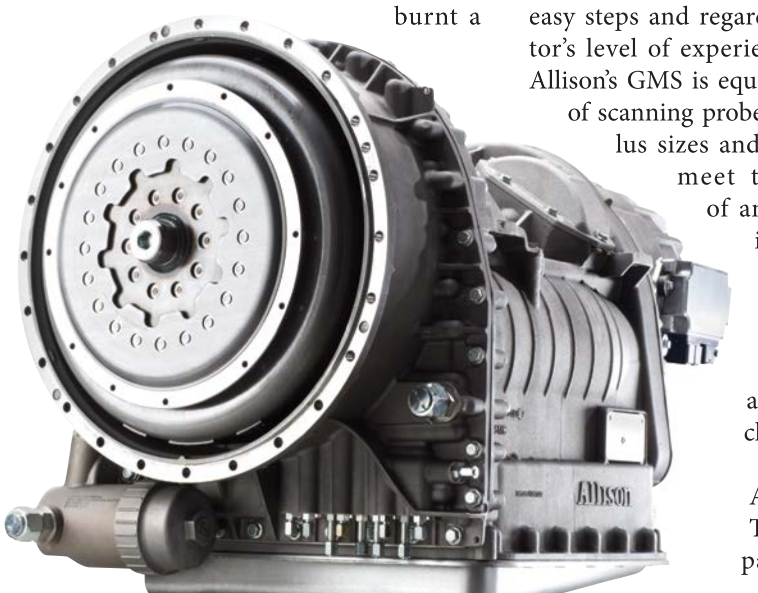
The Barkhausen noise analysis (BNA) method is based on the measurement of a noise-like signal, generated when a magnetic field is applied to a ferromagnetic sample. By applying an alternating magnetic signal to the gear, and essentially magnetizing it, any discontinuity in the microstructure becomes the source for a noise-like signal that can be detected and measured. James Thomas, applications engineer for American Stress Technologies, a pioneer in the application of Barkhausen technology and supplier of the technology to Gleason, explains it this way: "Barkhausen is very instructive because it provides a relative measurement that changes with varying stress in the material or microstructural variations in the material. We simplify it by expressing the measure with a signal number. With more tensile stress, the number increases; with more compressive stress, it decreases. As microstructure goes softer, the number increases; conversely, the number decreases with a harder microstructure. With grinding/retempering burn, you have a transformed, softer layer of microstructure with a different density than the surrounding material, thus creating high tensile stresses that might be 20 to 50 microns deep. The softened microstructure and high tensile stresses both drive the Barkhausen number we're able to report higher.

"Nital etch allows for detection of transformed microstructure on the surface, but it is insensitive to residual stresses that accompany grinding burn and reach a peak in the sub-surface."

Wilkerson concurs. "Nital etch is 'shades of grey' – you can't know with certainty about damage sub-surface," she says. "Say you've burnt a gear in a roughing pass, then finish ground it. On the surface it might appear OK with nital, but underneath there may be a layer of tempered material. As bad as we intentionally burnt the artifacts (master gears) we used for understanding and setting the high limit BNA number and for comparison to the parts we're producing, they didn't look that bad with nital etch. Barkhausen tells a completely different story."

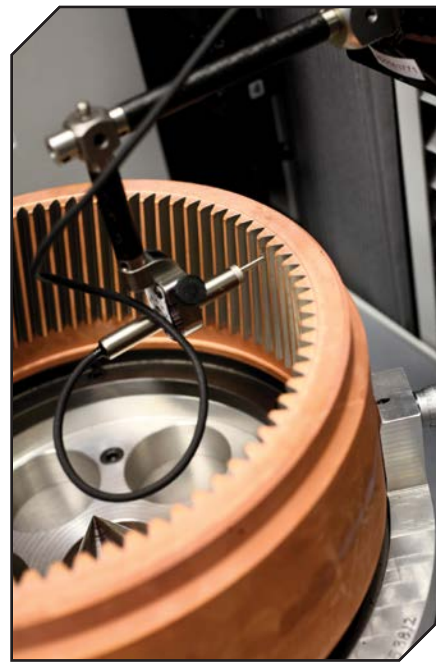
American Stress Technologies' Rollscan 300 digital Barkhausen noise analyzer and probe are easily integrated into the Gleason 350GMS. End result? All of the necessary gear inspection can be conducted on a single GMS machine, in a single setup, saving time and helping ensure inspection accuracy.

Barkhausen and GMS integration. Today, as Allison Transmission ramps up production of its TC10 transmission, the Gleason 350GMS is tasked with all the inspection requirements of the gears produced by Allison in Plant 16. Equipped with the *GAMA* applications suite of software, the GMS series empowers Allison's operators with the ability to completely inspect gears. *GAMA* puts a host of powerful features right at their fingertips, creating a simple, intuitive human/machine interface. The process of creating a new program, for example, is as easy as point and click, and can be done in just minutes in a few easy steps and regardless of the operator's level of experience, or gear type. Allison's GMS is equipped with a series of scanning probes with various stylus sizes and configurations to meet the requirements of any spur or helical, internal or external gear as large as 350 mm in diameter – all interchangeable with an automatic probe changer.



The new Allison TC10 tractor transmission: delivering 5% better fuel economy and a host of other long-sought benefits to Class 8 tractor operators.

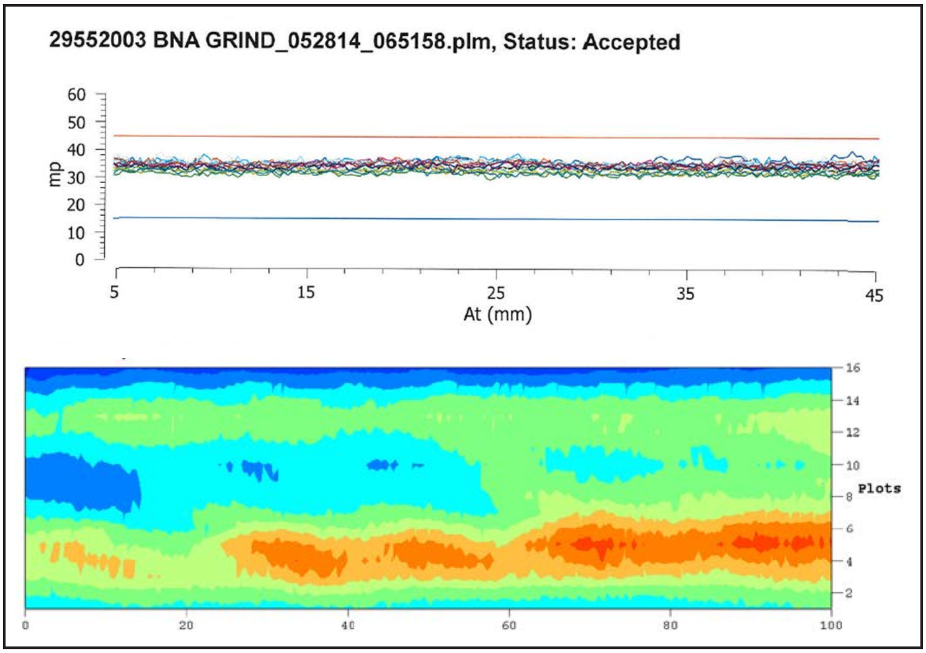
Gleason and American Stress Technologies have partnered to seamlessly integrate AST's proven Rollscan 300 digital Barkhausen noise analyzer and probe into the GMS platform. The operator sets up and conducts a Barkhausen test on the GMS just as he would with any inspection. He simply selects the Barkhausen test, and then fills in the test parameters in the familiar Windows-based GUI, identical to those used for any other GMS inspection. Since the probe must be free to rotate to follow the gear flanks, it must be manually aligned by the operator so it is flat against the first tooth flank to be inspected. Then *GAMA* does the rest, automating the Barkhausen measurement process, displaying results



The GMS' surface finish measurement capability allows Allison to inspect this internal ring gear after finish shaping. Inspection parameters are selectable from a variety of industrial standards, and parameters such as Ra, Rq, Rz, and Rmax. Programming for this measurement as well is incorporated into the *GAMA* suite of software.

to the operator as the measurement progresses, and providing results in the desired format –a plot of all traces with the desired/appropriate BNA numbers for each trace. The results and probe alignment can be verified by comparing the Barkhausen measurements with a known artifact (master gear) or, where more detail is needed, as a "heat map," visually depicting grinding burn as a hot spot.

"What made us particularly confident in our purchase decision of the Gleason 350GMS was our familiarity with Gleason metrology equipment (legacy systems are in use throughout Allison, and several GMM and GMS models have been purchased for Allison's India operations), and the knowledge that Gleason has excellent software engineering," recalls Wilkerson. "We knew they had good people to help us with the integration of Barkhausen and surface finish measurement."



Barkhausen inspection results: measurements comparing the actual part with an artifact that has grind burn (top). A detailed heat map (below) can be produced by using 16 traces per tooth flank. This pictorial analysis shows grind burn as hot spots.

Gleason Regional Sales Manager for Metrology Products Dave Taylor concurs. "The successful integration of Barkhausen analysis and internal surface finish inspection into the 350GMS is an example of our ability to meet ever-changing customers' needs with our resident staff of software and hardware engineers. We relish opportunities such as this."

Surface finish measurement. The TC10's higher gear quality requirements have even extended into surface finish – yet another reason the Gleason GMS has made so much sense for Allison, according to Wilkerson. The GMS has the capability to perform a wide range of surface roughness measurements and thus eliminate the setup time and additional equipment expense usually required when performing this inspection off-line. For Allison, this means that meeting the new surface finish inspection requirements for an internal ring gear after the finish shaping operation is all in a day's work. "The GMS works particularly well because with surface finish you always want to check perpendicular to the lines of finish and in the case of shaping these are axial lines, so we're checking from root to tip along the involute – a natural path for the GMS," she says. "The movements of the machine inherently ensure measurement reliability."

Commercially available probe styli are used, with choices to meet the tolerances of most required roughness parameters including Ra, Rq, Rz and Rmax. As with the Barkhausen inspection, programming for this measurement is incorporated into the *GAMA* suite of software, and results are made available on screen as well as in printed reports.

Finally, Wilkerson points out that, despite the array of different inspection tasks the GMS can perform, surprisingly few special arbors and fixtures are required. "The machine with its 3-D probes and journal reference software, working in combination with the 3-jaw chuck, allow us to set it up for almost any application without additional tooling, and this includes measurement of all purchased gears.

"At the end of the day, we're getting a lot of extra mileage out of the 350GMS."

(From left to right) Gleason Metrology Systems' Dave Taylor, with Allison Transmission's Ann Wilkerson and Paul Marshall.

For more information:

Gleason Metrology Systems Corporation
Phone: (585) 473-1000
Fax: (585) 461-4348
www.gleason.com

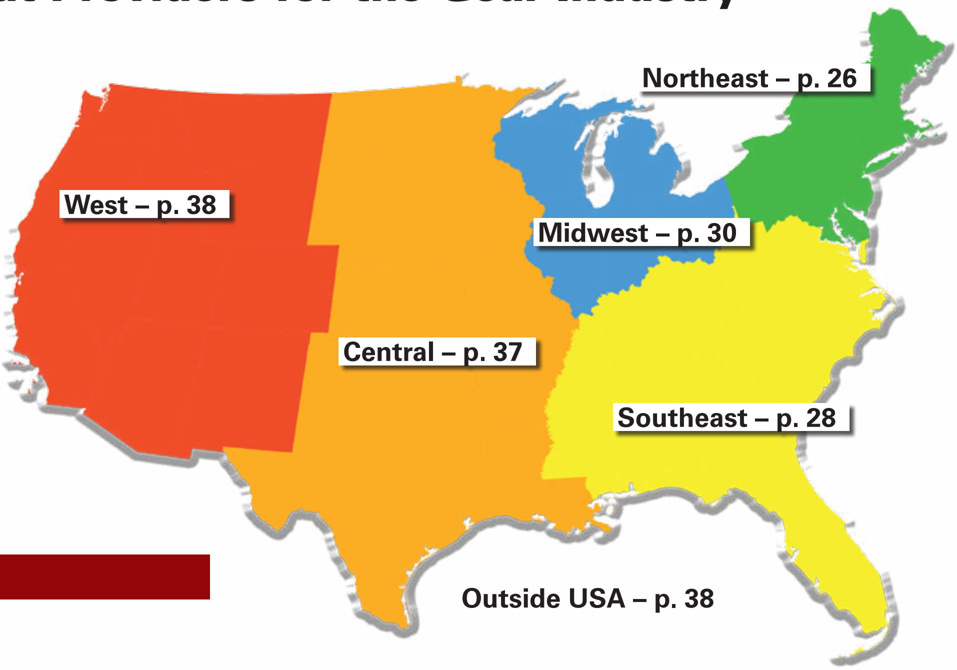
Gear Industry Heat Treat Resource Guide

Commercial Heat Treat Providers for the Gear Industry

Heat treating is one of the most critical operations in the manufacture of quality gears. Everything can be done to perfection, but if the heat treating isn't right, all of your hard work and efforts are wasted. We know how important it is for gear manufacturers to find the right heat treating service provider. That's why we've compiled this Heat Treat Resource Guide—the only directory of heat treat service providers that's specific to the gear industry. The companies listed here are all interested in working with gear manufacturers, and many of them have specialties and capabilities that are uniquely suited to the types of products you manufacture.

In order to help you quickly find the best heat treater who is closest to home, we've organized the guide into geographic regions. Use the map on this page to find the appropriate page number in the guide.

If your company provides commercial heat treating services but is not listed, please visit *www.geartechnology.com/getlisted.php*.



NORTHEAST

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Ivyland, PA - (215) 674-8120
www.bennettheat.com

Bennett Heat Treating and Brazing is a full in-process service company, servicing the complete metal working industry.

Categories: Age Hardening, Aluminum Treating, Annealing, Black Oxiding, Blast Cleaning, Brazing, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Flame Hardening, Hot Oil Quenching, Induction Hardening, Nitriding, Nitrocarburizing, Normalizing, Press Quenching, Sintering, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Bluewater Thermal Solutions
St. Mary's, PA - (814) 781-6262
Bluewaterthermalsolutions.com

Bluewater Thermal Solutions provides a wide variety of thermal processing for steel, stainless steel, cast irons, powder metals, titanium, aluminum, nickel-based alloys, and non-metallic materials.

Categories: Age Hardening, Annealing, Boronizing, Brazing, Carbonitriding, Carburizing, Induction Hardening, Other Heat Treating Services, Stress Relieving, Tempering, Vacuum Treating.

Bodycote Thermal Processing
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Cryogenic Institute of New England, Inc.
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ElectroHeat Induction
Jersey City, NJ - (908) 494-0726
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Electroheat Induction is a provider of custom induction melting furnaces, induction heating and hardening equipment, and pipe heating quality products.

Categories: Aluminum Treating, Induction Hardening.

Flame Treating & Engineering Co.
West Hartford, CT - (860) 953-3519
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Categories: Flame Hardening, Induction Hardening, Tempering.

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Categories: Carbonitriding, Carburizing, Cryogenics, Die Quenching, Flame Hardening, Hot Oil Quenching, Induction Hardening, Normalizing, Other Heat Treating Services, Stress Relieving, Tempering, Vacuum Treating.

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Metal Improvement Company
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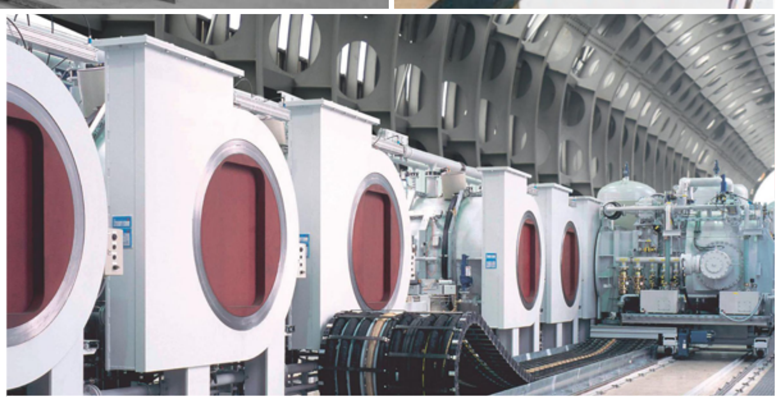
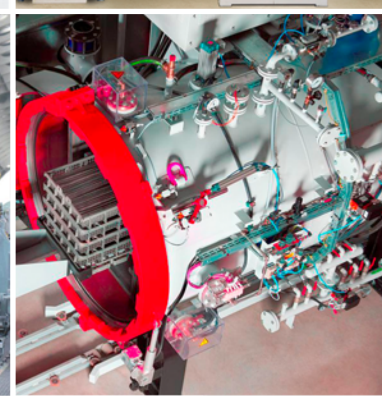
www.metalimprovement.com

Metal Improvement Company provides precision metal finishing services for gears, including shot peening, superfinishing, laser peening, heat treating and coating.





Categories: Aluminum Treating, Annealing, Austempering, Black Oxiding, Carbonitriding, Carburizing, Flame Hardening, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Salt Bath Nitriding, Straightening, Stress Relieving, Vacuum Treating.

Metallurgical Processing, Inc.
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Hardening and softening of parts for both wear resistance and machinability, as well as PVD coating, cold treating, and variety of support services.

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Metlab
Wyndmoor, PA - (215) 233-2600
www.metlabheattreat.com

Metlab heat treats gears to 15' in diameter. Processes: Carburizing, nitriding, hardening, induction

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Penna Flame Industries
Zelienople, PA - (800) 245-5084
www.pennaflame.com

Penna Flame Industries offers surface hardening and flame hardening processes.

Categories: Cryogenics, Flame Hardening, Induction Hardening, Straightening, Stress Relieving, Tempering,.

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Categories: Age Hardening, Annealing, Black Oxiding, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Induction Hardening, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Stress Relieving, Tempering, Vacuum Treating.

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Rex Heat Treat
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Categories: Age Hardening, Annealing, Brazing, Carburizing, Ion Nitriding, Nitriding, Normalizing, Other Heat Treating Services, Sintering, Stress Relieving, Tempering, Vacuum Treating.

Specialty Steel Treating Inc.
East Granby, CT - (860) 653-0061
www.specialtysteeltreating.com

Specialty Steel Treating, founded 1956, has been performing precision heat treating for more than 40 years.

Categories: Brazing, Carbonitriding, Carburizing, Cryogenics, Hot Oil Quenching, Nitriding, Normalizing, Stress Relieving, Vacuum Treating.

Spectrum Thermal Processing
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Categories: Age Hardening, Annealing, Brazing, Carburizing, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Stress Relieving, Tempering, Vacuum Treating.

SOUTHEAST

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Categories: Age Hardening, Annealing, Black Oxiding, Carbonitriding, Carburizing, Induction Hardening, Ion Nitriding, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Plasma Carburizing, Stress Relieving, Tempering, Vacuum Treating.

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Conyers, GA - (770) 922-3954
Princeton, KY - (270) 365-0100
Reidsville, NC - (336) 342-0308
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www.bodycote.com

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Deep Cryogenic Treatment (DCT) for wear resistance.

Categories: Cryogenics.

Extremeion Hard Carbon
Denver, NC - (704) 489-1488
www.CarbonRaptor.com

Hard carbon coatings, PACVD friction reduction, part longevity for steel, titanium, aluminum, and various other metals.

Categories: Aluminum Treating.

Flame Treating Systems, Inc.
Durham, NC - (919) 956-5208
www.flametreatingsystems.com

Custom Flame Heat Treating solutions for all sizes of gears, sprockets, shafts and splines.

Categories: Annealing, Brazing, Flame Hardening.

Ionic Technologies Inc.
Greenville, SC - (864) 288-9111
www.ionic-tech.com

Categories: Cryogenics, Nitriding, Vacuum Treating.

Mid-South Metallurgical
Murfreesboro, TN - (615) 896-6212
www.midsouthmetallurgical.com

Since 1985, Mid-South Metallurgical has provided customers with precision and specialty heat treating services.

Categories: Age Hardening, Aluminum Treating, Annealing, Austempering, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Flame Hardening, Induction Hardening, Ion Nitriding, Nitrocarburizing, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Oerlikon Balzers
Pell City, AL - (205) 884-1210
www.oerlikon.com

Oerlikon Balzers is one of the world's leading suppliers of surface technologies that significantly improve the performance and durability of precision components as well as tools.

Categories: Ion Nitriding, Nitriding.

Paulo Products Company
Murfreesboro, TN - (615) 896-1385
Nashville, TN - (615) 228-2526
www.paulo.com

Paulo provides innovative engineered solutions in heat treating, brazing and metal finishing.

Categories: Age Hardening, Aluminum Treating, Annealing, Austempering, Black Oxiding, Blast Cleaning, Boronizing, Brazing, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Flame Hardening, Hot Oil Quenching, Induction Hardening, Ion Nitriding, Laser Hardening, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Plasma Carburizing, Press Quenching, Salt Bath Nitriding, Sintering, Steam Treating, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Progressive Heat Treating Co.
Chester, VA - 804-717-5353
www.pecgears.com

Vacuum Heat Treating, including Ion nitriding.

Categories: Age Hardening, Aluminum Treating, Annealing, Carbonitriding, Carburizing, Cryogenics, Hot Oil Quenching, Induction Hardening, Ion Nitriding, Stress Relieving, Tempering, Vacuum Treating.

Rex Heat Treat
Anniston, AL - (800) 229-4739
rexht.com

Commercial Heat Treater serving a range of industries from aerospace and automotive to construction and defense.

Categories: Age Hardening, Annealing, Austempering, Carbonitriding, Carburizing, Cryogenics, Hot Oil Quenching, Nitrocarburizing, Normalizing, Stress Relieving, Tempering.

Thermal Braze, Inc.
Jupiter, FL - (561) 746-6640

We do heat treating, furnace brazing in vacuum and hydrogen, annealing, silver soldering, assembly.

Categories: Age Hardening, Annealing, Brazing, Cryogenics, Stress Relieving, Tempering, Vacuum Treating.

Woodworth Heat Treating
Ashland, VA - (804) 412-0206
www.woodworthheattreat.com

Categories: Nitriding, Vacuum Treating.

Zion Industries
Hildebran, North Carolina 828-397-2701 - (330) 483-4650
www.zioninduction.com

We are a TS-16949 Certified induction heat treater with plants in Michigan, Ohio and North Carolina.

Categories: Induction Hardening, Straightening.

MIDWEST

300 Below Inc.
Decatur, IL - (217) 520-3335
300Below.com

Deep Cryogenic Processing and Tempering, Stress Relief and Stabilization, Corrosion Resistance.

Categories: Age Hardening, Blast Cleaning, Cryogenics, Stress Relieving, Tempering.

Accu-Temp Heat Treating
Racine, WI - (262) 634-1905
www.accutempheat.com

Categories: Annealing, Austempering, Black Oxiding, Carbonitriding, Carburizing, Cryogenics, Flame Hardening, Nitriding, Nitrocarburizing, Normalizing, Salt Bath Nitriding, Straightening, Stress Relieving .

Advanced Heat Treat Corp.
Monroe, MI - (734) 243-0063
www.ahtweb.com

AHT is a recognized leader in providing heat treat services and superior metallurgical solutions.

Categories: Age Hardening, Annealing, Black Oxiding, Carbonitriding, Carburizing, Induction Hardening, Ion Nitriding, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Plasma Carburizing, Stress Relieving, Tempering, Vacuum Treating. Advanced Nitriding Solutions
Batesville, IN - (812) 932-1010
www.ans-ion.net

ANS specializes in pulse plasma "ion" nitriding.

Categories: Carbonitriding, Ion Nitriding, Nitriding, Nitrocarburizing.

Aichelin Heat Treatment Systems, Inc.
Plymouth, MI - (734) 459-9850
www.aichelinusa.com

Low Pressure Carburization, High Efficiency/Low NOx Burner Systems, Induction Hardening and Specialized Quenching Techniques.

Categories: Annealing, Austempering, Carbonitriding, Carburizing, Die Quenching, Hot Oil Quenching, Induction Hardening, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Press Quenching, Stress Relieving, Tempering.

Ajax Tocco Magnethermic Corp.
SEE OUR AD P34
Warren, OH - 800-547-1527
ajaxtocco.com

Ajax TOCCO Magnethermic Corp. is a world leader in the induction heating, melting and forging industries.

Categories: Induction Hardening, Tempering.

Akron Steel Treating Company
Akron, OH - (330) 773-8211
www.akronsteeltreating.com

Full service heat treating provider and metallurgical service provider. Since 1943. IntensiQuench licensee.

Categories: Age Hardening, Aluminum Treating, Annealing, Austempering, Black Oxiding, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Hot Oil Quenching, Nitrocarburizing, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering, Vacuum Treating.

ALD Thermal Treatment, Inc.

Port Huron, MI - (810) 357-0682
www.aldtt.net

ALD Thermal Treatment is the premier source for vacuum heat treatment services to the precision manufactured component segment.

Categories: Age Hardening, Annealing, Blast Cleaning, Brazing, Carbonitriding, Carburizing, Cryogenics, Normalizing, Plasma Carburizing, Stress Relieving, Tempering, Vacuum Treating.

American Metal Treating Co.

Cleveland, OH - (216) 431-4492
americanmetaltreating.com

Gear induction hardening experts. Tooth-by-tooth hardening from .66 DP to 10 DP.

Categories: Induction Hardening.

Applied Process

Livonia, MI - (734) 464-8000
www.appliedprocess.com

Applied Process is a world leader in austempering technology.

Categories: Austempering.

Applied Thermal Technologies

Warsaw, IN - (574) 269-7116
www.appliedthermaltechnologies.com

Since 1992 Applied Thermal Technologies, Inc. has focused on servicing the medical, orthopedic, aerospace, military, food handling, and stamping industries.

Categories: Age Hardening, Annealing, Brazing, Carbonitriding, Other Heat Treating Services, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Bluewater Thermal Solutions

South Bend, IN - (574-232-3338
Benton Harbor, MI - (269-925-6581
Northlake, IL (2 plants) - (708) 410-8000
Melrose Park, IL - (864) 990-0050
Rockford, IL - (815) 397-5424
Saginaw, MI - (989) 753-7770
Coldwater, MI - (517) 279-4981
Bluewaterthermalsolutions.com

Bluewater Thermal Solutions provides a wide variety of thermal processing for steel, stainless steel, cast irons, powder metals, titanium, aluminum, nickel-based alloys, and non-metallic materials.

Categories: Age Hardening, Annealing, Boronizing, Brazing, Carbonitriding, Carburizing, Induction Hardening, Other Heat Treating Services, Stress Relieving, Tempering, Vacuum Treating.

Bodycote Thermal Processing

Melrose Park, IL - (708) 344-4080
Indianapolis, IN - (317) 924-4321
Fort Wayne, IN - (260) 423-1691
Greensburg, IN - (812) 663-4114
Elkhart, IN - (574) 295-2491
Canton, MI (Ronda Drive) - (734) 459-8514
Canton, MI (Haggerty Road) - (734) 233-8847
Livonia, MI - (734) 427-6814
Grand Rapids, MI - (616) 245-0465
Holland, MI - (616) 399-6880
Cincinnati, OH - (513) 921-2300
Highland Heights, OH - (440) 473-2020
London, OH - (740) 852-5000
Columbus, OH - (614) 444-1181
New Berlin, WI - (262) 782-5553
Sturtevant, WI - (262) 554-8770
www.bodycote.com

Bodycote offers an extensive range of heat treatment services. Our facilities process a wide variety of component sizes to exacting standards with reliable, repeatable results.

Categories: Age Hardening, Annealing, Austempering, Blast Cleaning, Brazing, Carbonitriding, Carburizing, Cryogenics, Hot Oil Quenching, Nitriding, Nitrocarburizing, Normalizing, Stress Relieving, Vacuum Treating.

BOS Services Company
Willoughby, OH - (440) 946-5101
http://bosservicesheattreating.com

Heat treat and metal cleaning.

Categories: Tempering.

Calumet Surface Hardening
Hammond, IN - (219) 844-5600

Flame hardening and straightening of steel, some induction hardening.

Categories: Carburizing, Flame Hardening, Induction Hardening, Straightening.

Chicago Flame Hardening
East Chicago, IN - (219) 397-6475
www.cflame.com

Flame hardening, stress relieving, mechanical straightening.

Categories: Flame Hardening, Straightening, Stress Relieving.

Cincinnati Steel Treating Co.
Cincinnati, OH - (513) 271-3173
www.steeltreating.com

We are a full service Heat Treating Co. We process several thousand parts to just one small part.

Categories: Age Hardening, Aluminum Treating, Annealing, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Flame Hardening, Induction Hardening, Nitriding, Nitrocarburizing, Normalizing, Press Quenching, Straightening, Stress Relieving, Tempering.

Clifford-Jacobs Forging
Champaign, IL - (217) 352-5172
www.clifford-jacobs.com

Closed-die custom forging producer of gear blanks up to 30 inches in diameter and/or 50 inches in length. Heat treating and rough machining.

Categories: Annealing, Normalizing.

Complete Heat Treating
Milwaukee, WI - (414) 643-5161
completeht.com

Quenching to 22' × 22' × 13' deep and 100,000 lbs. Furnaces to 53'L × 22'W × 15'H. Polymer & water quenching.

Categories: Age Hardening, Aluminum Treating, Annealing, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving.

Contour Hardening, Inc.
Indianapolis, IN - (317) 876-1530
Contour de Mexico Silao Mexico, - (317) 876-1530
www.contourhardening.com

Provider of induction equipment and services. Contract induction heat treat.

Categories: Induction Hardening, Stress Relieving, Tempering.

Controlled Thermal Processing, Inc.
Antioch, IL - (847) 651-5511
Park City, IL - (847) 651-5511
www.metal-wear.com

Deep Cryogenic Treatment (DCT) for wear resistance.

Categories: Cryogenics.

Cryoplus Inc.
Wooster, OH - (330) 683-3375
www.cryoplus.com

Categories: Cryogenics.

Dayton Forging & Heat Treating Company
Dayton, OH - (937) 253-4126
www.daytonforging.com

Custom tailored processing of parts to meet your requirements. Oil and water quenching available.

Categories: Age Hardening, Annealing, Blast Cleaning, Carbonitriding, Carburizing, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering.

Detroit Steel Treating Co.
Pontiac, MI - (248) 334-7436

Controlled atmosphere for neutral, carburize and carbo-nitride processing.

Categories: Age Hardening, Aluminum Treating, Annealing, Black Oxiding, Blast Cleaning, Carbonitriding, Carburizing, Flame Hardening, Hot Oil Quenching, Normalizing, Straightening, Stress Relieving, Tempering.

Duffy Company, The
Palatine, IL - (847) 202-0000
www.duffycompany.com

For over 30 years The Duffy Company has been the exclusive North American distributors of Condursal stop-off paints to the Heat Treating Industry

Categories: Stop-off Paints.

East-Lind Heat Treat, Inc.
Madison Heights, MI - (248) 585-1415
www.eastlind.com

Carburize/Quench/Temper. Specializing in gear specs - AGMA, AMS, Axletech, Dana, Deere, Eaton, GQS-2, etc.

Categories: Age Hardening, Aluminum Treating, Annealing, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Flame Hardening, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering, Vacuum Treating.

EFD Induction Inc.
Madison Heights, MI - (248) 658-0700
www.efdinduction-usa.com

Inventor of the dual frequency hardening power supplies, it propose a whole range of solutions for gear hardening.

Categories: Die Quenching, Induction Hardening.

Eldec Induction USA, Inc.
Auburn Hills, MI - (248) 364-4750
www.eldec-usa.com

Specializing in SIMULTANEOUS DUAL FREQUENCY hardening systems which can eliminate distortion problems associated with carbonization.

Categories: Annealing, Austempering, Brazing, Induction Hardening, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering.

Eltro Services, Inc.
Oxford, MI - (248) 628-9790
www.eltroservices.com

Eltro Services, Inc. uses patented pulsed ion nitriding furnaces to provide superior surface engineering solutions at the lowest possible cost.

Categories: Age Hardening, Black Oxiding, Carbonitriding, Ion Nitriding, Nitriding, Nitrocarburizing, Other Heat Treating Services, Plasma Carburizing, Steam Treating, Stress Relieving, Tempering, Vacuum Treating.

Engineered Heat Treat, Inc.
Madison Heights, MI - (248) 588-5141
www.ehtinc.com

We were founded in 1959 and provide a variety of heat treating services to the aircraft, agriculture, automotive, high-performance racing, military and tooling industries.

Categories: Age Hardening, Annealing, Austempering, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Hot Oil Quenching, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Press Quenching, Salt Bath Nitriding, Straightening, Stress Relieving, Tempering, Vacuum Treating.

ERS Engineering Corp.
West Bloomfield, MI - (248) 538-9082
www.ersengine.com

ERS is the exclusive distributor in N. America of Techmash (Moscow) through surface hardening technique.

Categories: Induction Hardening.

Euclid Heat Treating Company, The
Euclid, OH - (216) 481-8444
www.euclidheattreating.com

Neutral harden, carburize, ferritic, nitride, induction, vacuum, Intensiquench, Endocarb, XRF test

Categories: Age Hardening, Aluminum Treating, Annealing, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Induction Hardening, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Press Quenching, Straightening, Stress Relieving, Tempering, Vacuum Treating.

FPM Heat Treating
Elk Grove Village, IL - (847) 228-2525
Cherry Valley, Il (815) 332-4961 - (847) 228-2525
Milwaukee, WI (414) 355-7900 - (847) 228-2525
www.fpmht.com

Full range of commercial heat treating services with focus on carburizing, Nitrotec& hardening.

Categories: Age Hardening, Annealing, Austempering, Blast Cleaning, Brazing, Carbonitriding, Carburizing, Hot Oil Quenching, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering, Vacuum Treating.

General Metal Heat Treating, Inc.
Cleveland, OH - (216) 391-0886
www.generalmetalheat.com

NADCAP and AS9100 certified. Carburizing, hardening, normalizing, annealing. Batch, salt, pit and vacuum.

Categories: Age Hardening, Annealing, Austempering, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Hot Oil Quenching, Nitriding, Nitrocarburizing, Normalizing, Stress Relieving, Tempering, Vacuum Treating.

General Surface Hardening Inc.
Chicago, IL - (312) 226-5472
gshinc.net

GSH has worked with the "Top" gear engineers in the United States and Europe. Gears Up to 20,000 lbs.

Categories: Age Hardening, Annealing, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Flame Hardening, Induction Hardening, Normalizing, Straightening, Stress Relieving, Tempering.

Heat Treating Services Corporation of America
Pontiac, MI - (248) 858-2230
Waterford, MI – (248) 858-2230
Pontiac, MI (2 plants) - (248) 858-2230
Homer, MI - (248) 858-2230
www.htsmi.com

TS-QS-CQI-9. Heat treating of 40M lbs/month at five plants. Castings & forgings prior to machining via normalizing/annealing & oil quench & temper.

Categories: Annealing, Blast Cleaning, Normalizing, Other Heat Treating Services.

Hi TecMetal Group
Cleveland, OH (HQ) - (216) 881-8100
Cleveland, OH (Brazing & Metal Treating) - (216) 881-8100
Cleveland, OH (Brite Brazing) - (216) 426-6650
Cleveland, OH (Commercial Induction) - (216) 883-4820
Cleveland, OH (Walker Heat Treating) - (216) 941-0440
Eastlake, OH - (440) 946-2280
Wickliffe, OH - (440) 943-4555
www.htg.cc

Provides induction and furnace heat treating services to the gear industry.

Categories: Annealing, Blast Cleaning, Brazing, Carbonitriding, Carburizing, Induction Hardening, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Vacuum Treating.

Horsburgh & Scott Co.
Cleveland, OH - (216) 431-3900
www.horsburgh-scott.com

Horsburgh & Scott offers complete captive and commercial heat treating services out of a 50,000 sq ft facility.

Categories: Annealing, Carburizing, Hot Oil Quenching, Normalizing, Stress Relieving, Tempering.

Hudapack Metal Treating
Elkhorn, WI - (262) 723-3345
Franklin, WI - (414) 421-5140
Glendale Heights, IL - (630) 858-0505
www.hudapack.com

We offer a large array of heat treat capabilities to meet many customer needs.

Categories: Age Hardening, Aluminum Treating, Annealing, Austempering, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Flame Hardening, Hot Oil Quenching, Induction Hardening, Nitrocarburizing, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Induction Hardening Specialists
Peninsula, OH - (330) 315-8129
inductionhardeningspecialists.com

Specialists in single tooth contour gear hardening. AGMA pattern "A."

Categories: Induction Hardening.

Induction Resources
Canton, MI - (734) 776-1026

Induction consulting, project management, development, process troubleshooting and heat audits, CQI-9.

Categories: Annealing, Austempering, Brazing, Induction Hardening, Press Quenching, Stress Relieving, Tempering.

Induction Services, Inc.
Warren, MI - (586) 754-1640
www.inductionservicesinc.com

Provider of induction hardening services.

Categories: Induction Hardening.

Induction Tooling, Inc.
North Royalton, OH - (440) 237-0711
www.inductiontooling.com

We specialize in the design, build and repair of inductors used in the induction hardening process.

Categories: Induction Hardening.

Inductoheat Inc.
SEE OUR AD P29
Madison Heights, MI - (248) 585-9393
www.inductoheat.com

We design & build heat treating equipment & power supplies for heating a wide range of parts including gears & sprockets.

Categories: Annealing, Brazing, Induction Hardening, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering.

Ipsen, Inc.
SEE OUR AD INSIDE BACK COVER
Cherry Valley, IL - (800) 727-7625
www.IpsenUSA.com

Ipsen, Inc. designs and manufactures thermal processing systems (vacuum heat treat furnaces and atmosphere heat treat furnaces) for a wide variety of markets.

Categories: Age Hardening, Aluminum Treating, Annealing, Austempering, Brazing, Carbonitriding, Carburizing, Hot Oil Quenching, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Sintering, Stress Relieving, Tempering, Vacuum Treating.

Kowalski Heat Treating
Cleveland, OH - (216) 631-4411
www.khtheat.com

Specializing in the PIA (pain in the @#$) jobs! Salt to Salt - Heat set flatten - ION Nitriding.

Categories: Age Hardening, Annealing, Austempering, Blast Cleaning, Cryogenics, Die Quenching, Ion Nitriding, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Press Quenching, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Lambda Technologies
Cincinnati, OH - (513) 561-0883
www.lambdatechs.com

We specialize in metal improvement and surface enhancement techniques, such as low plasticity burnishing (LPB™).

Categories: Stress Relieving.

Magnum Induction
New Baltimore, MI - (586) 716-4700
www.magnuminduction.com

Induction Heat Treating large and unique part configurations.

Categories: Induction Hardening, Stress Relieving, Tempering.

Midwest Thermal-Vac Inc.
SEE OUR AD P35
Kenosha, WI - (262) 605-4848
www.mtvac.com

MTV Premier Vacuum Facility specializing in Vacuum Carburizing with both HPGQ and vacuum oil quench.

Categories: Age Hardening, Annealing, Austempering, Blast Cleaning, Brazing, Carbonitriding, Carburizing, Cryogenics, Flame Hardening, Hot Oil Quenching, Induction Hardening, Ion Nitriding, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Nitrex Inc.
Franklin, IN - (317) 346-7700
Aurora, IL - (630) 851-5880
Mason, MI - (517) 676-6370
www.nitrex.com

NITREX improves the properties of metals, extending the life of gears for a wide range of industries

Categories: Age Hardening, Annealing, Austempering, Black Oxiding, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Hot Oil Quenching, Ion Nitriding, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Plasma Carburizing, Press Quenching, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Ohio Vertical Heat Treat
Cleveland, OH - (216) 965-0124
www.ov-ht.com

Vertical processing of parts that are up to 72" in diameter and 192" long.

Categories: Age Hardening, Aluminum Treating, Annealing, Austempering, Carburizing, Hot Oil Quenching, Normalizing, Other Heat Treating Services, Straightening, Stress Relieving, Tempering.

Paulo Products Company
Willoughby, OH - (440) 946-5900
www.paulo.com

Paulo provides innovative engineered solutions in heat treating, brazing and metal finishing.

Categories: Age Hardening, Aluminum Treating, Annealing, Austempering, Black Oxiding, Blast Cleaning, Boronizing, Brazing, Carbonitriding, Carburizing, Cryogenics, Die Quenching, Flame Hardening, Hot Oil Quenching, Induction Hardening, Ion Nitriding, Laser Hardening, Nitriding, Nitrocarburizing, Normalizing, Other Heat Treating Services, Plasma Carburizing, Press Quenching, Salt Bath Nitriding, Sintering, Steam Treating, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Pillar Induction
Brookfield, WI - (262) 317-5300
www.pillar.com

Manufactures services & supports induction heating and coreless melting systems for a variety of metal and material thermal processing.

Categories: Brazing, Induction Hardening.

Precision Heat Treating Co.
Kalamazoo, MI - (269) 382-4660
www.precisionheat.net

Commercial heat treating services since 1948.

Categories: Annealing, Carbonitriding, Carburizing, Induction Hardening, Other Heat Treating Services, Stress Relieving, Tempering.

Precision Heat Treating Corporation
Fort Wayne, IN - (260) 749-5125
www.phtc.net

Batch Furnace (Q&T, Carbonitride, Carburize), Induction and Vacuum Tool Steel Heat Treating.

Categories: Age Hardening, Annealing, Carbonitriding, Carburizing, Induction Hardening, Nitriding, Normalizing, Stress Relieving, Tempering, Vacuum Treating.

Precision Thermal Processing
Clintonville, WI - (715) 701-0971
www.precisionthermal.com

Carburize of gears and pinions; Quench & Temper of various machined products; A2LA Lab Services.

Categories: Age Hardening, Annealing, Blast Cleaning, Boronizing, Carburizing, Cryogenics, Induction Hardening, Normalizing, Straightening, Stress Relieving, Tempering, Vacuum Treating.

Preco, Inc.
Somerset, WI - (715) 247-3285
www.precoinc.com

Laser welding: fast, accurate, dissimilar materials, little distortion & complex gear mfg. costs decreased.

Categories: Laser Hardening.

Pro-Beam USA
Aurora, IL - (312) 953-8083
www.pro-beam.com

Gear Welding, EB Drilling, Metal Washing. Integrated design transmission and gear system assembly line design, Hysteresis heat treatment. Lasers and Consultation.

Categories: Aluminum Treating, Brazing, Induction Hardening, Laser Hardening, Other Heat Treating Services, Vacuum Treating.

Rockford Heat Treaters
Rockford, IL - (815) 874-0089
www.rockfordheattreaters.com

Categories: Annealing, Carbonitriding, Carburizing, Flame Hardening, Induction Hardening, Nitriding, Sintering, Stress Relieving, Vacuum Treating.

Rubig US, Inc.
Rockford, IL United States - (779) 500-0269
www.rubig.com

Categories: Nitriding, Vacuum Treating.

Sedlock Companies - Euskal Forging
Wales, WI - (262) 968-3900
www.sedlockcompanies.com

U.S. sales representation of Euskal Forging.

Categories: Annealing, Austempering, Induction Hardening.

Specialty Heat Treating
Grand Rapids, MI - (616) 245-0465
Holland, MI - (616) 245-0465
Elkhart, IN - (616) 245-0465
www.specialtyheat.com

Specialty Steel Treating, founded 1956, has been performing precision heat treating for more than 40 years.

Categories: Age Hardening, Annealing, Black Oxiding, Brazing, Carbonitriding, Carburizing, Hot Oil Quenching, Nitriding, Nitrocarburizing, Normalizing, Plasma Carburizing, Vacuum Treating,

Specialty Steel Treating Inc.
Fraser, MI (2 plants) - (586) 293-5355
Farmington Hills, MI - (248) 478-5900
www.specialtysteeltreating.com

Specialty Steel Treating, founded 1956, has been performing precision heat treating for more than 40 years.

Categories: Brazing, Carbonitriding, Carburizing, Cryogenics, Hot Oil Quenching, Nitriding, Normalizing, Stress Relieving, Vacuum Treating.

Sun Steel Treating Inc.
South Lyon, MI - (877) 471-0840
www.sunsteeltreating.com

Since 1958, Sun Steel Treating Inc. has specialized in providing our customers precision and specialty Salt Bath Heat Treatments.

Categories: Age Hardening, Annealing, Die Quenching, Ion Nitriding, Nitriding, Normalizing, Other Heat Treating Services, Steam Treating, Straightening, Stress Relieving, Tempering.

SWD Inc.
Addison, IL - (630) 543-3003
www.swdinc.com

SWD Inc specializes in metal finishing and self- lubricating coatings. Our services include: Black Oxide, Passivation of Stainless Steel, Moly Disulfide or Moly Coat, Manganese Phosphate, Cleaning and Pickling.

Categories: Black Oxiding.

Thermtech
Waukesha, WI - (262) 549-1878
www.thermtech.net

Categories: Annealing, Blast Cleaning, Carbonitriding, Carburizing, Cryogenics, Flame Hardening, Nitriding, Other Heat Treating Services, Straightening, Stress Relieving.

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CENTRAL

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Wichita, KS (McLean Plant) - (316) 267-0239
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Categories: Cryogenics.

Flame Metals Processing Corporation
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Categories: Die Quenching, Flame Hardening, Hot Oil Quenching, Induction Hardening, Laser Hardening, Press Quenching.

Portable Gear Inspection

R&P Metrology Measures Directly on the Production Machine

Matthew Jaster, Senior Editor

Compact, custom and portable solutions are gaining more attention in manufacturing today as companies seek out the tools that offer the greatest productivity gains on the shop floor. Gear inspection seems to be following suit. R&P Metrology (partnered with Kapp Technologies in the United States), offered a first look at its portable measuring equipment for large gears last fall at Gear Expo in Indianapolis.

Since Gear Expo, the company has been adding new measurement capabilities for the RPG PM 750/1250 Portable Gear Metrology machines. They are capable of a full range of 3-D prismatic metrology when used with the available docking station and can perform CMM measuring tasks with full CNC control and lab grade accuracy.

According to Hans Rauth, president of R&P Metrology, "The docking station, with the extremely accurate rotary table, extends the use of the PM system beyond the plant floor, to the inspection lab. Not only can it use generative metrology for gear inspection, it can become a precise CMM with the customer's choice of software." All R&P Metrology systems adhere to the I++ (Inspection Plus-Plus) protocol and can utilize any CMM software that is compliant, such as Wenzel and Zeiss. "When used as a portable system, the PM 750/1250 can measure gears of unlimited size," Rauth adds.

Rauth is enthusiastic about the potential for integrating inspection equipment throughout the machine shop. "The PM portable machines allow accurate independent inspections, with industry accepted reports. This translates into time savings because there is no need to realign gears taken out for external inspection. Because the system can be used on different machines, higher accuracy and quality assurance is achieved across the whole shop, all for a reasonable investment," Rauth says. "Integrated in-process inspection as part of the manufacturing plan for larger gears is now achievable. There is now the chance to upgrade older machines with no onboard inspection."

With the unique needs of each customer, many solutions require more than an off-the-shelf CMM. R&P specializes in custom equipment and works to develop a measuring solution that best fits the customer's machine requirements as well as their budget.

"With intense contact with customers, new ideas based on the variety of gears and existing facilities are the real drivers for the custom machines. Working with large set of "modules" and technologies at R&P, new functions such as surface finish and Barkhausen inspection can be added to gear measuring systems as needed. Economic factors drive customers to get exactly what they need and not to overbuy."

Flexibility is equally important. "Inspection of large gears has more factors to consider. Mass, inertia, fixturing, accessibility to references, loading/unloading, and integration to existing plants are only a few aspects. R&P offers a unique solution to every customer, in effect allowing the customer to design what best fits the needs," Rauth adds.

With the full integration of the rotary table, the RPC, for example, represents a convergence of technology yielding a universal metrology system encompassing high accuracy roundness/form/profile measurements, as well as "no compromise" generative gear inspection and 3-D CMM measurements. "With one setup, a part's gear features as well as all 3-D CMM measurements can be accom-

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plished with real inspection software and charts and real CMM software and outputs," Rauth says.

The PM 750 will be on display in September during IMTS 2014 in Chicago. "The focus is always on helping customers define their requirements and then designing and building systems that meet and exceed those needs," Rauth says. "Accurate mobile/portable inspection systems such as the R&P Metrology PM 750 can change how we look at gear metrology systems. When it is time for the replacement of older inspection machines, companies can now replace old machines at nearly the cost of a retrofit, and gain modern, state-of-the-art technology. With the high accuracy and flexibility of the RPC machines, gear shops without gear measuring machines now can get one machine to do both CMM 3-D measuring and generative gear inspection without compromise."

When a business invests, they want 100 percent of their needs met, according to Rauth. "They don't want, for example, to buy a larger machine than is needed if only one axis needs to be larger. So, custom and special machines will continue to gain momentum."

In gear metrology, the standard catalog is never enough. R&P recognizes this dynamic and has established a company and brand to meet the ever-changing needs of the gear customer.

"Our role is to be a niche supplier of custom and special machines – beyond the standard offerings of other manufacturers. We don't have a catalog of standard machines; rather, we offer platforms that are customized for each application ," Rauth adds.

For more information:

Kapp Technologies
Phone: (303) 447-1130
www.kapp-usa.com

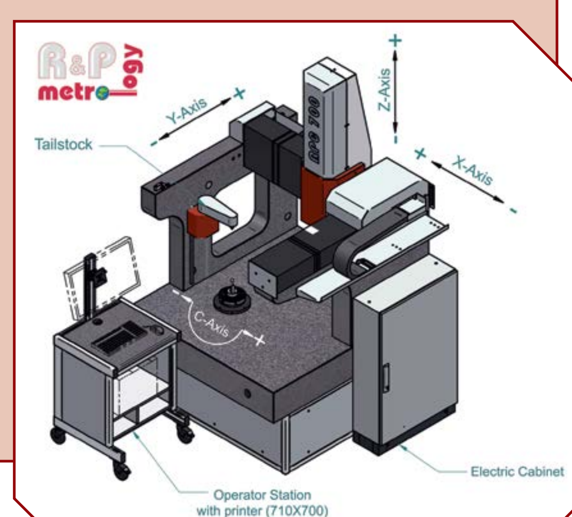
R&P Metrology
Phone: +(49) 7231 15404 0
www.rp-metrology.de

Product Round-Up

In addition to the portable gear inspection systems, R&P Metrology has added some significant offerings to the gear metrology market in 2014. Here's a quick rundown of some of the measuring equipment available to the industry today. Information on these and other products from R&P and Kapp Technologies will be available at Booth N-7036 during IMTS 2014 in Chicago.

RPC 700 Designed for Accurate Profile and Form Measurements

The RPC 700 is a new, smaller development based on well-proven technologies, extending the range of systems to meet customer requirements. It joins the RPC 1000 and the RPC 1600 in the R&P Metrology lineup of highly accurate systems capable of form, profile and generative gear inspection. The RPC 700 is designed for extremely accurate profile and form measurements on rotationally symmetrical workpieces, such as bearing rings and races, as well as demanding aerospace and cylindrical workpieces. According to Hans Rauth, president of R&P Metrology, "The RPC 700 is unique in the metrology world. This four axis machine utilizes the highly accurate air bearing, direct drive rotary table to measure form and profiles along with true generative gear measuring. The RPC 700 represents the perfect combination of metrological features." Rauth added, "Our use of linear motor technologies and granite air bearing guide elements provide wear-free, consistent and thermally stable measurements." All RPC systems are I++ compatible, allowing a variety of CMM software packages from various suppliers to be supported. A tailstock is offered as an option on the RPC 700.



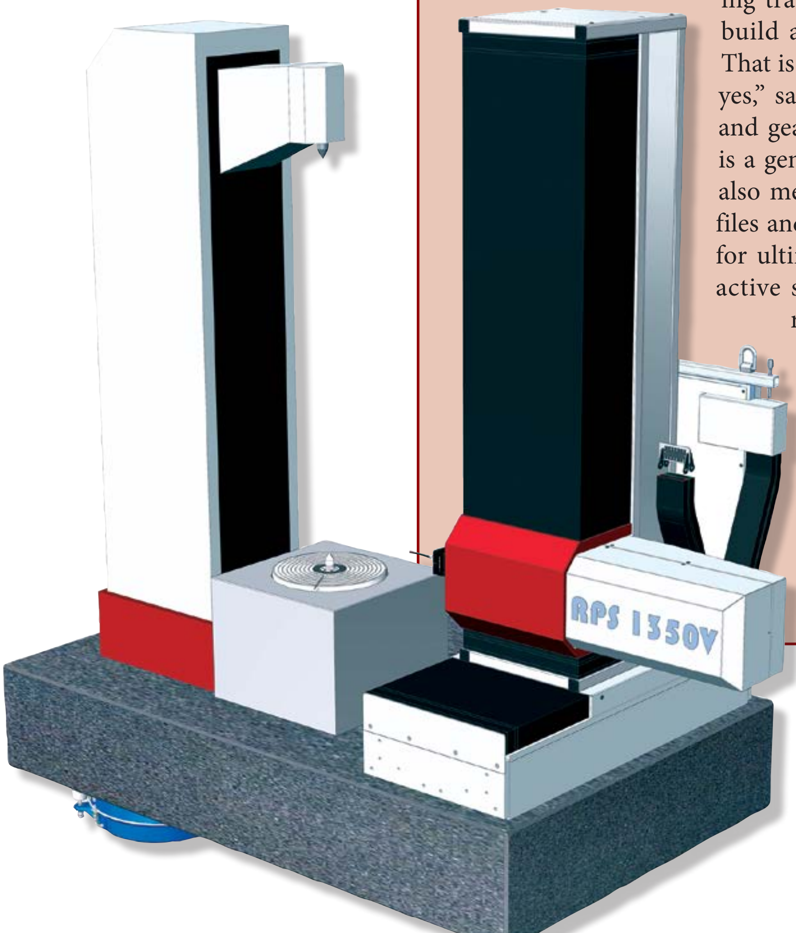
The RPC systems are now available in three standard sizes, with the RPC 700 able to accommodate workpieces up to 700 mm in diameter. The linear travels are X = 600 mm, Y = 700 mm and Z = 500 mm. Parts up to 300 kg are accommodated on the rotary table. The larger RPC 1600 handles 1,600 mm parts and increases the X-axis travel to 900 mm. Rauth notes that, "By understanding customer needs, R&P customizes these special machines." The RPC 1000 is also available, with a maximum diameter of 1,000 mm. "Of course," nearly any custom and special requirements can be met," Rauth says.

SMS Siemag Chooses R&P Metrology

SMS Siemag AG understands that to be competitive in today's global business requires state-of-the-art equipment and technology. In 2012, the company installed the R&P Metrology RPG 4000/5500 gear inspection machine. The ability to quickly and accurately measure large gears (up to 5,500 mm diameter, 40,000 kg max. weight) allows SMS Siemag to better meet the requirements of its customer base. Thanks to ease-of-operation and support from R&P Metrology, the investment in the RPG 4000/5500 will solidify SMS Siemag's position in the market.

R&P Offers Special Measuring System

Responding to specific customer requirements, R&P Metrology GmbH announced a new model in their full line of custom metrology systems, the RPS 1350V. Designed for ball screws and shaft parts, this system boasts capacity for 1,350 mm between centers and 1,300 mm of vertical measuring travel. "A customer asked if we could design and build an inspection system for their specific needs. That is what R&P Metrology does, so of course we said yes," says Rauth. "The customer produces ball screws and gears up to 600 mm in diameter. The RPS 1350V is a generative, four axis gear inspection machine, and also measures 3-D CMM type features as well as profiles and forms. The X, Y and Z axes use linear motors for ultimate precision. Since the machine rests on an active suspension system, no separate foundation is required. The high precision, air bearing rotary table is mounted on a granite bed and is driven directly by a torque motor." The RPS 1350V achieves the highest European class for inspection equipment accuracy: VDI/VDE 2612/13 Group I. Using an industry standard CNC control system, the RPS 1350V is I++ compliant, allowing the use of many CMM inspection packages.



Deciding When to Go Plastic

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

QUESTION

Can my metal gear(s) be replaced with plastic gears?

Expert Response Provided by Joseph L. Elmquist, R&D designer, Kleiss Gears:

As specialists in the design, manufacture, and inspection of polymer injection-molded gears, we get asked this a lot. The answer, unsurprisingly, is a definite maybe. It really depends upon the application and how the performance is evaluated. Typically, someone asking this question is looking for a cost savings, but for many applications polymers are a better material choice than metals for gearing. Depending upon the application and critical design objectives, a polymer substitution may provide a significant increase in performance benchmarks and/or a reduction in cost. Polymers exhibit fundamentally different behavior than that of metals; their mechanical properties are heavily time-and-temperature-dependent. In a dynamic application such as gearing, these dependences, if designed correctly, can contribute to polymer gears vastly outperforming metal gears in many performance benchmarks including noise, vibration and harshness (NVH), with a gear strength much higher than material predictions would indicate. As a result, we have seen applications where:

- Polymer gears out-performed metal gears in performance and cost
- Polymer gears performed comparably to metal gears, and at a cost reduction
- Polymer gears out-performed metal gears in performance, at a cost increase
- Polymer gears were not suitable
- Metal gears were not suitable

With this in mind I would like to discuss how to determine if polymer gears are good candidates for a particular system. I will summarize the performance characteristics of polymer gears and discuss general differences between polymer and metal gear design and manufacture.

The most critical consideration when deciding if polymers may be a good material choice for a gearset is environmental. If the temperature is above 150°C, the mechanical properties of even our highest-performance polymers degrade significantly, and polymer gears become unpractical. A chemical environment may drive the consideration towards, or away from, polymers as a material choice. We often see this as a driving consideration in medical applications where metals and their necessary lubricants are often unsuitable.

If the environment is one in which a polymeric material can survive, the next most critical consideration is strength. A common misconception is that plastic gears are cheaper, but weaker, versions of metal gears, and therefore accounting for the decrease in material yield strength alone will accurately represent plastic gear behavior. This is inaccurate at a fundamental material level, and it becomes rapidly apparent within a gearing application. While a metal gear under load may have line contact between gear and pinion, and a contact ratio such that only one tooth is in mesh, the involute surface of a polymer gear under load will deform under similar loading conditions, distributing the contact pressure over a larger surface, and tooth bending will initiate contact between adjacent teeth, resulting in load sharing (Fig. 1). This can result in a polymer gear having higher life expectancy than a metal equivalent in certain applications. Typically these are applications where there is high-impact loading, with a relatively low steady-state load.

As a result of the lower polymer modulus and damping properties, polymer gears almost always significantly out-perform metal gears in NVH. While there is variation in the degree to which different polymers improve in this measure, in our experience a polymer replacement in a spur gear pair typically reduces sound levels between 2-5 dB, with a reduction in frequency, no ringing, and a more uniform sound level.

Material weight can also dramatically improve transmission efficiency and response. With a lighter material, system inertia can be dramatically reduced, contributing to a more responsive and efficient system. There are many applications where overall system weight is a critical parameter, such as in the aerospace industry, and polymer gears are one potential solution.

Polymer material properties also play a role in lubrication requirements. Many polymer gears will run in some kind of lubricant; however, polymer gears have lower lubrication requirements than metal gears, reducing the complexity of, or even negating the need for, complex lubrication systems. It is often even possible to embed lubricants such as Teflon or graphite in the polymer gear material, or remove lubrication entirely.

The last property of polymers I want to discuss is cost. Obviously, this is a critical consideration in any production component. Typically at the production level, an injection-molded polymer gear costs less to produce than a metal one. The material and per-part processing costs are typically, but not always, less than the metal counterparts. There can also be significant cost advantages to injection molding, such as the ability to produce multiple parts simultaneously in multi-cavity tools. While upfront tooling costs are typically higher, over the course of a production run, a higher-performance polymer gear may cost 10-50% less than a metal one. These savings do not account for cost savings or revenue gains due to improved performance, which are also likely to be present. However, actual figures are highly project-dependent.

Due to the differences in the material properties, and manufacturing techniques of metals and polymers, different design expectations are needed. From a design perspective, the injection molding process contributes geometric flexibility at the expense of tolerance precision. With our injection-molded gears, the dimensional tolerance is on the order of < 0.025 m/m, while the repeatability is typically an order-of-magnitude better. This is an acceptable trade-off because polymers, with their lower modulus, are more forgiving of small dimensional errors than are metals. To further strengthen a polymer gear and to fully utilize its novel polymer characteristics, it is highly desirable to use a shape-optimized design. Where metal gears are traditionally defined by their machine process and tools, an injection-molded polymer gear has the advantage of being definable directly by the gear geometry. As a result of this trade-off and the fundamentally different behavior of polymeric materials, the first step in a polymer gear design is to evaluate the entire system for suitability, followed by a polymer-optimized and application-specific design, then prototyping, and finally production tooling and molding.

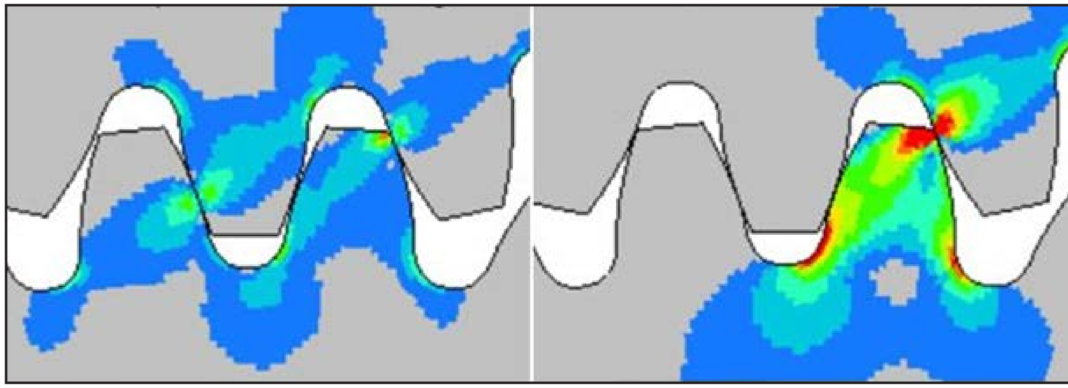


Figure 1 Finite Element simulation of a loaded polymer-polymer mesh (left) and loaded steel-steel mesh (right) showing load sharing between teeth under load. The contact ratio for the steel mesh under load is 1.2, while the polymer mesh under load has a contact ratio of 2.1 (Analysis courtesy of Vitrex USA.)

To answer the original question: if the environment does not exclude the use of polymer gears, and you are looking for an improvement over metal gears in cost, weight, NVH, and/or design simplicity, the likely answer is a resounding *Yes.*

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The Influence of Tool Tolerances on the Gear Quality of a Gear Manufactured by an Indexable Insert Hob

Mattias Svahn, Lars Vedmar and Carin Andersson

Recently, a new type of hob with carbide inserts has been introduced, providing higher cutting speeds, longer tool life and higher feed rates when compared to re-grindable, high-speed steel hobs. But with this kind of hob, new challenges occur due to positional errors of the cutting edges when mounted on the tool. These errors lead to manufacturing errors on the gear teeth which must be controlled. In this paper, the tooth quality of a gear manufactured by hobs with different quality classes is analyzed using a simulation model in combination with Monte Carlo methods.

Introduction

The most common and economical method to produce involute gears — both spur and helical — is by hobbing. Hobs have been — until now — mainly re-grindable, high-speed steel (HSS) with additional coatings such as TiN, TiCN, etc. Today's new type of hob with carbide inserts is advantageous to HSS hobbing with its ability to increase cutting speed and feed rate while prolonging tool life. However, one obstacle to overcome is to fulfil the requirements for hobbing accurate gears for high-performance applications while using hobs with inserts. The geometry and the positioning of the inserts must be highly accurate for the hob to comply with the tight tolerances of, for example, DIN 3968 (Ref. 1). In the literature (Ref. 2) it is stated that hobbing in industrial applications achieves gear quality according to DIN in the 8-11 range, and grade 7 in less frequent applications. However, there is little experience of the gear quality achieved using the new type of indexable insert hobs, due possibly to errors of the inserts and the higher feed rates that they are capable of operating at. The purpose of this study is to analyze the impact of possible errors of the hob geometry on the manufactured gear tooth.

Previous work in modeling the manufactured gear tooth geometry encompasses, for example, the work of Michalski (Ref. 3) that, by use of CAD environment and logical material removal to determine the manufactured tooth flanks, and Visalis et al (Ref. 4), presents the software module *HOB3D* for CAD systems, where the un-deformed chip geometry and the manufactured tooth surface are modeled. These works do not consider any manufacturing errors due to the tool or machine settings. Chiu et al (Ref. 5) computed the manufactured tooth surface by modeling the hobbing process with introduced eccentricity to the hob axis. Svahn et al (Ref. 6) modeled the manufactured gear tooth hobbed with errors introduced to the manufacturing process.

In this paper a simulation tool is used based on a mathematical, geometric model where the hobbed tooth surface can be determined in three dimensions (Ref. 7). The cutting teeth of the hob can be individually positioned in the axial and in the radial direction, compared to their nominal positions. This is done by using results from measurements of an actual hob or applying continuous probability density functions. Utilizing this simulation model it is possible to compute the gear tooth surface topography manufactured by hobs of different tolerance classes. By applying gear tooth deviation standards, the expected gear tooth quality for the corresponding hob quality class is determined. The input to the simulation software is provided by an analysis of the cutting tooth deviations of a commercial hob with inserts.

Using the Monte Carlo method (Ref. 8), the expected gear tooth quality can be determined by this simulation tool and with hob geometry generated by predetermined statistical functions. The aim of the study is to identify which parameters are influencing gear tooth quality for this new tool concept, and to show that these types of results can be provided without costly, time consuming — and often impossible — experimental testing. The use of simulation tools to analyze the gear hobbing process can be a great benefit to tool developers in finding out which tolerances and other parameters are of importance, and in manufacturing an involute gear within given tolerances. In this study, the focus is on the radial and the axial errors from the nominal position of these inserts. The shape of the inserts, the tool body and generating process will otherwise be considered perfect. The results in this study are based on the numerical values listed in Table 1.

Table 1 Nomenclature and numerical example

Basic Rack		Gear	
Normal module	$m_n = 4.75$ mm	Number of teeth	$z = 56$
Normal pressure angle	$\alpha_n = 20°$	Face width	$b = 50$ mm
Helical angle	$\beta = 21.5°$	**Hob**	
Tip addendum	$h_t = 7.50$ mm	Number of entrances	$g = 1$
Tip radius	$r_t = 1.63$ mm	Lead angle	$\lambda = 2.37°$
Protuberance	$p = 0.1$ mm	Total number of cutting teeth	$N = 120$
		Cutting teeth per revolution	$N = 12$

This paper was first presented at the 2013 VDI International Conference on Gears, Technical University of Munich, Garching, Germany, and is reprinted here with VDI permission.

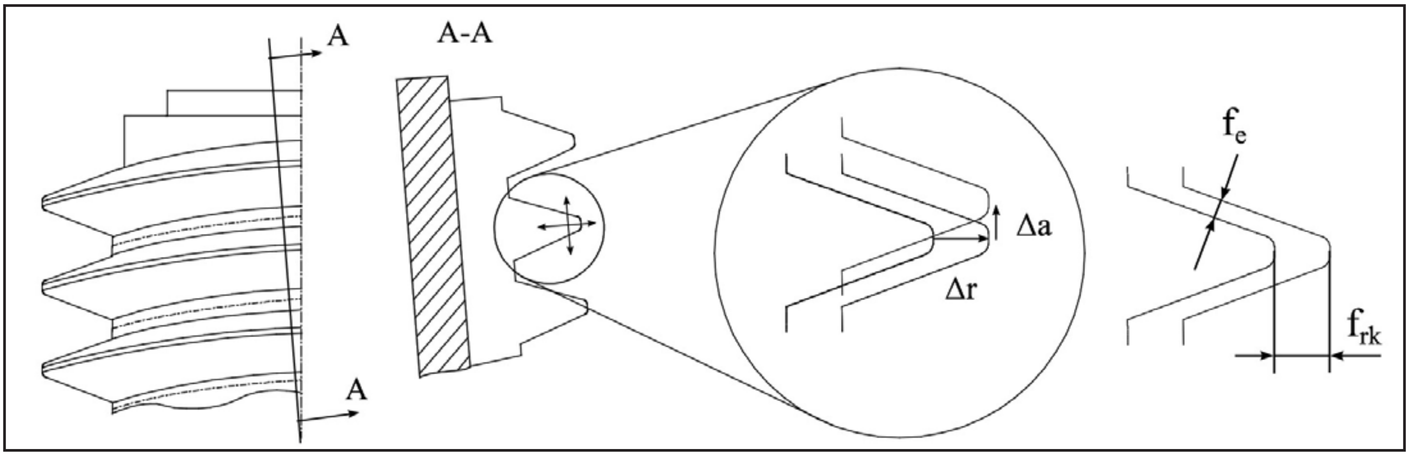

Figure 1 **Deviation of inserts of hob, where Δr is the radial displacement and Δa is the axial displacement. Related measured quantities in DIN 3968 are f_{rk} and f_e.**

Generation of Hobs

The hob used in this study is an indexable, insert hob; individual inserts are assembled on the tool body. The position of the cutting edges, which are the boundaries of these inserts, is affected by the geometry of the inserts and their positioning on the tool body. Overly large deviations will directly affect the tooth quality of the hobbed gear tooth negatively. In order to manufacture a gear with satisfactory quality, these deviations must be controlled.

The DIN 3968 standard for single-start hobs (Ref. 1) measures the hob in 17 steps and, depending on normal module m_n, classifies the hob in the quality classes AA through to D, with AA being the most accurate hob. The measuring procedure of hobs is well described in VDI/VDO (Ref. 9) and by Goch (Ref. 10). The cutting tooth deviation Δa and Δr are presented in Figure 1, together with measured quantity f_e and f_{rk} from DIN 3968.

The statistical distribution of the positional error must be known to be able to apply the Monte Carlo method. Knowing the statistical distribution enables generation of new hobs based on this distribution within the same or other tolerance range. These hobs are then to be used as input to the simulation software later described, where the gear tooth topography and the gear quality manufactured by different hob quality classes can be determined.

A commercial hob with carbide inserts is control-measured using a CNC measuring center, Zeiss *CenterMax* with software packages *Calypso* and *Gear Pro Hob*. The distribution of the axial and the radial deviations of the cutting edges of the hob are tested by a null-hypothesis using the $Ç^2$ - test. The measured distribution complies with a normal distribution in both cases at the 5% significance level (Figs. 2, 3). This allows that the inserts follow a normal distribution; it is now assumed that the positional errors of the inserts for all hobs in this study comply with normal distribution.

Considering now only these deviations being present, different hob classes can be generated by positioning the inserts according to a normal density probability function. The position of each individual insert is random, but confirms the given probability functions. For a hob with normal module $m_n = 4.75$ mm, the tolerance levels for different hob classes, according to DIN 3968 (Ref. 1), are defined in Table 2.

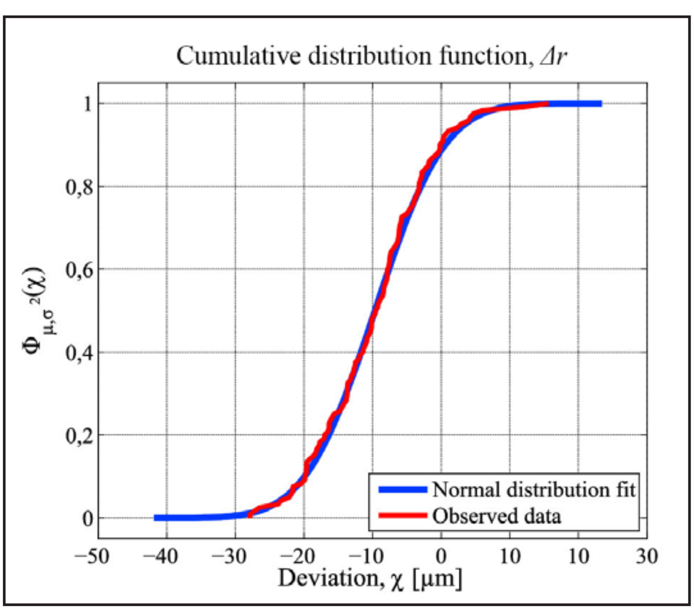

Figure 2 **CDF: plot, radial deviation of inserts.**

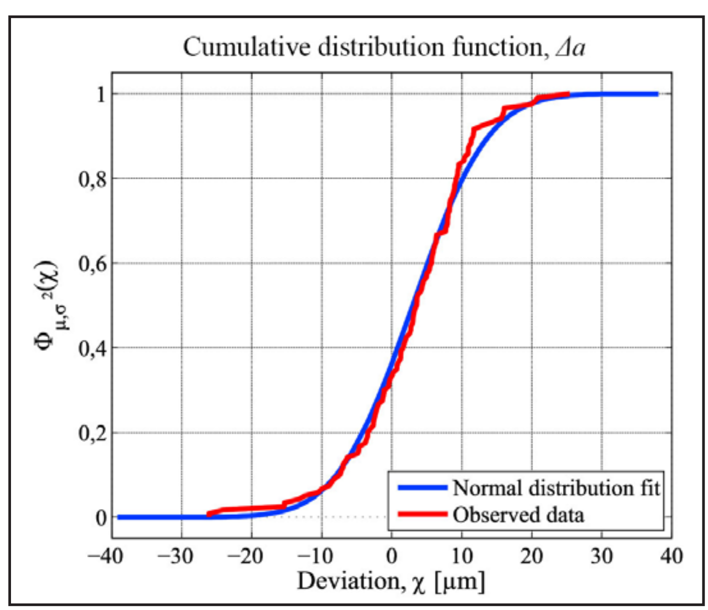

Figure 3 **CDF: plot, axial deviation of inserts.**

Simulation of the Manufacturing Process

To isolate manufacturing errors that arise to only the prescribed positional errors of the tool inserts and to determine the impact of these errors on the manufactured gear tooth, a simulation model is used. With this model, developed by Vedmar (Ref. 7), the hobbed tooth surface topography is determined in three dimensions by using analytical, parametric, differentiable functions. By comparing the hobbed tooth surface with the ideal smooth gear tooth geometry, deviations from the manufacturing process can be analyzed.

To use this simulation tool to determine the manufacturing errors due to imperfections of the hob, hobs are generated by choosing the tolerance levels according to DIN 3698. It is assumed that the positional error of the inserts complies with normal distribution — i.e., N (μ,σ^2). Hobs are now generated using probability density function N (0, $T_i/1.96$), where T_i is the tolerance for the respective hob quality class. These hobs are then used as input to the simulation model to determine the expected gear tooth topography after manufacturing by these hobs. An example of the results from the simulation model is presented in Figure 4, showing gear teeth manufactured using a perfect hob and a hob of quality class B with grinding stock.

Using a hob allows manufacturing of gears with or without protuberance. In the case of protuberance, the gear tooth is manufactured with grinding stock. The remaining material in the involute region is to be removed in a subsequent refining process, such as grinding or skiving. The gear quality is determined after an eventual refining process, but the same types of measurements are also applied just after hobbing to ensure controlled finished results. If the gear tooth is manufactured with protuberance, the gear tooth quality has no information if the amount of grinding stock accounts for the manufacturing errors. This will then not guarantee that the finished tooth surface is not impaired. In the simulation model this is, however, possible; this could give an indication of the necessary amount of protuberance needed for the specific hob class. The material removal rate is far greater in hobbing than in any refining process, so minimizing the grinding stock would lead to less time-consuming refining steps. As the main

Table 2 Tolerance levels of a single-start hob with normal module m_n = 4 - 6.3 mm

	Hob class			
	AA	A	B	C
f_{rk} [μm]	20	32	63	125
f_e [μm]	6	10	20	40

Table 3 Gear tooth quality according to DIN 3962, for a gear with normal module m_n = 3.55 - 6 mm and width b = 40 - 100 mm (- not presented)

		Gear quality							
		5	6	7	8	9	10	11	12
Deviation [μm]	$f_{g\pm}$	-	-	10	14	20	32	50	80
	$f_{f\pm}$	7	10	14	20	28	45	71	125
	f_{H^2}	-	10	14	20	28	45	71	110
	f_{f^2}	7	9	12	18	28	45	63	110

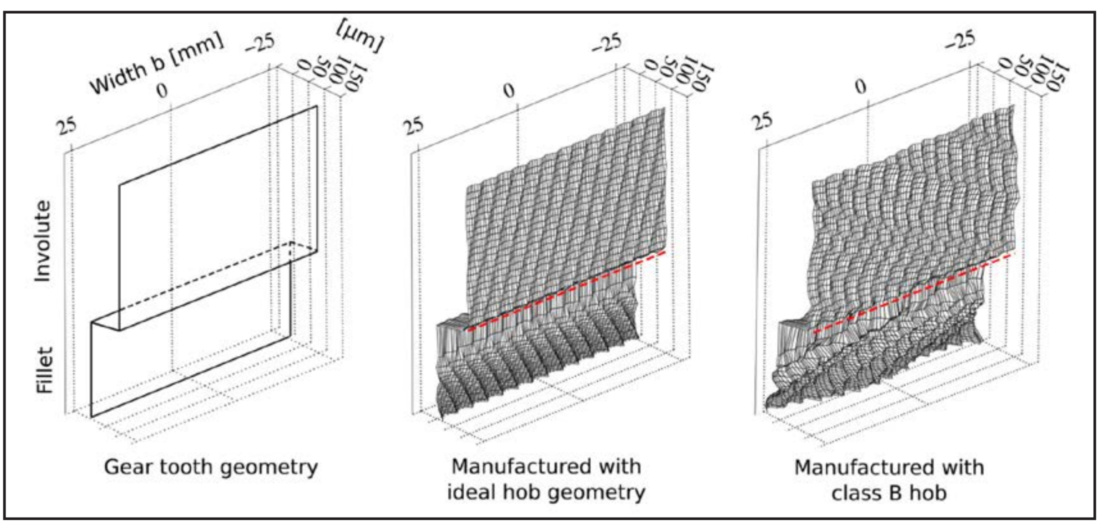

Figure 4 Hobbed gear tooth from simulation model manufactured by a hob with protuberance = 0.1 mm.

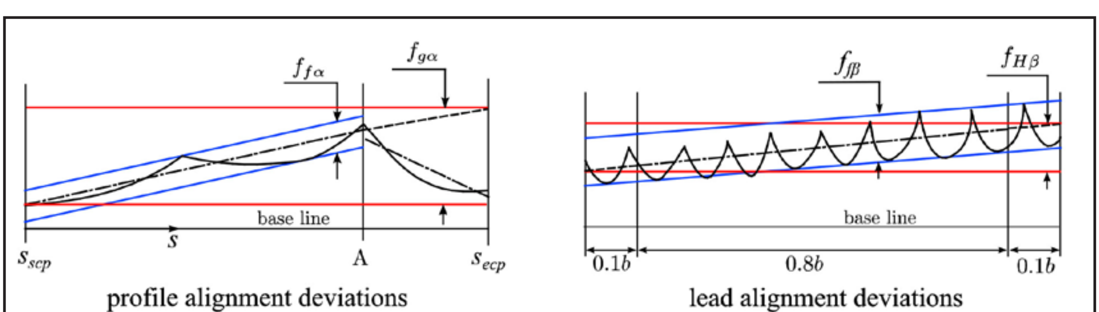

Figure 5 Inspection charts of manufactured gear tooth for the profile and the lead deviations.

objective is to find the correlation of the quality class between the hob and the gear tooth, measurements will be restricted to after hobbing and no considerations are taken to any finishing process.

After manufacturing, measurements of the gear tooth are drawn on inspection charts. These charts can be used to determine alignment and form deviations for both the profile and the lead. In the Volvo group standard (Ref. 11), these deviations are defined as $f_{g\alpha}$ for profile alignment and $f_{f\alpha}$ for profile form deviation; $f_{H\beta}$ for lead alignment and $f_{f\beta}$ for lead form deviations.

A stylus tracks the tooth surface at designated lines. For profile deviations the probe starts at s_{scp} (start control point), records tooth deviations and ends at s_{ecp} (end control point), where $s=\sqrt{r^2-r_b^2}$ and r_b is the base circle radius. This is normally performed in the middle of the face width. $f_{g\alpha}$ and $f_{f\alpha}$ are defined in Figure 5, where point A is specified tip relief. The lead deviations are measured of the whole face b at the line $s=(s_{scp}+s_{ecp})/2$. A mean line of first order least square is established within the evaluation area 0.8b. The mean line is then extrapolated over the whole width b and $f_{H\beta}$ and $f_{f\beta}$ are defined (Fig. 5).

The quantitative measure of these tooth deviations quantifies the gear tooth quality by using DIN 3962–Part 1 (Ref. 12) and Part 2 (Ref. 13), depending on the normal module m_n and the face width b of the gear.

Results

To determine the quality grade of the hob needed to manufacture gears within given tolerance, and what deviation of the inserts impacts the gear quality most, simulations are performed with different hob grades. For each hob class, eight hobs are generated to manufacture one gear each; and for every gear four diametrically positioned gear teeth are control-measured using gear tooth deviation standards. This is performed for two feed rates; the more conventional feed rate $S=3.5$ mm/rev for HSS hobs and the higher feed rate $S=8.0$ mm/rev which hobs with carbide inserts are capable of.

In Figures 6 and 7 the profile and lead deviations are presented. These are separated to only axial deviations of inserts in the left column and only radial deviations of inserts in the right column. The

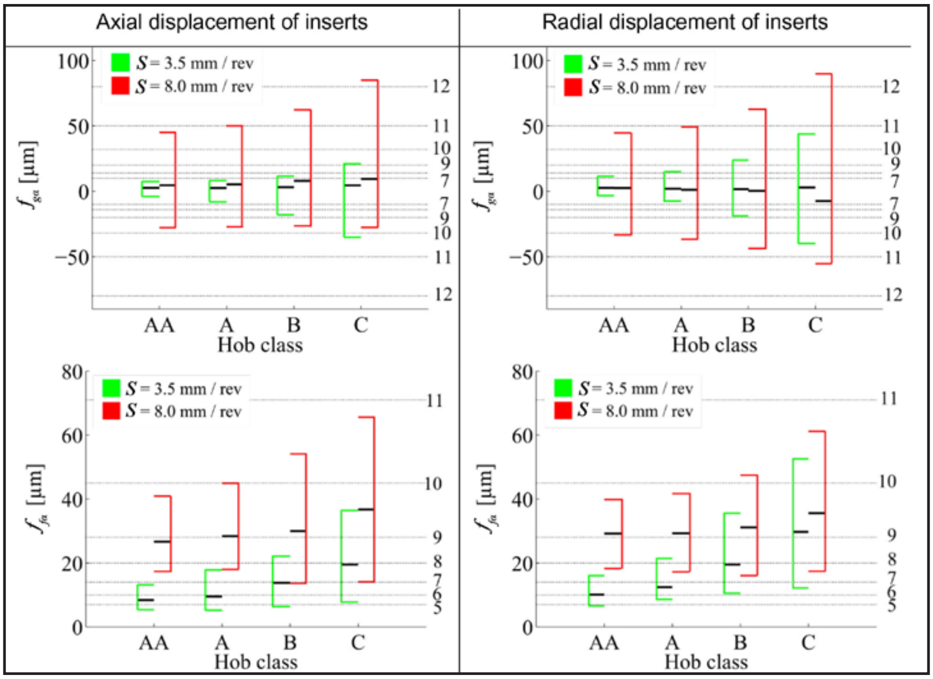

Figure 6 Result from simulation where the profile deviations are plotted with varying hob classes. On the left ordinate, the gear tooth deviation, and on the right ordinate, the gear quality, is plotted.

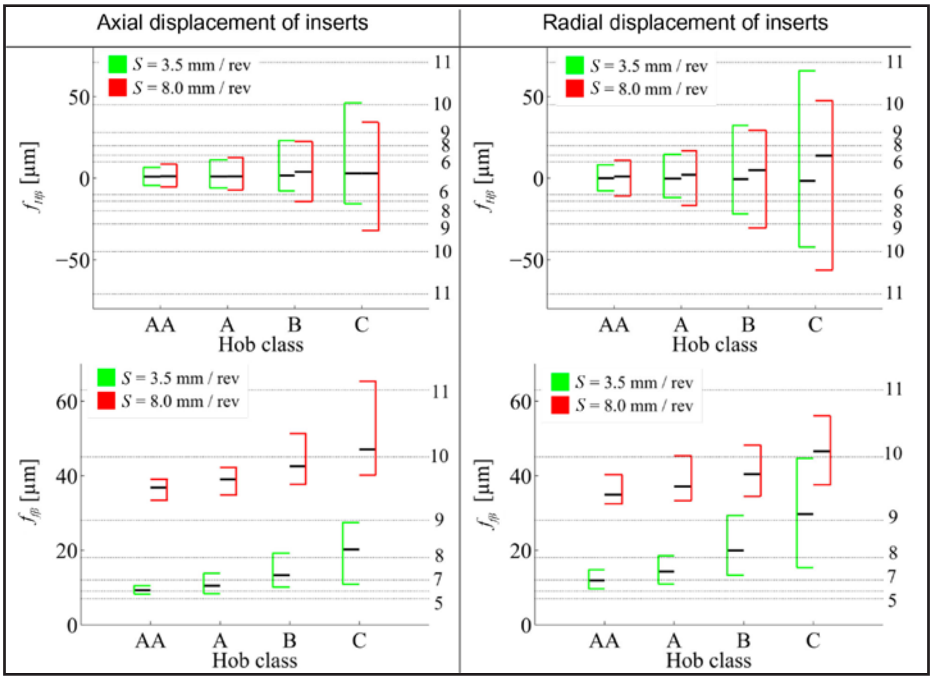

Figure 7 Result from simulation where the lead deviations are plotted with varying hob classes. On the left ordinate, the gear tooth deviation, and on the right ordinate, the gear quality, is plotted.

Table 4 Gear tooth quality classes achieved in simulations for different hob classes, presented for two feed rates; mean/maximum quality is considered

	Hob class							
	AA		A		B		C	
	Δa	*Δr*	*Δa*	*Δr*	*Δa*	*Δr*	*Δa*	*Δr*
$S=3.5$ mm/rev	<7/**7**	7/**8**	7/**8**	8/**9**	8/**9**	9/**10**	9/**11**	10/**11**
$S=8.0$ mm/rev	10/**11**	10/**11**	10/**11**	10/**11**	10/**12**	10/**12**	11/**>12**	11/**>12**

Table 5 The minimum amount of grinding stock needed for each hob class for the feed rates considered

	Amount of protuberance, p[μm]			
	AA	A	B	C
S = 3.5 mm/rev	20	20	30	50
S = 8.0 mm/rev	30	30	45	65

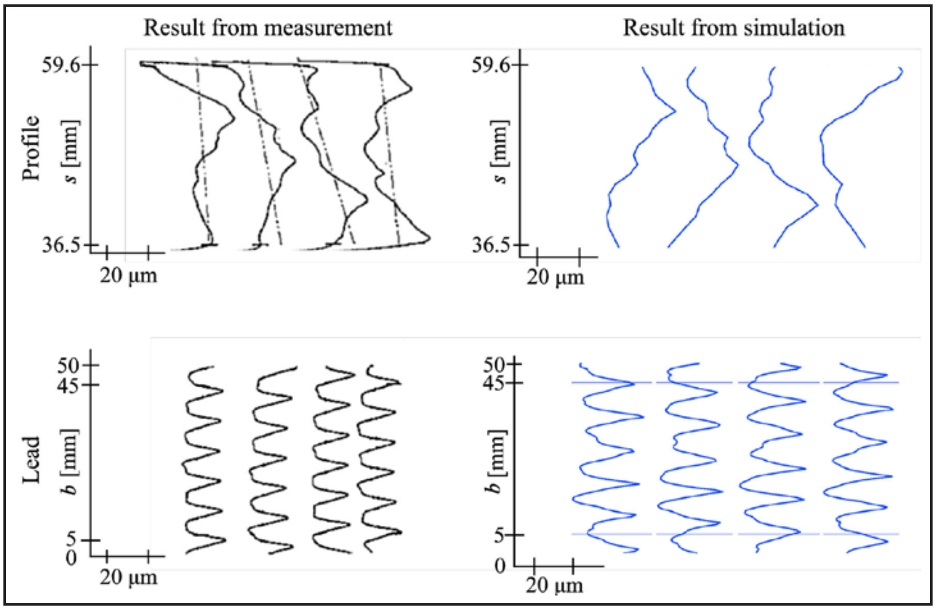

Figure 8 Inspection chart over profile and lead for a gear; hobbed at the feed rate S = 8.0 mm/rev. On the left, results from industrial hobbing machine; and right, results from simulation are presented.

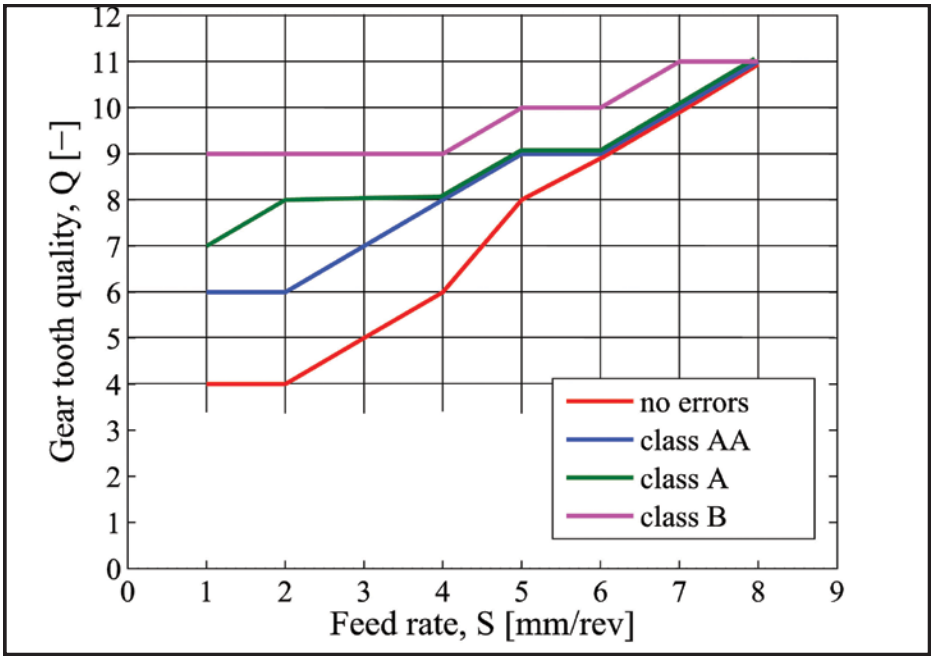

Figure 9 Gear tooth quality vs. axial feed rate of hob for different hob classes.

Table 6 Gear tooth deviations, results from experiments and simulations

	Tooth deviation, mean value of four diametrically positioned teeth.							
	$f_{g\alpha}$ [μm]		$f_{f\alpha}$ [μm]		$f_{H\beta}$ [μm]		$f_{f\beta}$ [μm]	
	manu.	sim.	manu.	sim.	manu.	sim.	manu.	sim.
S = 8.0 mm/rev	-15	7.3	31	26.2	1	2.7	21	38.3

positional error of the cutting edges, giving the different hob classes, complies with given distribution function, here $N(\mu,\sigma^2)$. The outcome from the simulation model will also yield a distribution. In these plots, 95% of the set of the tooth deviation are comprised by the colored bracket, and the mean value is presented by the black line. On the left ordinate in each plot, the measured quantity is presented and on the right ordinate the corresponding gear tooth quality according to DIN 3962 Part 1 and Part 2.

The gear tooth quality is determined by the maximum deviation:

$$Q_{max} = \max(Q(f_{g\alpha,max}), Q(f_{f\alpha,max}), Q(f_{H\beta,max}), Q(f_{f\beta,max})) \quad (1)$$

For the gear geometry in this study (Table 1), the corresponding gear qualities for the resulting tooth deviations from simulations are given in Table 3.

Using the results in Figures 6 and 7, the gear quality according to Equation 1 is given in Table 4.

As earlier mentioned, the presented measurements do not consider if the amount of grinding stock is adequate to ensure that the involute region is not impaired after subsequent refining steps. This is, however, possible in the described simulation model. The amount of protuberance needed for each hob class in this example is given in Table 5. This means the gear in this study will be correct for all hob quality classes using a hob with protuberance $p = 0.1$ mm.

Experimental Verification

To verify the results from the simulation model, they are compared with a gear manufactured using an industrial hobbing machine, i.e., a Liebherr LC 380. The hob used in this verification was control- measured, and the positional error of the inserts in the axial and in the radial direction was used as input to the simulation model. The gear manufactured — in both experiments and in simulation — was control-measured for alignment and form deviations, according to previous section. The results from these measurements are presented graphically (Fig. 8) and in measured quantity (Table 6).

The shape of the curves corresponds remarkably well for both profile and lead. There is, however, a systematic alignment error present on all gear teeth for the profile. For the lead errors, the form error is overestimated in simulations compared to experiments.

Conclusions and Discussions

In this paper it is shown that the gear tooth topography and the corresponding quality, manufactured by different hob quality classes, can be determined using a developed simulation model (Ref. 7). Here, errors in the cutting edge position are introduced, so that the cutting teeth deviate in the axial and the radial directions when compared to their nominal positions.

The results show very good agreement with experimental results (Fig 8.; Table 6). Conclusions that can be drawn are that radial deviations impair the gear tooth more than the axial deviation of the inserts. The effect is only slight and most noticeable for the low feed rate, more specific $f_{g\alpha}$, $f_{H\beta}$ and $f_{f\beta}$ in Figures 6 and 7.

For the low feed rate considered in this study, both the mean value and the dispersion of the alignment and the form errors differ significantly between hob classes. But for the higher feed rate, the gear tooth will be manufactured with same quality grade for the hob classes AA and A. The alignment and form errors will differ in small degree but are still classified in the same quality grade. An explanation is due to the higher feed rate. With increasing feed rate the distance between the feed marks will increase, resulting in larger gear tooth deviations and inferior gear tooth quality. However, the positional error of the inserts between the hob classes AA and A impair the gear tooth quality less than the feed rate. Even using a perfect hob, the expected gear tooth quality will not improve significantly. Figure 9 presents the result from the simulation model showing how the gear tooth quality is affected by the feed rate. At the lower feed rate, suitable for HSS hobs, there is a significant difference in gear quality achieved for the different hob classes. However, for the higher feed rate the gear quality converges resulting in the same quality gear tooth for an A, AA and a perfect hob.

The amount of grinding stock needed to account for manufacturing errors, such as tool errors and feed marks, may be minimized if the expected gear tooth deviations can be controlled.

The gear tooth is manufactured with grinding stock by introducing protuberance to the tool. If the protuberance is minimized this will promote the finishing operations.

There are other parameters determining the quality of the gear in addition to those presented in this study. Here, only the form and the alignment deviations of the gear tooth are considered. In DIN 3962, there are also pitch error, concentricity, etc. that are not considered in the quality grading of the gears in this study. The simulations show good agreement with experimental results but additional deviations to the hob cutting teeth may be introduced for even better agreement, such as rotation of the inserts of the hob. This type of error is more probable to insertable hobs than conventional HSS hobs, and is not included in the hob standards.

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Loaded Behavior of Gears Made of Fiber-Reinforced PA6

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This paper presents an original method for computing the loaded mechanical behavior of fiber-reinforced polymer gears. Although thermoplastic gears are unsuitable for application transmitting high torque, adding fibers can significantly increase their performance. The particular case of polyamide 6 + 30% glass fibers is studied in this paper.

Introduction

The LaMCoS laboratory (*Ed.'s Note: a joint research laboratory of the French National Institute of Applied Sciences and National Centre for Scientific Research*) has developed several numerical models to predict essential results such as load sharing, tooth root stress, contact pressure and transmission error for different types of gears made with elastic or visco-elastic materials. These include, for example, cylindrical gears (Ref. 1); face gears (Ref. 2); spiral bevel gears (Ref. 3); pinion racks (Ref. 4); and worm gears (Ref. 5). To determine load sharing, LaMCoS uses an approach that focuses on solving the displacement/compatibility equation. The influence coefficients method (Ref. 6) is also used and the contact and volume effects are separated; this method is much less time consuming.

Polymer gears are being used in increasing applications due to their low material and manufacturing costs. They also present some advantages unmatched by steel gears in that they can be used without lubricant, their meshing is quieter, and they are lighter. However, they have poor heat resistance and are limited to rotation transmission. In order to improve polymer gear performance, glass fiber is being increasingly used where their lower cost and higher

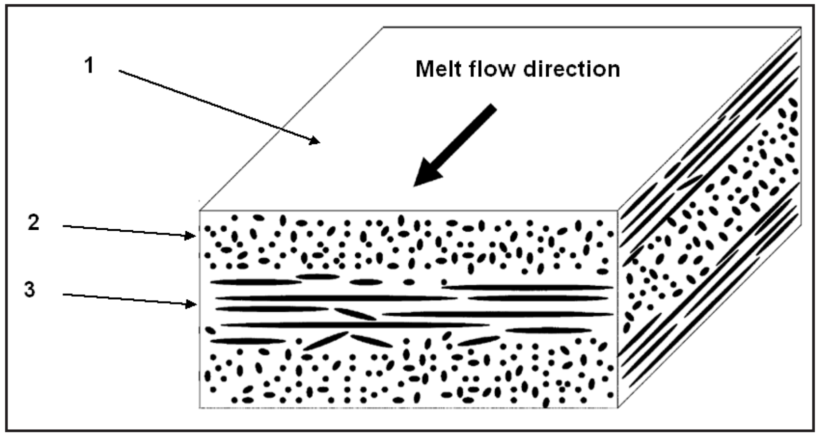

Figure 1 Fiber orientation in a unidirectional flow (Ref. 10).

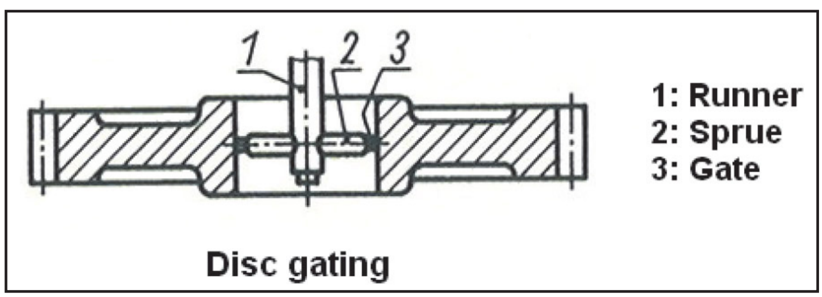

Figure 2 Gating location (Ref. 11).

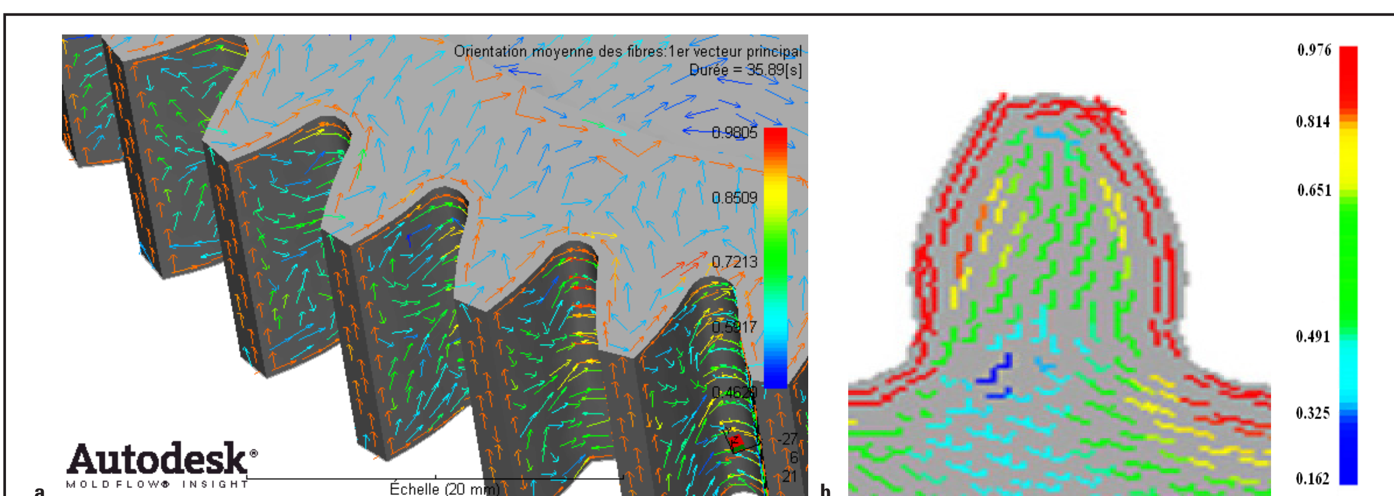

Figure 3 Shell fiber orientation (a); and core orientation fiber in teeth (b).

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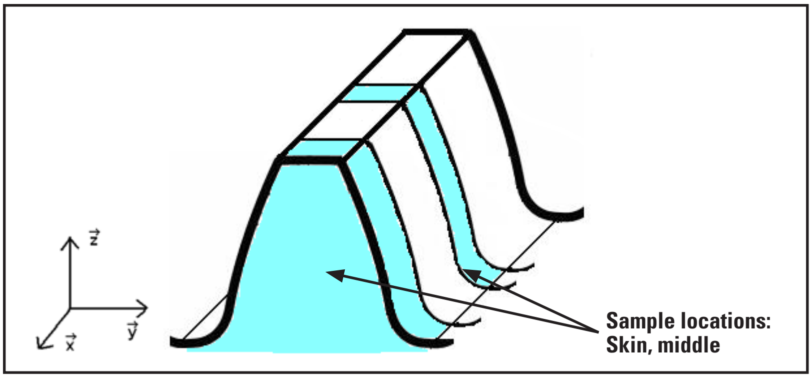


Figure 4 Sample location on teeth.

strength, when compared to unreinforced polyamide, offer a potential increase in gear performance (Ref. 7).

More recently, Hiltcher et al (Ref. 5) developed a quasi-static load-sharing model in the case of a polyamide 66 wheel-and-steel worm. Based on this model Letzelter et al (Ref. 8) developed a quasi-static, load-sharing model in the case of polyamide 66-machined spur gears, taking into account visco-elastic properties and temperature dependence. But unlike the work by Letzelter (Ref. 8) and Hiltcher (Ref. 5), in this paper the gears were molded and the material is anisotropic due to the addition of the glass fibers. Thus this study is limited to the linear domain of the material and it is assumed that the tooth is relaxed for each rotation.

Numerical examples are presented to show the load-sharing and transmission error, depending on the fiber orientation model as well as the elastic and viscous displacement contribution.

Fiber-Orientation in a Molded Gear

Generally concerned fiber orientation. The fiber orientation and distribution in an injection-molded component is dependent on component geometry, molding conditions (gating, temperature, pressure and holding time), matrix material, polymer viscosity and fiber type (aspect ratio, density and volume fraction) (Ref. 9).

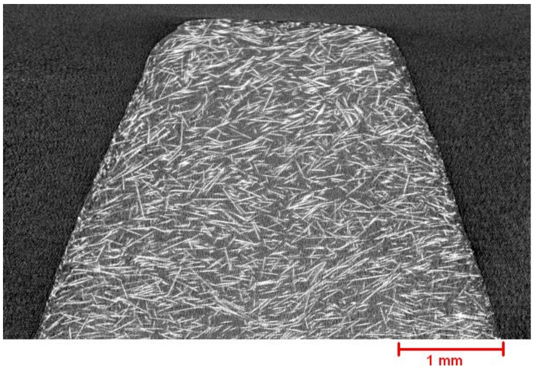
The shear forces are dominant in the shell structure orientation. In the shell area, high shear forces tend to align fibers along the melt flow direction. However, in the middle of the core region, shear forces are annulled and so the fiber orientation is situated in the transverse flow direction. Figure 1 shows the schematic of reinforced, glass fiber orientation in a unidirectional flow.

Molding conditions. In this study a disc gating solution (Fig. 2) is used that has the best filling and fiber orientation regularity (Ref. 11).

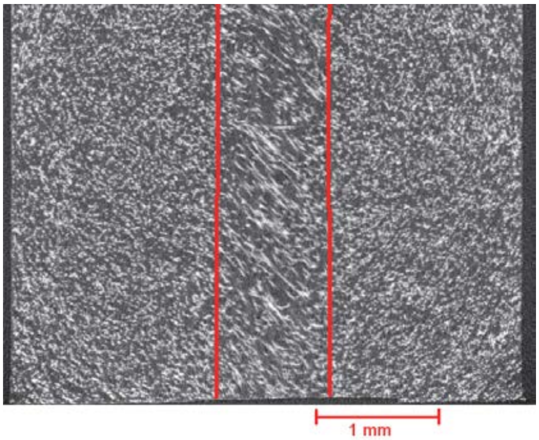
The cavity geometry, molding conditions and cooling conditions are obtained thanks to commercial molding process simulation software.

Fiber orientation. Fiber orientation simulations were conducted and compared to tomographical, experimental observations. The polymer used is the same in the simulation and for tomographical observations. Figure 3 shows fiber orientation on shell (a) and fiber orientation in the core zone (b). The anisotropy parameter corresponds to the first tensor order and varies between 0 and 1. Number 1 indicates the perfect alignment of the fibers parallel to the reference direction, and 0 is the case of perfect perpendicular alignment with the reference direction.

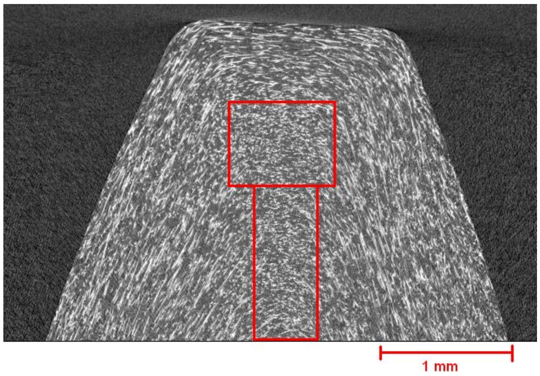
A quantitative examination has been carried out using tomographic microscopy machines. Sample locations are described in Figure 4; observations are presented in Figure 5.



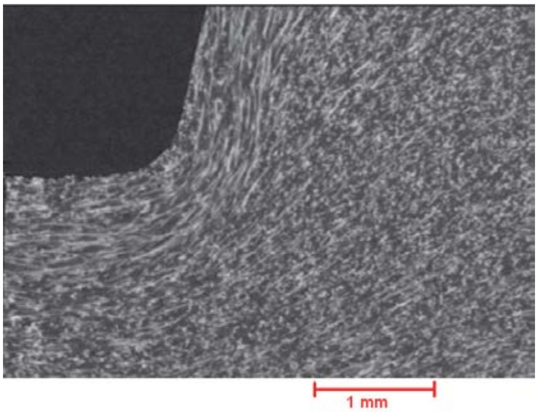
a. Cutting plane ($\vec{y},\vec{z}$), skin



b. Cutting plane ($\vec{x},\vec{y}$), middle



c. Cutting plane ($\vec{y},\vec{z}$), middle



d. Cutting plane ($\vec{y},\vec{z}$), middle

Figure 5 Disc gating gear: $Z=41$; $m=3$.

A comparison between quantitative, simulated fiber orientation prediction and the qualitative, tomography observations reveals similar trends — i.e., three main fiber organization areas are defined: one on the tooth flank, one in the core zone of the teeth, and the last in the root area (Fig. 6).

Mechanical Modeling of Polyamide 6 + 30% GF

The mechanical behavior of polyamide is viscoelastic in that it depends on loading duration or, in other words, on the history of displacement and temperature. Humidity is another factor to be taken into account in the specific case of polyamide 6.

In order to simulate the wide relaxation time spectrum of polyamide, a generalized Kelvin model is used (Ref. 12) (Fig. 7).

In order to compute the load-sharing, knowledge of the temporal displacement of polyamide 6 material is necessary. The total strain of the generalized Kelvin model is computed in Equation 2. This requires the use of an incremental scheme based on differential Equation 1; the relationship of Equation 1 can be written in each block of the model:

$$\sigma(t) = \frac{1}{\Delta J_i}\varepsilon^i(t) + \frac{\tau_i}{\Delta J_i}\dot{\varepsilon}^i(t) \quad (1)$$

τ_i is the retardation time; i the index of the block in the generalized Kelvin model; and n is the number of blocks in the model.

$$\varepsilon(t) = \sigma(t)\sum_{i=0}^{n}\Delta J_i\left(\frac{\Delta t}{\Delta t+\tau_i}\right)\sum_{i=0}^{n}\varepsilon^i(t-dt)\left(\frac{\tau_i}{\Delta t+\tau_i}\right) \quad (2)$$

With the relationship of Equation 2, the viscoelastic displacement $u(t)$ is then deduced (Eq. 3):

$$u(t) = l.\sigma(t)\sum_{i=0}^{n}\Delta J_i\left(\frac{dt}{dt+\tau_i}\right) + \sum_{i=0}^{n}u^i(t-dt)\left(\frac{\tau_i}{dt+\tau_i}\right) \quad (3)$$

l is the length of the polyamide 6 specimen (small displacement assumption).

The relationship in Equation 3 is thus used to solve the load-sharing problem. But before doing so, it is necessary to determine the viscoelastic properties ΔJ_i and τ_i.

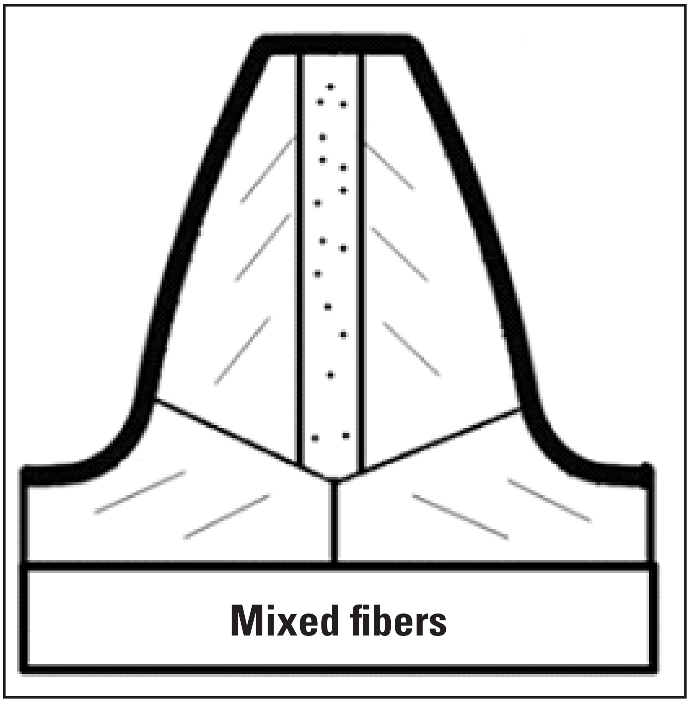


Figure 6 Fiber distribution outline.

Results and Viscoelasticity Modeling

Using polymer material, the time-temperature superposition principle can be applied. With this principle and the spectrometer tests — also known as DMA (dynamic mechanical analysis) — it is possible to build, at a given reference temperature, the storage compliance curve $J'(i\omega, T_{ref})$ or the loss compliance curve $J''(i\omega, T_{ref})$, over a very wide frequency range. This curve, known as the "master curve," is obtained from the shift of experimental DMA curves obtained at different temperatures.

In order to determine the distribution of the retardation time τ_i, the numerical Master Curves $J'(i\omega, T_{ref})$ is necessary. It is determined by fitting the Master Curve with a phenomenological model. To do so, the biparabolic model (Eq. 4) developed by Decroix et al. is used (Ref. 13).

$$J^*(i\omega, T_{ref}) = \frac{1+\delta(i\omega\tau')^{-x}+(i\omega\tau')^{-x'}}{\frac{1}{J_u}-\frac{1}{J_r}} + \frac{1}{J_r} \quad (4)$$

To obtain the time spectrum, a discretization by pulsation step of the numerical Master Curve of storage compliance $J'_i(i\omega, T_{ref})$ is needed. In this study, 25 elements of Kelvin Voigt in the Kelvin-

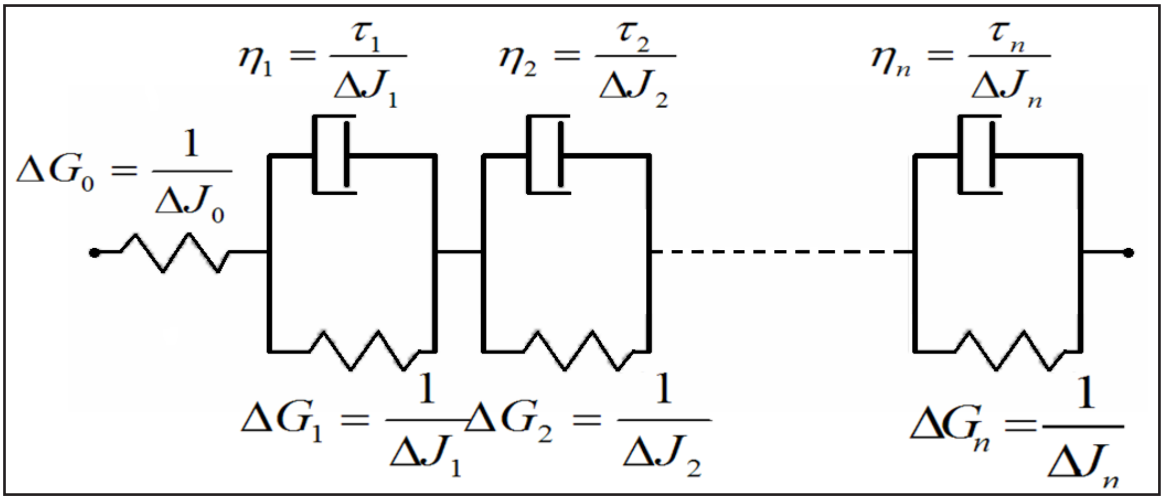


Figure 7 Generalized Kelvin model.

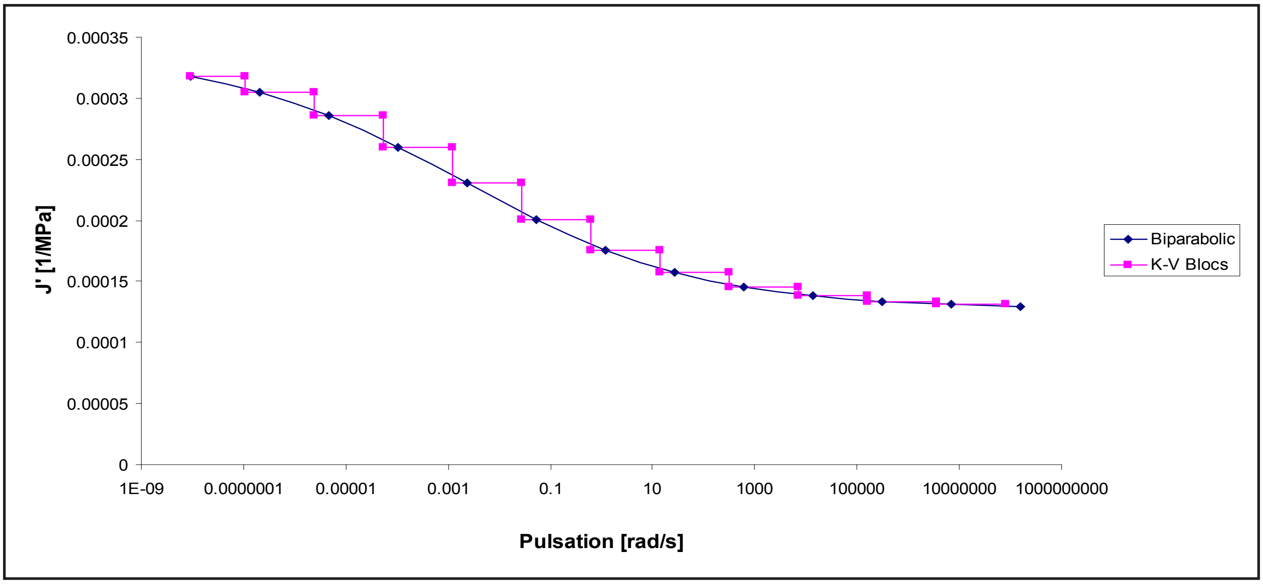


Figure 8 Discretization of the master curve.

generalized model are necessary to take into account a large relaxation time spectrum of the polyamide 6. The distribution of retardation time $\tau_i(T_{ref})$ is deduced from pulsation ω_i at the maximum of $J''_i(i\omega, T_{ref})$; i.e.—in the middle of the frequency segment. The retardation times are deduced with the relationship shown in Equation 5. Figure 8 shows a Master Curve built at the glass transition temperature of 60°C, with fiber parallel to the solicitation direction.

$$\tau_i = \frac{1}{\omega_i} \tag{5}$$

Shift factors $a_{Tref}(T)$—obtained via the time-temperature superposition principle—enable deducing the retardation time spectrum at temperature T, from the retardation time spectrum obtained at T_{ref} as follows:

$$\tau_i(T) = \tau_i(T_{ref}).a_{T_{ref}}(T) \tag{6}$$

Humidity influences the evolution of viscoelastic properties. Letzelter et al (Ref. 8) assumed that humidity has a similar effect as the temperature on the retardation time spectrum. Within this assumption, a relationship (Eq. 6) can be modified to integrate the relative humidity:

$$\tau_i(T,RH) = \tau_i(T_{ref}Dry).a_{T_{ref},dry}(T).b_{Tref}(RH) \tag{7}$$

The linear viscoelastic properties of polymers can be deduced from spectrometer test DMA.

Load-Sharing Model

The numerical model is based on the procedure developed at LaMCoS. Instantaneous quasi-static studies are computed for steel and polyamide 66 gears (Fig. 9). This procedure is divided into three principal steps. Initially, tooth geometry is obtained with tooth corrections adapted to molded gears; the second step consists of an unloaded kinematics simulation to determine the potential contact zones, while the third step achieves the computation of load sharing between all teeth in contact. This third step integrates the viscoelastic displacement and the loading history in the case of PA6 + 30% GF material. The method yields some results, such as instantaneous pressure distribution, transmission error, load sharing, etc.

For polymer gears it is necessary to know the displacement history of gear and pinion. Consequently, the meshing developed for the polymer gears covers the entire tooth surface. The displacements of pinion and gear are saved for each kinematics position and injected into the next one in order to account for the material relaxation.

The equation of compatibility of displacement. The load-sharing problem consists of solving the equations of displacement compatibility (Eq. 8) while balancing the driving torque (Eq. 9).

$$p(M_k).e(M_k) = p(M_k).(\delta(M_k) + u(M_k) - \alpha) = 0 \tag{8}$$

$$C_{moteur} = \sum_{k=0}^{K} (p_k s_k n_k \wedge M_k) \tag{9}$$

K is the number of nodes of the meshing;
$P(M_k)$ is the contact pressure at point M_k
$e(M_k)$ is the gap between the profiles of the gear and pinion at point M_k after loading
$\delta(M_k)$ is the gap between the profiles of the gear and pinion at point M_k before loading

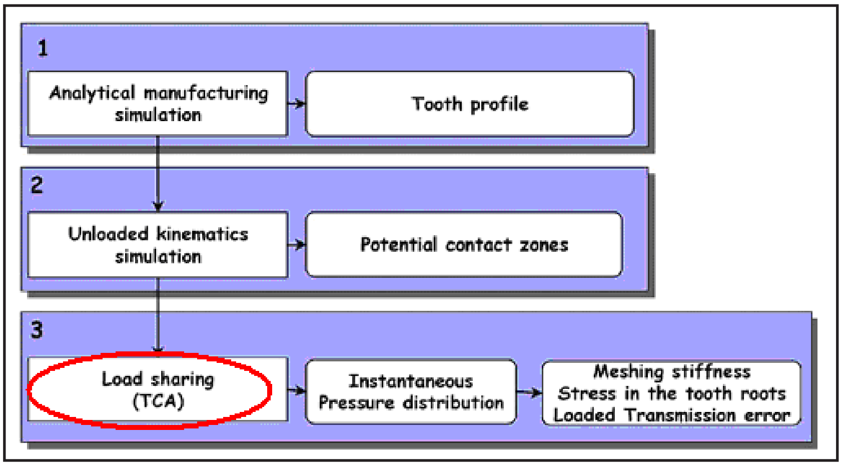


Figure 9 Computing process.

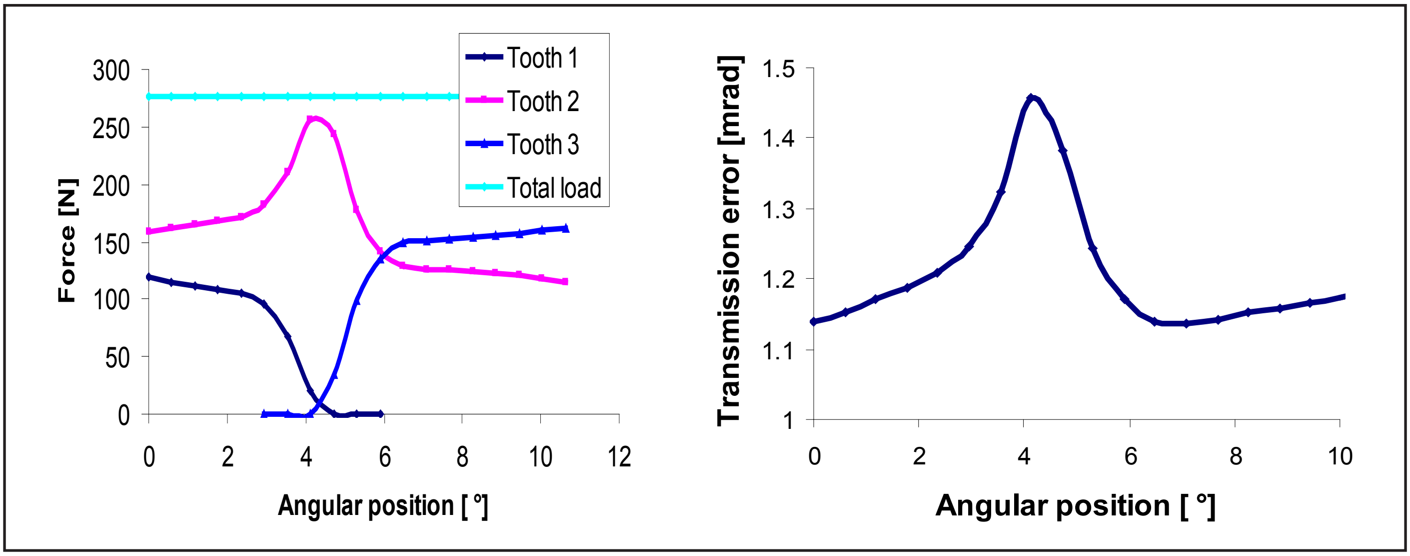


Figure 10 Load-sharing model (a); transmission error at 25°C, 50% of relative humidity, 300 rpm and 15 Nm (b).

$u\,(M_k)$ is the displacement at point M_k and α is the global body adjustment

The influence coefficient. In order to solve the load-sharing problem, it is necessary to compute the displacement u_k, depending on pressure p_k. It is possible to write the relationship (Eq. 10) between the displacement and the pressure with the method of the influence coefficients C_{kj}. There are two types of influence coefficients — the geometrical bulk influence coefficients C_{kj}^V obtained with a standard finite element method, and the contact influence coefficients C_{kj}^S computed with the Boussinesq theory.

$$u_k=\sum_{j=1}^{K}C_{kj}p_j \text{ with } C_{kj}=C_{kj}^V+C_{kj}^S \qquad (10)$$

With the polymer gears the surface geometrical influence coefficients are not linked with the material's compliance; they are defined by the relationship found in Equation 11:

$$C_{kj}^S+J_{mat}\,C_{kj}^{*S} \qquad (11)$$

The geometrical bulk influence coefficient method is obtained in the case of an elastic material. They are computed on gear geometry where the fiber orientation is taken into account in each section (Fig. 6); they are defined by the relationship found in Equation 12:

$$C_{kj}^V+J_{mat}\,C_{kj}^{*V} \qquad (12)$$

The viscoelastic displacement on meshing. In order to determine the nodes displacement in the meshing, the displacement $u_k\,(t)$ is determined (Eq. 12) by the link between the relationships found in Equations 3, 10, 11 and 12.

$$u_k(t)=\sum_{i=0}^{n}u_k^i(t) \qquad (13)$$

$$u_k^i(t)=\sum_{j=0}^{K}\left[C_{kj}^{*V}p_j(t)\,\Delta J_i^V\left(\frac{\Delta t}{\tau_i+\Delta t}\right)+C_{kj}^{*S}p_j(t)\,\Delta J_i^S\left(\frac{\Delta t}{\tau_i+\Delta t}\right)\right]u_k^i(t-dt)\left(\frac{\tau_i}{\tau_i+\Delta t}\right) \qquad (14)$$

ΔJ_i^V represents the bulk storage compliance of polyamide 6 matrix behavior for each block. ΔJ_i^S represents the surface storage compliance of polyamide 6 behavior for each block. Moreover, ΔJ_i^s acknowledges the presence of fibers perpendicular to the solicitation direction.

τ_i remains the same for the surface and bulk material, with the assumption that fiber doesn't affect the viscoelastic behavior of the polyamide 6 matrix. Indeed, τ_i can be adapted to the surface and bulk temperature by the link between the relationship of Equation 7 and the thermal behavior equations proposed by VDI 2736 (Ref. 14).

Numerical Results

Generality. The gear data of the studied gears are shown in the Table 1.

Table 1 Gear data

	Pinion	Gear
Module (mm)	3	3
Pressure angle (°)	20	20
Number of teeth	32	41
Tooth width (mm)	20	20

Figure 10 (a) shows the load-sharing simulated; Figure 10 (b) shows the transmission error simulated for polymer gears during the meshing of one tooth at 25°C and 50% relative humidity, 300 rpm, and 20 Nm. Figure 10 (a) shows a correct shape for the simulated load-sharing. Tooth -1 is unloaded and Tooth 1 is loaded gradually. Tooth 0 — i.e., the central tooth — remains constant. The sum of three forces is equal to a constant force created by the driving torque.

Fiber orientation influence. Three different fiber organization models were used:

- **Case 1**: ***Homogeneous model***:
  Halpin Kardo mixture (Eq. 15) is used to describe the fiber influence (Ref. 15):

$$E_{3D}=0.184\times E_{//}+0.816\times E_{\perp} \qquad (15)$$

- **Case 2:** ***Unidirectional model***:
  3D stiffness matrix is used for each material section represented in Figure 6.
- **Case 3:** ***Anisotropic model closed to the tomographical and simulation observations.***

These three models are implemented on standard finite element software in order to obtain the influence coefficients C_{kj}^{V}.

A review of the results reveals that the tooth root stress and contact pressure were minimally impacted by the three models; differences remained under 3%.

Regarding the contact pressures, the material models remain the same at the surface in all three cases. Fibers are always perpendicular to the solicitation direction. This similarity results in equal contact displacements and contact pressure.

Regarding the tooth root stress, this is explained by a low load-sharing change among the different cases.

Table 2 represents the transmission error amplitude in (mrad) where Model 3 is considered the reference.

Differences between the three models did not exceed 8%; the greatest difference between the three models corresponds to the cases where the tooth bending is the most important at 20N-m and 100°C.

Tooth bending displacements. Displacements are observed at the highest contact line. They correspond to the wheel and pinion bending displacement in the case of a tip circle contact of the pinion. Corresponding gear data is found in Table 1; measured displacements take into account the bulk and contact displacements. Also, for both of them the elastic, viscous, and historic origins of displacements are measured. Figure 11 represents the total displacement of pinion and gear at the highest contact point — dependent upon torque and temperature at different rotation speed levels. Total displacements are strongly impacted by temperature and torque, whereas rotation speed has minimal influence.

Bulk and contact displacements. Bulk and contact displacements are distinguished in the displacement equation (Eq. 14) that allows for a separate evaluation of their value. Figure 12 represents the bulk displacements (%) compared to the total displacement at the highest contact line and at different rotation speeds from 10 – 1,000 rpm. It can be noticed that contact displacement plus surface displacement correspond to 100% total displacements.

A look at Figure 12 shows that the bulk displacements are dominant and strongly influenced by the temperature where they represent 85% of the total displacements at 120°C, whereas they represent 65% at 40°C.

Influence of the history of displacements. It is assumed that the tooth is relaxed for one gear rotation. However, the history of displacement due to load just before the tooth arrives in the contact area (2 pitch taken into account) between each quasi-static position is addressed accordingly. An investigation of the influence of history displacement dependent upon temperature, torque and rotation speed has been completed. Displacements are observed at the highest contact line. Results are presented in Figure 13 and the gear data correspond to that found in Table 1.

The history of the displacement is mainly impacted by temperature; at the glass temperature transition and 10 rpm, the history of the displacement represents 18% of total displacement.

Displacements reach their highest value at the glass temperature. It is apparent that

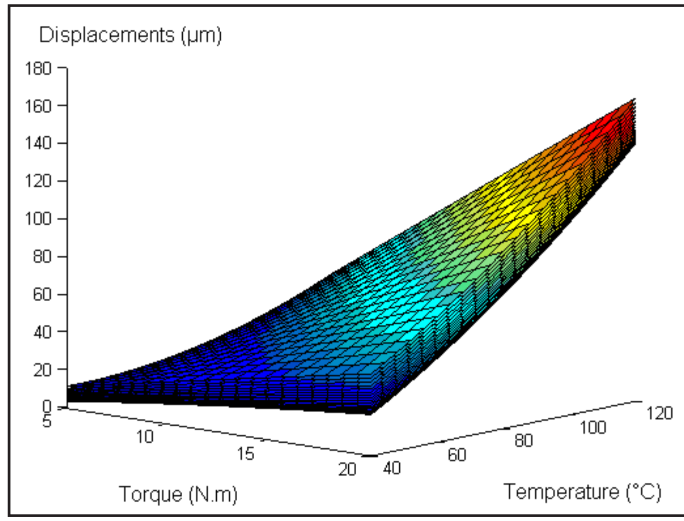


Figure 11 **Total tooth displacements at the highest contact point at different rotation speed levels (10–1,000 rpm), Rh = 0%.**

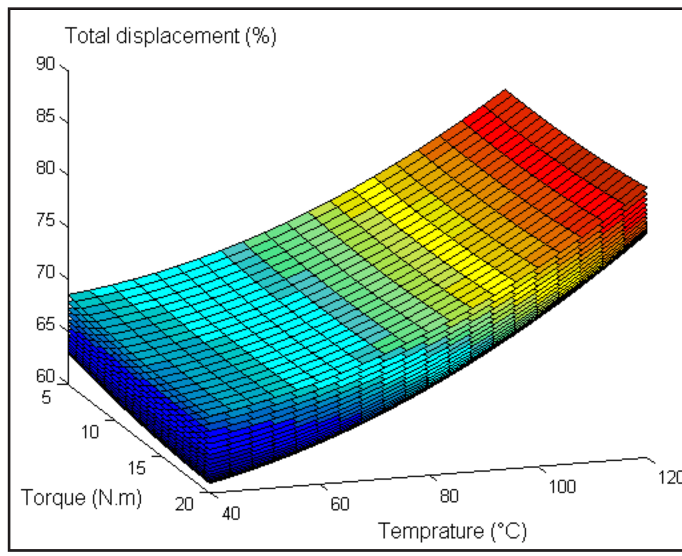


Figure 12 **Bulk displacements (%) of the total displacement at the highest contact regarding the bulk displacements at different rotation speed level (10–1,000 rpm), Rh = 0%.**

Table 2 Transmission error depending on temperature, torque and model

	T = 0°C		T = 60°C		T = 100°C		
Model 1	0.125	7.4%	0.142	7.2%	0.274	0.7%	C = 5N-m
Model 2	0.132	2.2%	0.150	1.9%	0.272	1.5%	
Model 3	0.135		0.153		0.276		
Model 1	0.285	2.4%	0.286	0.7%	0.233	6.8%	C = 12.5N-m
Model 2	0.288	1.3%	0.280	1.4%	0.221	1.3%	
Model 3	0.292		0.284		0.218		
Model 1	0.304	3.7%	0.278	7.7%	0.206	8.1%	C = 20N-m
Model 2	0.288	1.7%	0.253	1.9%	0.230	2.6%	
Model 3	0.293		0.258		0.224		

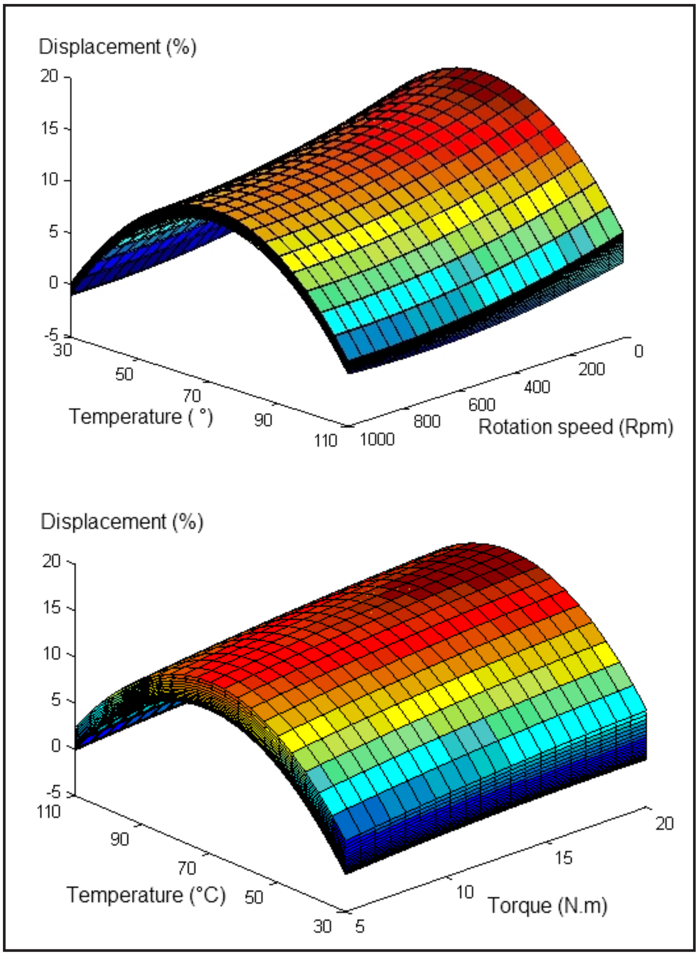


Figure 13 Historic displacements (%) of total displacement (a) depending on temperature and rotation speed at different torque levels (0–20 N-m.); (b) function of temperature and torque at different rotation speed levels (10–1,000 rpm), Rh = 0%.

at low rotation speed (Fig. 13 (a)) the history of displacement impact is more significant, which is attributed to the longer loading time.

Conclusion

This study presents a fast and efficient method to predict the mechanical behavior of polyamide 6 + 30% GF spur gears meshing. The visco-elastic properties are simulated with the generalized Kelvin model. This model takes into account speed, temperature, humidity and fiber orientation. With the viscoelastic displacement and the method-of-influence coefficients calculated over the entire surface of the tooth, it is possible to solve the load-sharing problem.

The computation time is reasonable — i.e., 40 min for 17 quasi-static kinematics positions. Also, this model allows simulation of the fiber amount and orientation influence. Unidirectional models — compared to homogeneous versions and based on a rule of mixture and realistic fiber orientation models — reveal a difference of less than 8% regarding the transmission error amplitude and less than 3% regarding contact pressure and tooth root stresses. The calculated results confirmed that the variation of temperature, humidity and rotation speed can have a considerable influence on the history of displacement, and so they must be taken into account in any model devoted to plastic gears.

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Innovative Induction Hardening Process with Pre-heating for Improved Fatigue Performance of Gear Component

Dr. Zhichao (Charlie) Li

Contact fatigue and bending fatigue are two main failure modes of steel gears, while surface pitting and spalling are two common contact fatigue failures—caused by alternating subsurface shear stresses from the contact load between two gear mates. And when a gear is in service under cyclic load, concentrated bending stresses exist at the root fillet—the main driver of bending fatigue failures. Induction hardening is becoming an increasingly popular response to these problems, due to its process consistency, reduced energy consumption, clean environment and improved product quality—but not without issues of its own (irregular residual stresses and bending fatigue). Thus a new approach is proposed here that flexibly controls the magnitude of residual stress in the regions of root fillet and tooth flank by pre-heating prior to induction hardening. Using an external spur gear made of AISI 4340 as an example, this new concept/process is demonstrated using finite element modeling and *DANTE* commercial software.

Introduction

Residual stresses embedded inside a hardened gear are critical to its fatigue performance. There are two main failure modes for gear components: contact fatigue and bending fatigue. In service, one pair of gears transfer torque load through the contact of two teeth. High shear stresses co-exist with high hydrostatic pressure under the contact surface. Depending on the load magnitude and the gear size, the depth of the highest shear stress point varies. To improve the contact fatigue life, the hardened case depth needs to be deeper than the highest shear stress point. Compressive residual stresses located inside the hardened case benefit the contact fatigue performance (Ref. 1). The bending fatigue failures are commonly found at root fillet location where tooth flank and root meet. Under the contact load between two gears, the root fillet experiences cyclic stresses, which is the driver of bending fatigue failure. Compressive residual stresses from heat treatment or other surface processing can significantly improve the bending fatigue performance (Ref. 2).

Induction hardening is more environmentally friendly than conventional furnace heating and liquid quenching. It also provides flexibility in control of case depth, residual stresses, and part distortion. Due to these advantages, the induction hardening process is becoming more popular to harden steel gears.

During induction heating, the energy to heat the part is generated inside the part by eddy currents in response to the imposed alternating magnetic field. The energy distribution in the part is directly related to the distance between the inductor and the part, the frequency and power of the inductor. Lower frequency and lower power heat the part deeper over longer time period. Higher frequency and higher power heat a shallower layer over shorter time period. The temperature distribution in the part is a combined result of induction heating and thermal conduction. During induction hardening of steel components, both thermal gradient and phase transformations simultaneously contribute to the evolution of internal stresses and shape change. Recent developments in heat treatment modeling technologies make it possible to understand the material's responses during heat treatment processes, such as how the internal stresses and distortion are generated. *DANTE* is a commercial heat treatment software based on the finite element method (Refs. 3-5) that was designed to model the responses of steel parts during heat treatment processes. The material's responses include phase transformations, deformation, residual stresses, hardness, etc. Typical heat treatment process steps include austenitization, carburization, quench hardening, and tempering. Phase transformation kinetics and mechanical properties are required for modeling the heat treatment processes (Refs. 6, 7). *DANTE* has a validated database for most common low- and medium-alloy carbon steel grades that have been used successfully in the past to model induction hardening processes (Refs. 8, 9). With the help of computer modeling engineers with *DANTE* software have discovered that residual compression at the root fillet of a gear can be enhanced by applying pre-heating prior to induction hardening. The pre-heating process can be implemented either by furnace or induction heating. In this paper, this process is demonstrated by computer modeling, using an AISI 4340 spur gear example.

Phase Transformation Kinetics

Phase transformations are involved in most heat treatment processes of steel components. During heating, initial phases transform to austenite, and carbides dissolve while being held at the austenitization temperature. During cooling or quenching steps, austenite transforms to ferrite, pearlite, bainite, or martensite, depending on the cooling rate and hardenability of the steel grade. At different heat treatment stages, or at different regions in a part, the material can be composed of different phases and the volume fractions of individual phases are functions of chemical composition and thermal history. To model the heat treatment process of steel components, accurate descriptions of material properties and process information are required. The basic material property data includes phase transformation kinetics, and thermal and mechanical properties of individual phases.

Phase transformations during quenching are classified as diffusive and martensitic transformations. The diffusive transformation is time- and temperature-driven, and the martensitic transformation is mainly temperature-driven. The two types of phase transformation models used in *DANTE* are described in Equations 1 and 2.

$$\frac{d\phi_d}{dt} = v_d(T)\,\phi_d^{\alpha 1}(1-\phi_d)^{\beta 1}\,\phi_a \tag{1}$$

$$\frac{d\phi_m}{dT} = v_m(1-\phi_m)^{\alpha 2}(\phi_m+\varphi\phi_d)^{\beta 2}\,\phi_a \tag{2}$$

where

- ϕ_d is the volume fractions of individual diffusive phase and martensite transformed from austenite
- v_d is a transformation mobility and is a function of temperature
- $\alpha 1, \beta 1$ (superscripts) are constants of diffusive transformation
- ϕ_a is the volume fraction of austenite
- ϕ_m is the volume fractions of individual diffusive phase and martensite transformed from austenite
- v_m is a transformation mobility and is a constant
- $\alpha 2, \beta 2$ (superscripts) are constants of martensitic transformation
- φ is a constant of martensitic transformation

For each individual phase formation, one set of transformation kinetics parameters is required.

Different experiments can be used to characterize phase transformations, such as a dilatometry test, Jominy end-quench test, metallographic characterization, etc. Among these experiments, the dilatometry test is preferred due to its accuracy and economic advantage, as well for yielding more useful data (Ref. 7). Figure 1a is a strain curve of a martensitic phase transformation dilatometry test for AISI 4340. The X-axis is temperature in Celsius, and the Y-axis is strain from the combined effects of thermal shrinkage and phase transformations. During this specific cooling test the cooling rate of the sample is fast enough to avoid diffusive phase formations. During cooling, the dilatometry sample shrinks with the temperature dropping. When the sample reaches the martensitic transformation starting temperature (Ms), martensitic formation starts with volume expansion. The strain change during transformation is a combination of thermal strain and phase transformation volume change. The data obtained from this specific dilatometry test include coefficient of thermal expansion (CTE) for austenite and martensite, martensitic transformation starting and finishing temperature (Ms, Mf), transformation strain, and phase transformation kinetics (transformation rate) — from austenite to martensite. These data are critical to the accuracy of modeling the internal stresses and deformation during quenching.

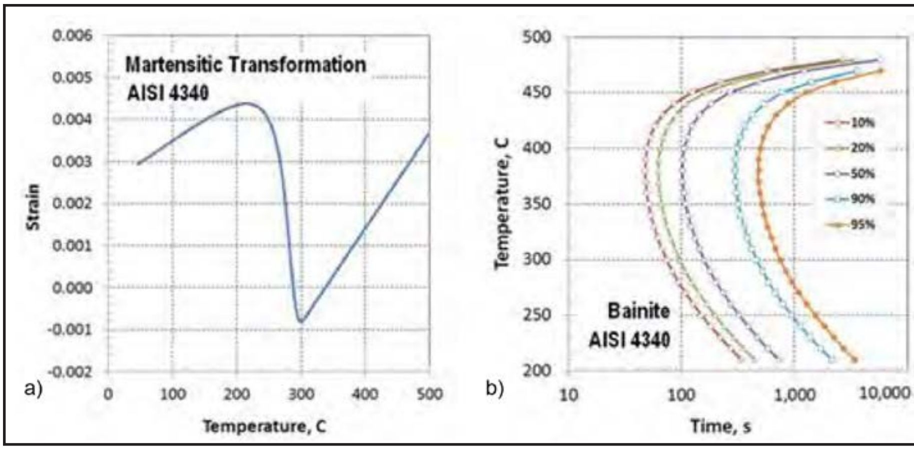

Figure 1 Dilatometry strain curve during continuous cooling (a); bainitic TTT diagram of AISI 4340 generated from DANTE database (b).

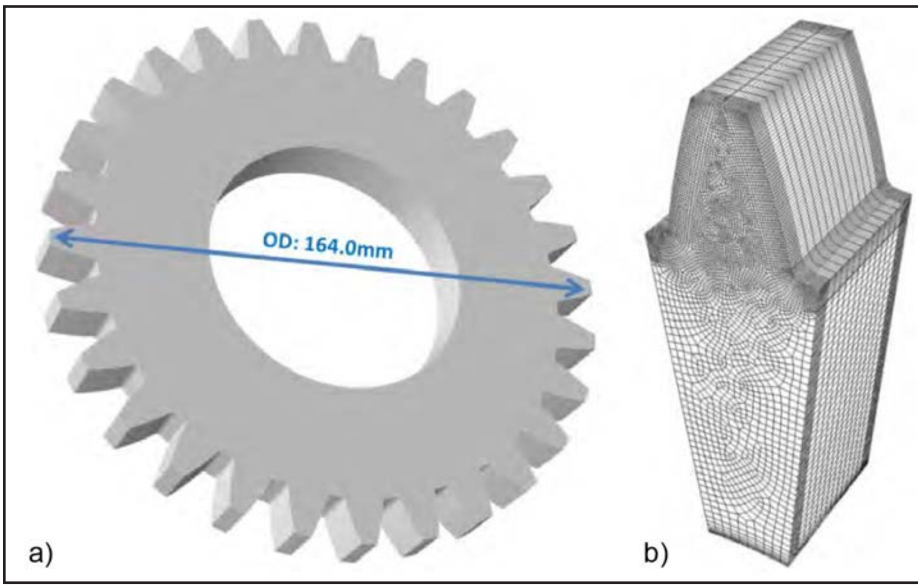

Figure 2 CAD model of the spur gear (a); single-tooth FEA model (b).

Diffusive transformations can also be characterized by dilatometry tests. In general, a series of dilatometry tests with different cooling rates are required to fit a full set of model parameters for diffusive and martensitic phase transformations. Once the phase transformation kinetics parameters are fit from dilatometry tests, TTT/CCT diagrams can be generated for users to review. TTT/CCT diagrams are not directly used by *DANTE* models of phase transformation kinetics, but they are often useful because they directly represent the hardenability. Figure 1b is the bainitic, isothermal transformation diagram (TTT) created from the *DANTE* database. The incubation times for ferritic and pearlitic transformations are much longer than that of the bainitic transformation for this steel, and therefore will not be discussed in this paper.

Descriptions of Gear Model and Heat Treatment Process

A spur gear (Fig. 2a) is selected to study the effect of pre-heating temperature on residual stresses. The outer diameter of this gear is 164.0 mm; the inner diameter 75.7 mm; and the thickness 15 mm. This gear has a total of 28 teeth. With the assumption that all teeth behave the same during the whole heat treatment process, a single-tooth model with cyclic boundary condition is used to represent the entire gear. The finite element meshing of the single-tooth model is shown in Figure 2b, with 106,850 nodes and 98,784 linear hexagonal elements. Fine elements are used in the part surface to catch the thermal and stress gradients.

Instead of modeling the electromagnetic field, the power distribution generated by inductor is applied directly to drive the heat treatment model. The power distribution can either be predicted by electromagnetic modeling software, or be estimated based on the relations of inductor power, frequency, and part geometry; both methods have been successfully used in the past (Refs. 8, 9). In this study the induction hardening process is simplified as two steps: 1) induction heating the gear teeth for 3.5 seconds, and 2) spray quench the gear to room temperature using a 6% polymer solution. There is no dwell-time between heating and spray quenching. The induction hardening process is also compared with traditional oil quench. Two oil quench processes are modeled: 1) furnace heating and oil quench of an AISI 4340 gear, and 2) furnace heating, carburization, and oil quench of an AISI 4320 gear. The carburization temperature is 900°C, held in 0.8% carbon potential atmosphere for 6 hours.

Six induction hardening processes are modeled. The first model has no pre-heating, and the other five models assume uniform pre-heating temperatures of 200°C, 250°C, 300°C, 350°C, and 400°C, individually. With pre-heating, the time duration and frequency of induction heating are kept the same, but the power of the inductor is reduced to avoid overheating the teeth. The powers of inductor are 80%,

75%, 70%, 65% and 60%, for pre-heating temperatures of 200°C, 250°C, 300°C, 350°C, and 400°C — relative to the inductor power without pre-heating. The temperature distributions at the end of the 3.5 s heating are shown in Figure 3 for all the six scenarios. The lower bounds of the legends in Figure 3 vary with pre-heating temperatures, and the upper bounds are the highest temperatures at the root. The temperature at root for the process without pre-heating is about 1,100°C, comparing to 1,050°C for all cases with pre-heating.

For all six induction hardening scenarios, the depths of hardened layer at the root are kept closely to 1.5 mm. However, the obtained martensite distributions at the tooth tip have a significant difference due to the pre-heating effect. With higher pre-heating temperature, more martensite is formed at the tooth tip. In general, a partially hardened tooth tip is preferred to reduce the possibility of brittle crack at the tooth tip edges (Fig. 4).

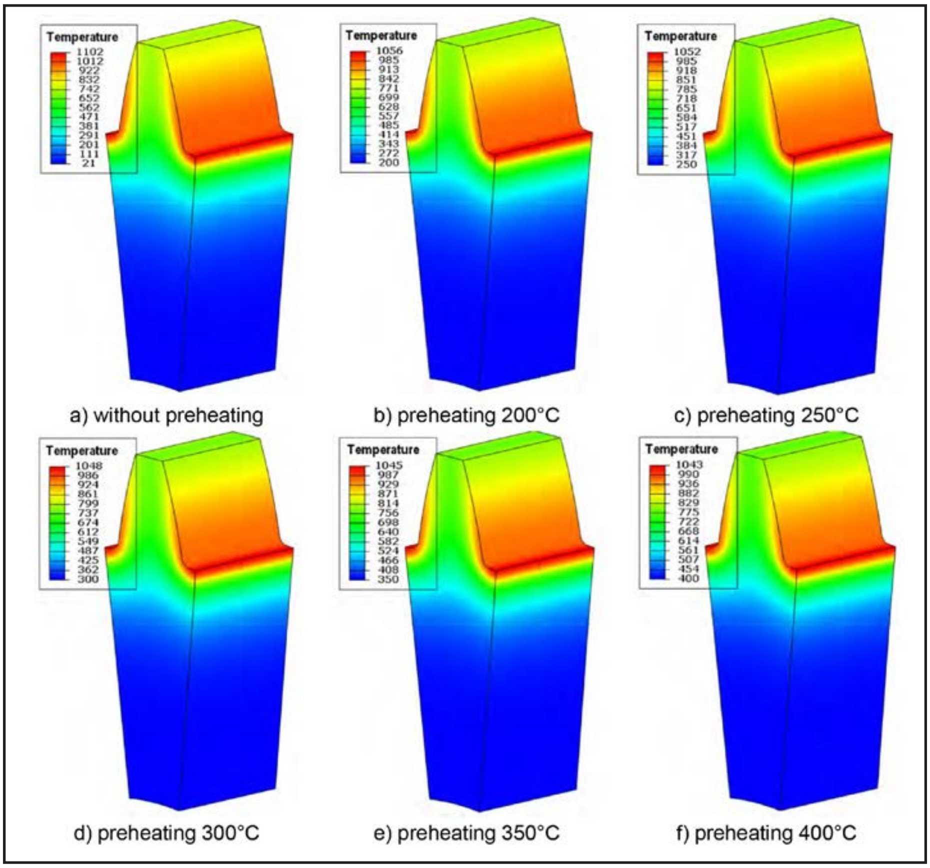

Figure 3 Contours of temperature distribution at the end of induction heating.

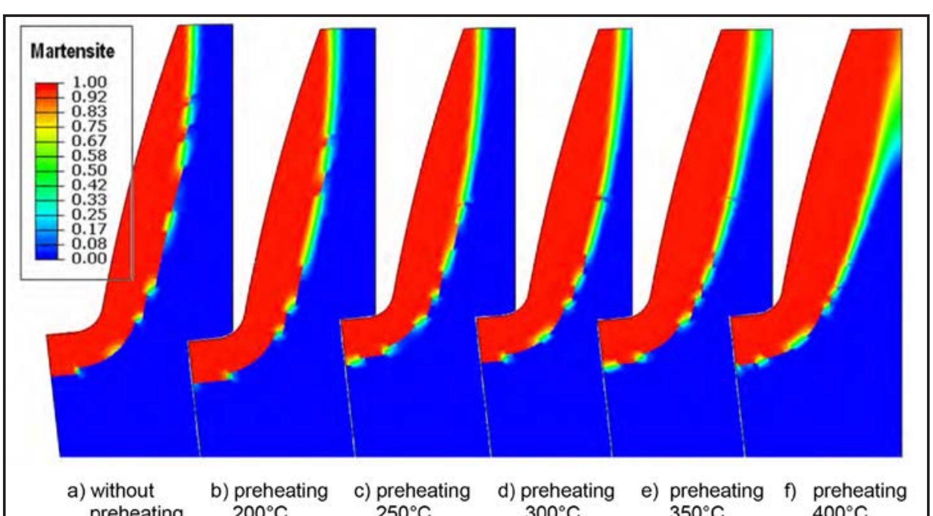

Figure 4 Contours of martensite distribution from various induction hardening scenarios.

Results and Discussions

In this study a global Cartesian coordinate system was used to calculate the stresses for all the heat treatment models. The origin of the global Cartesian coordinate system is located on the axis of the gear. Once the models are completed, two local cylindrical coordinate systems are created to post-process the tangential stresses at the tooth flank and root fillet regions (Fig. 5a). The tangential stresses at the root fillet are plotted using the first local cylindrical coordinate system, and the tangential stresses at the tooth flank are plotted using the second local cylindrical coordinate system. Figure 5b shows two highlighted lines representing the root fillet (CD) and pitch (AB), individually. Using the local cylindrical coordinate systems, stresses away from the root fillet or tooth flank are no longer tangential to the surface. Tangential, residual stresses predicted at the root fillet are used to evaluate the bending fatigue performance of the gear.

The tangential residual stresses at the root fillet are compared between induction hardening and traditional oil quench hardening processes. Oil quench of AISI 4340 creates a residual tension around 200 MPa at the root fillet (Fig. 6a). A combination of carburization and oil quench creates a residual compression around 580 MPa at the root fillet (Fig. 6b). The magnitude of the residual compression at the edge is to 350 MPa — or 230 MPa less than that at the middle width location. The effect of carburization on residual stresses has been reported in previous publications (Refs. 10, 11). The induction hardening process without pre-heating creates a residual compression about 500 MPa at the root fillet (Figure 6c). The case depth of induction hardening is deeper than that of carburization and oil quench. After induction hardening, the magnitude of tensile stress under the case is higher in order to balance the compression in the hardened case.

Residual stresses in the tangential direction at the tooth flank are shown (Fig. 7) for the same three hardening scenarios described in Figure 6. Slight tension is predicted for the oil quench of the AISI 4340 gear. A thin layer of compression is predicted for carburization and oil quench of the AISI 4320 gear. For the induction hardening process without pre-heating, the layer of compression is deeper and a higher magnitude of tensile stress is predicted under the case,

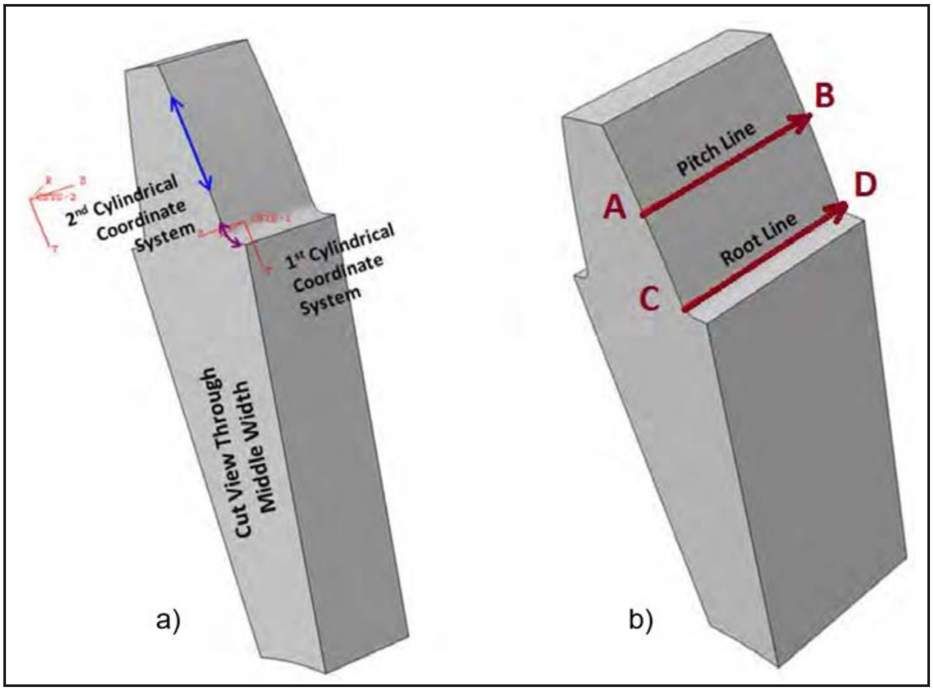

Figure 5 Definitions of two local, cylindrical coordinate systems (a); pitch and root fillet lines selected for post-processing tangential residual stresses (b).

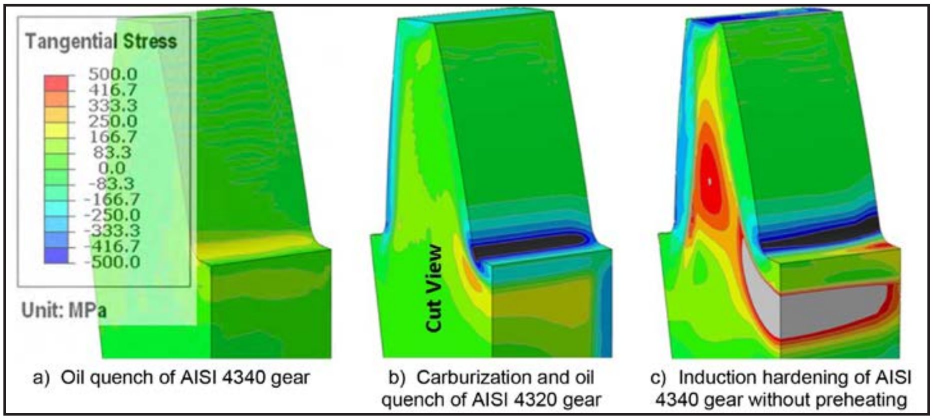

Figure 6 Contours of tangential residual stress at root fillet using the first local, cylindrical coordinate system.

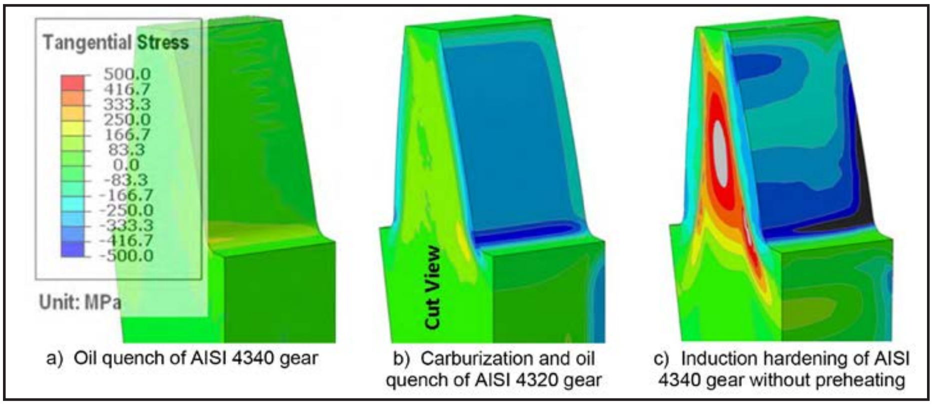

Figure 7 Contours of tangential, residual stress at tooth flank.

comparing to the carburization and oil quench process.

The effect of the pre-heating temperature on tangential residual stresses at the root fillet is shown in Figure 8 by the three pre-heating temperatures of 200°C, 300°C, and 400°C. The magnitude of residual compression at the root fillet are 750 MPa, 900 MPa, and 1,000 MPa, respectively, for the three scenarios. Pre-heating prior to induction hardening can effectively enhance the residual stresses at the root fillet. Relative to the traditional induction hardening without pre-heating, the increase of compression at the root fillet from a 200°C pre-heating temperature is 250 MPa, which is significant to the bending fatigue performance. With a higher pre-heating temperature, the effect can be more significant. However, care must be taken with the consideration of residual stresses at other regions beyond just the root fillet.

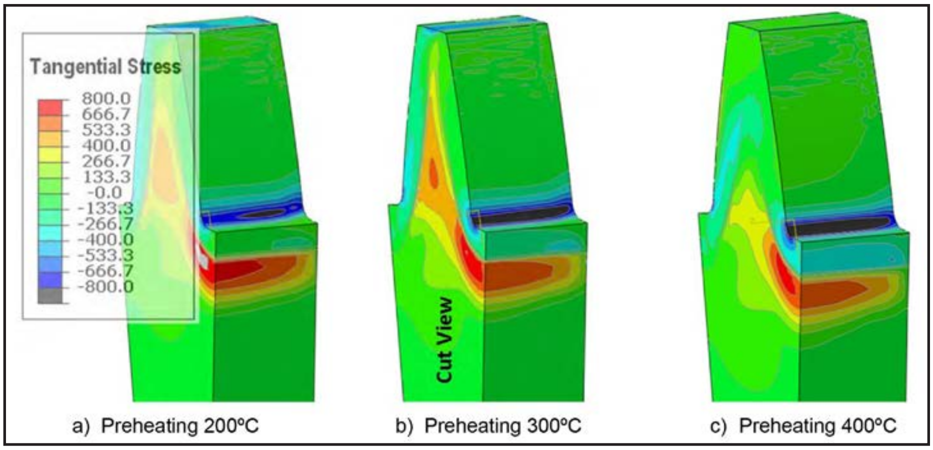

Figure 8 **Contours of tangential, residual stress at root fillet.**

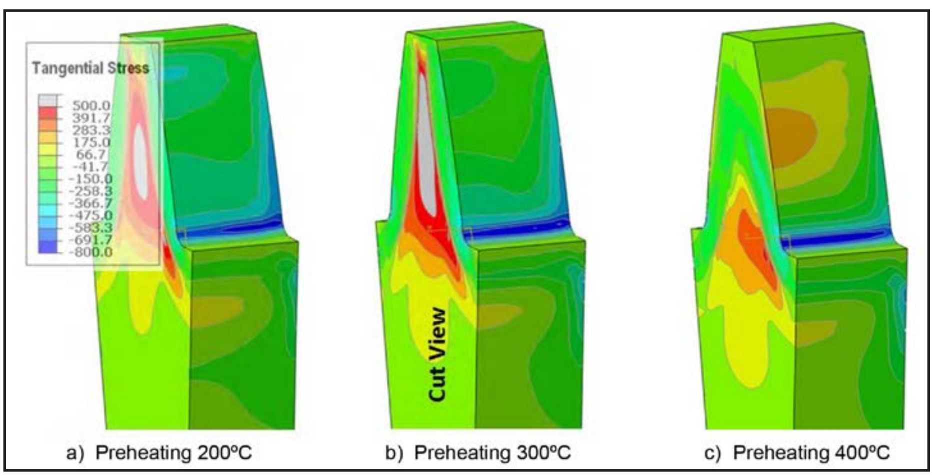

Figure 9 **Contours of tangential, residual stress at tooth flank.**

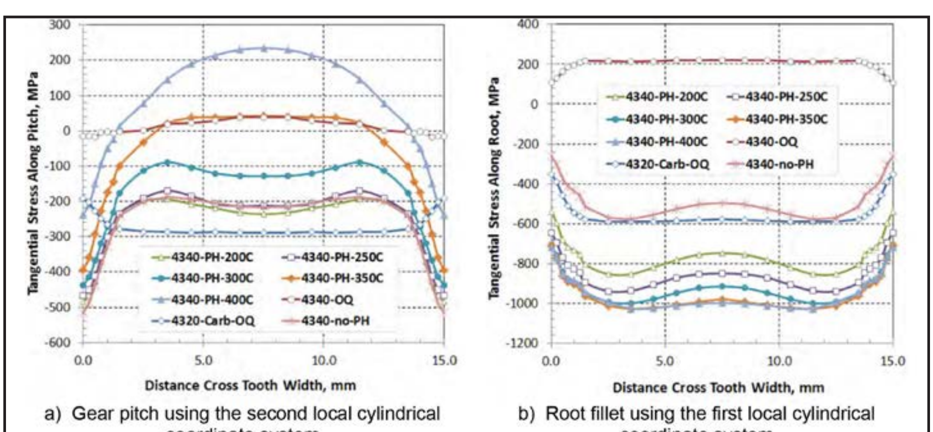

Figure 10 **Comparison of tangential, residual stress from various heat treatment scenarios.**

The pre-heating temperature affects the residual stresses not only at the root fillet, but also at the tooth flank. The residual stresses in the tangential direction at the tooth flank are calculated using the second local cylindrical coordinate system, and the contours of residual stresses are shown in Figure 9 for the three pre-heating temperatures of 200°C, 300°C, and 400°C. By increasing the pre-heating temperature from 200°C to 400°C, the magnitude of surface compression decreases. Surface tension is predicted with a 400°C pre-heating temperature. With higher pre-heating temperature, less power is required to austenitize the gear tooth during heating. The thermal gradient from the surface to the core is lower during both heating and quenching processes, which is the main reason for less compression obtained at the tooth flank.

The residual stresses in the tangential direction along the pitch line AB and the root fillet line CD in Figure 5b are plotted in Figures 10a and 10b for all the hardening processes. The X-axis is the distance from one face of the gear (point A or C) in the axial direction. The Y-axis is the tangential stresses along the two lines calculated using the two local cylindrical coordinate systems. By increasing the pre-heating temperature, the residual compression at the root fillet is enhanced, but the residual compression at the tooth flank is damaged when the pre-heating temperature is over 300°C. Depending on the load condition and failure mode in service, the pre-heating temperature can be optimized to balance the residual compression at both root fillet or tooth flank for improved fatigue performance.

Quench hardening is a high material's nonlinear process due to phase transformations. Distortion is inevitable, but accurate prediction of distortion using modeling helps the process optimization to minimize distortion. The predicted radial distortions for all eight hardening scenarios are shown in Figure 11. The contours shown are the radial distortion relative to the dimension prior to heat treatment. Also, Figures 11a–f represent the distortions caused by induction hardening, and Figures 11g and h are from oil quench. Pre-heating prior to induction hardening can have a significant effect on the distortion — especially when the whole tooth or a large region of the tooth is hardened rather than merely a shallow surface layer — which is shown in Figure 11f with a 400°C pre-heating temperature scenario. The same legend is used to plot the contours of radial distortion caused by the induction hardening processes, so the color of the contour represents the magnitude of distortion from Figures 11a–11f. A higher pre-heating temperature tends to generate higher distortion, which is mainly due to the more regional phase transformation in the tooth. Significant radial shrinkages are predicted for both oil quench scenarios. Different legends are used for the two oil quench scenarios. In this study the oil quench processes create larger distortion relative to the induction hardening processes.

During quenching, time and temperature are the two main drivers of phase transformations. Both thermal gradient and volume change caused by phase transformations contribute to the evolution of stresses. As shown in Figure 12a, one straight line MN is selected to demonstrate the relationship among temperature, phase transformation and stresses. The line MN is located at the middle width of the gear, with point M right on the surface and point N at a depth of 3 mm. The line MN is normal to the tangent of the root fillet. The induction hardening process with 250°C pre-heating temperature is used for this demonstration. The time is reset to zero at the beginning of the spray quench. The X-axis in Figures 12 b–d is the distance from the root fillet surface, with X = 0.0 mm representing the surface point M. The Y-axes are the volume fraction of austenite, temperature, and tangential stress, respectively. At time 0.0 s (the beginning of spray quench), small compressive stresses along the line MN are predicted, which is mainly caused by the thermal expansion of the tooth from induction heating.

During spray quenching, the cooling rate is fast enough to avoid the formation of diffusive phases, and martensite is the only phase transformed from austenite. The martensitic transformation starting temperature (Ms) is about 305°C for AISI 4340. At 1.219 s during quench, the

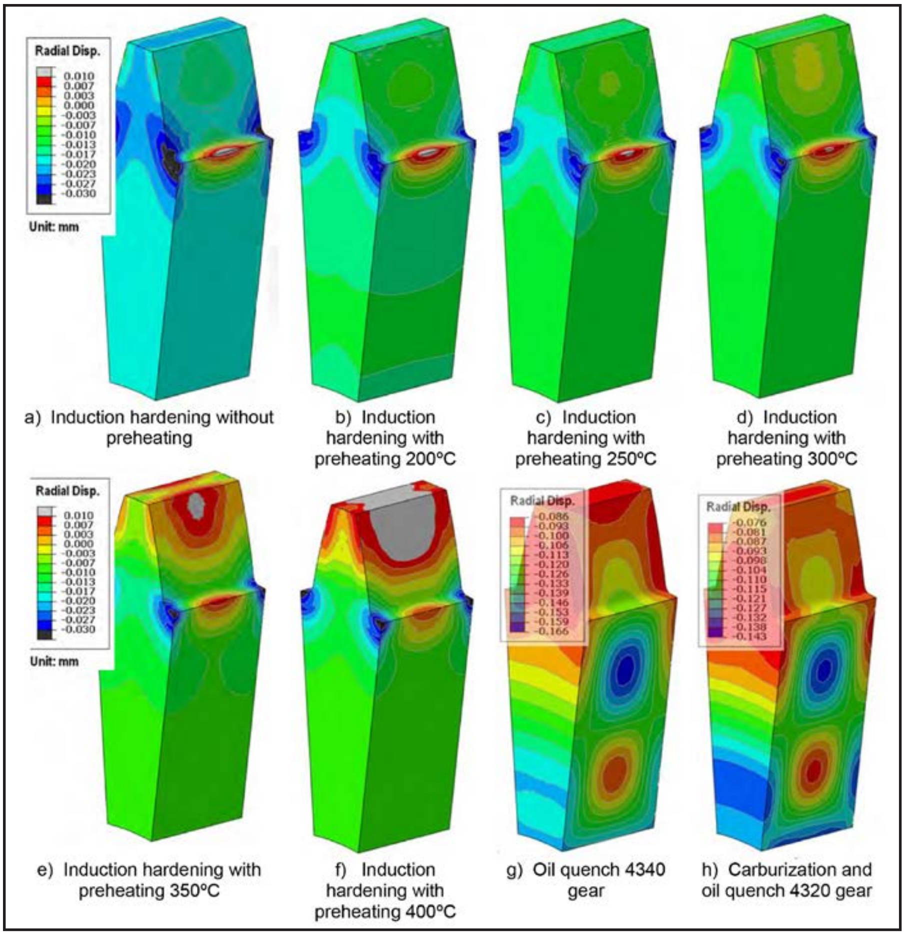

Figure 11 **Comparison of radial distortion from various heat treatment scenarios.**

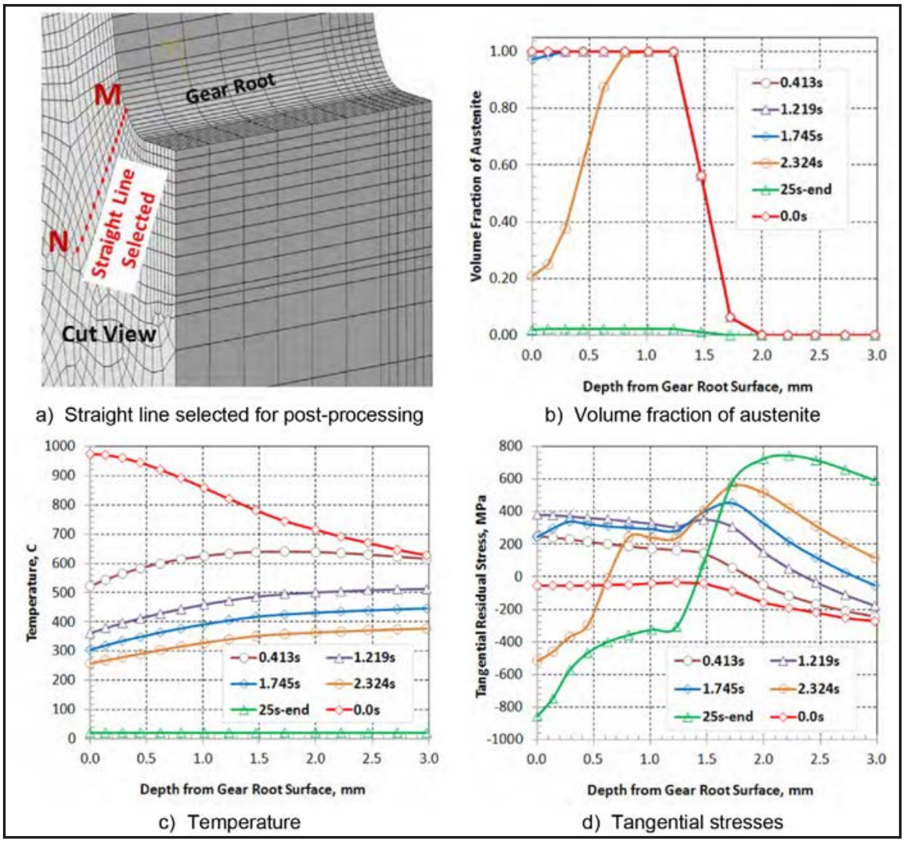

Figure 12 **Evolution of temperature, phase, and stress during spray quenching (induction hardening with 250° C pre-heating).**

temperature at the surface point is about 360°C (Fig. 12c). Martensite is not yet formed on the surface because the temperature is above Ms. Thermal shrinkage at the gear surface creates tensile stresses along line MN (Fig. 12d). At 1.745 s during quench, a small amount of martensite is formed on the surface and the volume expansion due to martensitic transformation reduces the magnitude of tensile stress in the transformation region. At 2.324 s during quenching, about 80% martensite is formed on the surface. The volume expansion from martensitic transformation shifts the surface stress from tension to a compression around 500 MPa. As shown in Figure 12c, the thermal gradient along line MN is relatively low, and the phase transformation plays a critical role to the stress evolution. The gear reaches room temperature at 25 s in quench. The residual stress at the surface point M is about 850 MPa in compression. With pre-heating prior to induction hardening, the bore continues to cool after the transformation of the austenite layer is completed. The further non-uniform thermal contraction contributes to residual compression at the gear root fillet.

Summary

An innovative approach of pre-heating prior to the induction hardening process is proved to be effective in enhancing the residual compressive stresses at the root fillet of gear components, which benefits the bending fatigue performance.

Uniform pre-heating temperature by furnace is assumed in this paper, but induction heating with lower frequency and lower power inductor can also be used to preheat the opposite side of gear teeth. The temperature distribution at the end of pre-heating doesn't need to be uniform.

With different gear geometry, steel grade and service condition, different inductor designs and pre-heating processes could be designed to enhance the residual compression at critical regions.

Future Works

In this conceptual modeling study the spray quench is applied right after induction heating — without delay. Past experience has shown that delay can have a significant effect on residual stresses, and further studies should consider delay time as one of the process parameters to optimize the induction hardening process with pre-heating. Experimental validation of this process should also be implemented.

Uniform pre-heating temperatures are assumed in this paper, which can be done by furnace heating for experimental studies. To be practical, the bore of the gear can be preheated using low power and low frequency inductor, and the pre-heating temperature doesn't need to be uniform throughout the part. Further modeling studies should be implemented to investigate the pre-heating by inductors.

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PARTICIPATES IN U.K. TECHNOLOGY RECEPTION

Dontyne Systems and several other entrepreneurs were invited to a special reception in honor of the U.K. technology industry given by Her Majesty the Queen and His Royal Highness the Duke of Edinburgh at Buckingham Palace on Monday June 9. The Queen and Duke of Edinburgh were joined at the reception by The Duke of Cambridge, The Duke of York (who is a long standing supporter and campaigner for technology and entrepreneurship in the U.K.), the Duke of Gloucester and the Duke of Kent. Approximately 350 guests in total were invited to attend the reception covering business leaders, innovators, academics, investors and tech start-ups from across the U.K. The networking during the event was invaluable. There is a drive by the Duke of York to continue the networking for the further development of the U.K. technology industry. Dontyne Systems will certainly be proposing several projects which would benefit greatly from collaboration with representatives of other companies present at the event to produce world-class products. Dontyne Systems would like to thank David Dunn and Sunderland Software City for the opportunity and the continued work to promote and support the Northeast of England IT sector both locally and across the globe.

Polygon Solutions

HOSTS OPEN HOUSE WITH SRMA

Polygon Solutions Inc. is a manufacturer of rotary broach tools for the precision machining industry focused on medical and aerospace parts. Polygon first entered the rotary broach market with an award winning tool holder, and continues to innovate with new tooling for manufacturing hexagon and six-lobe forms in titanium bone screws. These new tools were featured at the recent plant tour for the Southwest Regional Manufacturers Association (SRMA) located in Fort Myers, Florida.

Polygon's advancements with rotary broach technology have continued with a new micro size rotary broach holder for machining small shapes using Swiss type CNC machines and lathes. The innovative design of the tool holders includes sealed bearings for easy maintenance and pressure relief holes for smoother machining operations. However, the main interest of this year's tour was the broaches used for machining titanium fasteners and bone screws.

Polygon has been making the cutters out of high-speed steel, a very hard substrate that resists wear and chipping. The company currently offers M-2, M-42, PM M-4 and PM T-15 varieties for machining different materials. Peter Bagwell, a product engineer for the company, was asked about which materials are used for broaching bone screws, and explained how the choice of substrate material depends on the method of broaching. Bagwell also talked about a new rotary broach material the company is researching.

The demand for rotary broach tools is growing as more exotic materials are being used to make innovative aerospace and medical device fasteners. Polygon is working with bone screw manufacturers to help them choose the right method of broaching in addition to the selecting the right tools. Polygon specializes in standard hexalobular (or Torx-type) rotary broaches in addition to custom shapes and sizes. The six-lobe ISO standard hexalobular form is currently the most popular.

Polygon Solutions has hosted an open house with the SRMA for two years in a row. "We value the partnership with our local customers and suppliers and are happy to bring them in and show them what we're offering," says Bagwell. "We also maintain healthy relationships with other organizations like the Precision Machined Products Association (PMPA) and the National Tooling and Machining Association (NTMA). The company believes participation in each of these networks is key to remaining the leader in rotary broach technology.

Polygon is a newer member to the SRMA, which boasts a wide variety of manufacturing business. "Many people move here and move their businesses here due to the great lifestyle Southwest Florida has to offer," says Bagwell. "However, the exposure to the growing number of innovative medical and aerospace companies is really making it an attractive place for all manufacturers."

United Grinding Symposium

CLOSES WITH 1,400 DAILY VISITORS FROM 40 COUNTRIES

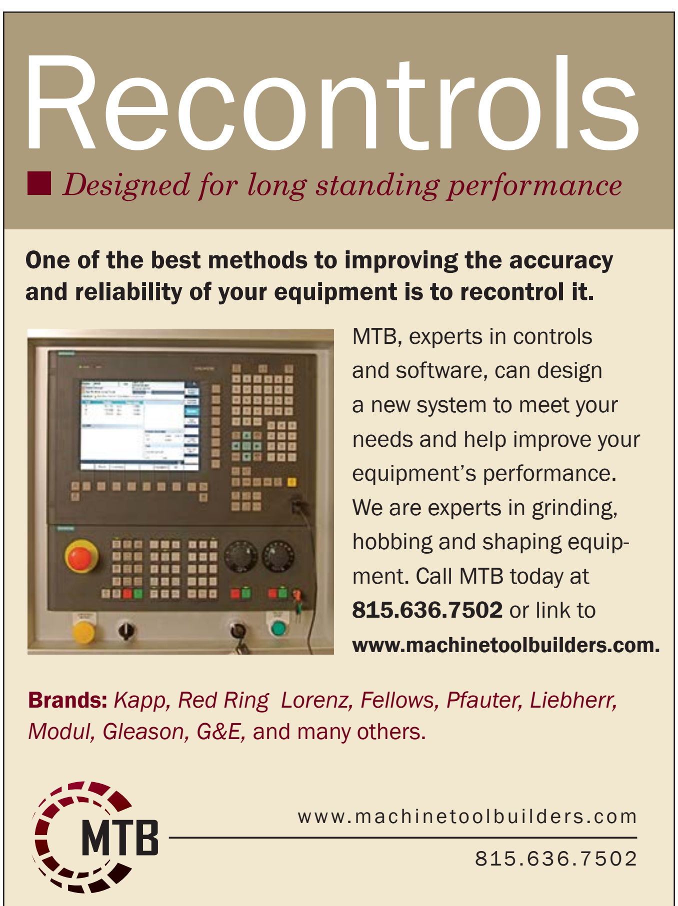
The United Grinding Symposium drew to a close in Thun (Switzerland) with an enthusiastic audience. The international nature of the United Grinding Group was demonstrated every day by more than 1,400 visitors from over 40 countries - including 70 international trade journalists - taking the opportunity to learn more about the future of grinding in more than 154 technology presentations and 20 lectures. In addition to technical exchanges, there were many opportunities for networking with colleagues from all over the world. "The symposium is also a way of thanking our customers," explained Stephan Nell, CEO

of the United Grinding Group AG, as he welcomed the participants. "A way of saying thank you for the loyalty and trust which our customers place in us."

The combination of technology presentations and world innovations, cross-cutting lectures and partner stands offered during the symposium allowed visitors to actively experience how the United Grinding Group fulfills its claim to offer its customers more than just the right grinding technology. "We also consciously deal with topics that are not directly connected to grinding," said Nell. "Trends and multiple opportunities for optimization in a wide range of fields play a central role in making our customers more successful and offering them added value in addition to the machines."

The technology presentations offered in four different languages met with a high level of interest. These offered each participant the opportunity to discover specific advantages of the machine innovations or to discuss them in direct dialog with developers. "These presentations are unique," said one participant, "because in just a short time you can understand things that are very difficult to grasp through other information channels." The demonstration of the Schaudt CrankGrind crankshaft grinding machine - among others - impressed visitors with the advantages offered for the first time by a machine of this type.

In addition to presentations on global trends and innovations, topics relating to increasing efficiency during grinding met with a particularly high level of interest. The breadth of the lectures ranged from materials in grinding tool development to increasing productivity in the design of grinding processes, as well as the reduction of grinding forces or processing and auxiliary times.



During the press conference, Michael Horn, COO of the United Grinding Group AG, explained the background and effects of the internal PuLs program. "It is more than just production optimization. PuLs illustrates our corporate philosophy, which is to align all processes with our customers' requirements, to find and utilize potential for optimization and to minimize waste." The level of actual customer satisfaction is regularly surveyed with the Net Promoter Score (NPS) measuring method. "The worldwide implementation of both standards demonstrates the aspiration by all companies in the United Grinding Group to set benchmarks with their production processes in the grinding machine industry throughout the world," said Nell.

Gleason

ACQUIRES DISTECH SYSTEMS

Gleason Corporation recently announced that it has acquired Distech Systems Inc., located in Rochester, NY. Distech is a leader in the design and manufacture of factory automation systems, serving a variety of customers in the automotive and other industries. Daniel J. Schwab, president of Distech Systems, said, "Gleason and Distech have successfully collaborated on many projects over the past several years, allowing both companies to become very familiar with each other's products, services and strengths. Our company has experienced significant growth recently and Gleason is the ideal partner to help in sustaining that growth. Gleason's market reach and technical and operational competencies will be important assets in our future success." John J. Perrotti, president and chief executive officer of Gleason Corporation, said, "We are excited about this opportunity and believe that the combined companies will be able to take advantage of significant synergies and provide our customers greater value by offering engineered manufacturing systems solutions with Gleason products as well as supporting Distech in many of the markets it serves." The existing Distech management team and entire staff will remain intact with an ever-greater focus on serving its customers.

Star SU

ADDS REGIONAL SALES MANAGER

Bruce Cowley has joined Star SU LLC as regional sales manager responsible for the Southern Ohio, Eastern Kentucky, and West Virginia territories. In addition to his new role, Cowley will support the Star SU sales network to further develop their spline gauge and master gear product programs. Cowley is a graduate of Ohio University and for the past 29 years has served the dimensional and gear measurement and gear and spline processing industries in various capacities that include: applications engineering, training instructor, director of international marketing and sales, gear and spline and related tool and gauge tool design, product management, and executive management. Cowley has authored gear industry technical articles, submitted various papers and made presentations at SME, VDI/VDE, IDMW, COGM, and ASPE conferences. Previously, he served as a member of the AGMA as chairman of Gear Data Exchange Committee and participant and contributor to both the Inspection Handbook and Gear Cutting Tool committees.

JRM International

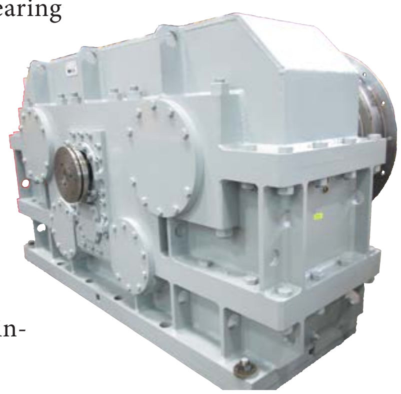
FORMS PARTNERSHIP WITH STROH DIAMANTWERKZEUGE

JRM International, Inc. is pleased to announce they have formed a partnership with Stroh Diamantwerkzeuge to supply diamond tooling to the North American gear industry. Stroh, located in Bruchköbel, Germany, has been producing high quality diamond tooling for more than 50 years. With facilities in Germany and Brazil Stroh is a supplier to the world gear production industry. Stroh specializes in the production of CVD reinforced diamond dressing rolls for all makes of form, generative and threaded wheel gear grinding machines. Their exclusive low temperature manufacturing process guarantees minimal distortion in the reverse plated form for greater accuracy and repeatability. While much of their production is focused on diamond tooling for the gear industry the engineering staff is capable of designing special diamond tools to meet their customer's special needs.

Broadwind Energy

ANNOUNCES SIGNIFICANT GEARING ORDERS

Broadwind Energy, Inc. recently announced an $8 million gearing order to be produced by its Brad Foote Gear Works, Inc. subsidiary for 2015 delivery. Broadwind President and CEO Peter Duprey stated, "I am encouraged to see our transformation efforts in this business segment starting to bear fruit. With this order, our second quarter gearing orders totaled nearly $19 million, the highest quarterly order rate in over four years, including a mix of wind and industrial orders. Industrial orders have strengthened in recent weeks due to increased demand for gears used in natural gas production equipment and growth in demand from steel customers. In addition, we recently concluded our gearing plant labor union negotiation, and with our plant consolidation essentially complete, we are seeing visible incremental improvement in our production flow. Together, these factors indicate to us that our turnaround of the gearing business is gaining traction."



Pentagear Products

ACQUIRES PECO GEAR METROLOGY DIVISION

Pentagear Products LLC, an Ohio-based company, has acquired Process Equipment Company (PECo) ND Gear Metrology Division effective June 27, 2014. Pentagear Products LLC, established in 2005 has developed gear functional gaging products for the gear industry. PECo's gear metrology division offers a full line of gear measurement products and services. "We are excited about the future with the ND Gear Analytical machines as well as the functional products. This move strengthens the focus of our business in the gear industry," says Marvin Nicholson, owner of Pentagear Products. "Nothing changes in respect to service, support and new product development. We are still building new machines, repowering our competitors machines and offering new functional gages including DOB and double flank inspection systems."

AMB 2014

PREPS FOR MACHINE TOOL DEVELOPMENTS

The machine tool industry is confronted with a large number of developments which are influencing investment decisions by its customers. In addition to the still dominant topics of Industry 4.0 and increased efficiency, other topics must be considered, i.e. hybridization of machines, software and IT security, increasing intelligence of machine peripherals and simulation of complete machining processes. Answers to complex requirements will be provided at AMB, the International Exhibition for Metalworking, which is being held in Stuttgart September 16-20. The topic of Industry 4.0 is "varied and interdisciplinary." This conclusion was drawn by the Fraunhofer Institute for Production Engineering and Automation (IPA) in the structural study entitled "Industry 4.0 for Baden-Württemberg," which was conducted on behalf of the Federal State of Baden-Württemberg. In addition to mechanical engineering skills, for example, purely technical implementation of Industry 4.0 also calls for knowledge of electrical engineering, software and information and communication technology. Other areas such as work organization must be included for the purpose of implementation at the organizational level. In order to successfully implement Industry 4.0, it is also necessary to include company-related services such as technology development, introduction, maintenance or service, as well as technology upgrading and non-technical areas such as general and advanced training.

August 11–14—Gleason Cutting Tools Gear School. Rockford, Illinois. This comprehensive 3½ day program is a blend of shoptime and classroom study. A coordinated series of lectures is presented by engineering, production, inspection and sales staff members averaging 27 years experience. It's an ideal course for those individuals who are seeking to understand the fundamentals of involute gear geometry, nomenclature, manufacturing and inspection. Training groups are kept small so that individual concerns may be fully addressed. Students are welcome to bring sample gear prints and inspection charts for discussion and interpretation. The fee is $895 per person (group rates available) which includes handbook and all materials, one group dinner and all lunches. Hotel room is not included. The curriculum includes fundamentals, high speed steels and coatings, cutting the gear, gear inspection, a plant tour as well as individual instruction and specific problems. For more information, visit www.gleason.com.

August 26–28—International Gear Conference 2014. Lyon-Villeurbanne, France. Mechanical transmission components (gears, bearings, CVTs, belts, chains, etc.) are present in every industrial sector and range from nano-gears to large gearboxes. Over recent years, increasing competitive pressure and environmental concerns have provided an impetus for cleaner, more efficient and quieter units. Moreover, the emergence of relatively new applications in wind turbines, hybrid transmissions and jet engines has led to even more severe constraints. The main objective of this conference is to provide a forum for the most recent advances, addressing the challenges in modern mechanical transmissions. Topics include gear noise, gear design, gear materials, gear failure, lubrication, gearbox efficiency and more. For more information, visit *http://int-gear-conf14.sciencesconf.org*.

September 8–10—Gear Failure Analysis Seminar. Big Sky Resort, Big Sky, Montana. In AGMA's Gear Failure Analysis Seminar, attendees will examine the various types of gear failure, such as macropitting, micropitting, scuffing, tooth wear and breakage. Possible causes of these failures will be presented, along with some suggested ways to avoid them. A gear failure analysis expert will use a variety of tools and methods—lectures, slide presentations, hands-on workshops with failed gears and Q&A sessions—to give a comprehensive understanding of the reasons for gear failure. Participants are encouraged to bring their own failed gears or photographs and discuss them during the Q&A sessions. The seminar brings together a vast amount of knowledge and will help you solve everyday problems whether you are a gear engineer, user, researcher, maintenance technician, lubricant expert or manager. The course manual offers more than 100 color photos, dozens of illustrations, a textbook and failure atlas that will become a permanent reference source. For more information, visit *www.agma.org*.

September 8–13—IMTS 2014. The International Manufacturing Technology Show (IMTS) is the largest manufacturing technology show in the Western Hemisphere. IMTS 2012 drew more than 100,000 industry decision-makers in areas like metal cutting, tooling, metal forming, abrasives, controls, CAD-CAM, EDM, gear generation, industrial automation and more. The IMTS conference brings the industry together to discuss new opportunities and network with the manufacturing community. Other highlights include the Smartforce Student Summit, Exhibitor Workshops, the Emerging Technology Center and IMTSTV. IMTS is co-located with Industrial Automation North America and Motion, Drive & Automation North America. For more information, visit *www.imts.com*.

September 16–20—AMB 2014. Stuttgart, Germany. AMB, the international exhibition for metalworking, has increased the number of exhibitors in 2006, 2008, 2010 and 2012. All global market and technology leaders will be represented in Stuttgart. Exhibitors from over 30 nations present their new products and services in the area of machines and tools for metalworking. The trade show features more than 105,000 square meters of exhibition space, clear, structured hall divisions, and optimal accessibility. Special programs during AMB include Art Meets Technology, Metalworking Innovation Tour, WorldSkills Germany, Career Walk and more. The topics will extend from solving economic problems to searching for production or sales partners. For more information, visit *www.messe-stuttgart.de*.

October 8–10—RMGFS 2014. Boulder, CO. The Rocky Mountain Gear Finishing School (RMGFS), presented by Kapp-Niles, is a multi-layered program designed to optimize learning and strengthen your understanding of gear finishing processes, no matter your experience level. The curriculum features sessions which are interconnected and lead from one step to the next. Participants study the underlying principles and mechanics of different gear finishing processes, apply them through practical sessions on a Kapp-Niles machine, and take part in group workshops for more in-depth discussions. Kapp encourages attendees to bring applications to the school for small group or one-on-one discussions. Presenters include Jim Buschy, Bill Miller, Dwight Smith, Paul Brazda, Michael Ruppert, Sascha Ungewiss, Thomas Schenk, Nidam Meharzi, Eric Dixon and Hans-Helmut Rauth. For more information, visit *www.kapp-usa.com*.

October 27–30—Gear Dynamics and Gear Noise Course. Ohio State University Campus. The Gear Dynamics and Gear Noise Short Course has been offered for 35 years and is considered extremely valuable for gear designers and noise specialists who encounter gear noise and transmission design problems. Attendees will learn how to design gears to minimize the major excitations of gear noise: transmission error, dynamic friction forces and shuttling forces. Fundamentals of gear noise generation and gear noise measurement will be covered along with topics on gear rattle, transmission dynamics and housing acoustics. This four-day course includes extensive demonstrations of specialized gear analysis software in addition to the demonstrations of many Ohio State gear test rigs. A unique feature of the course is the interactive workshop session (on Day 3) that invites attendees to discuss their specific gear and transmission noise concerns. The roundtable discussions on Day 4 are intended to foster interactive problem solving discussions on a variety of topics. Cost is $1,950 per person. For more information, visit *www.nvhgear.org*.

ad index

CORRECTION

In the June issue, a mistake occurred regarding the lineup of Technical Papers. While the Table of Contents listed "The Influence of Tool Tolerances on the Gear Quality of a Gear Manufactured by an Indexable Insert Hob," by Mattias Svahn, Lars Vedmar and Carin Andersson, as appearing on page 62, in fact another work—"Gear Ratio Epicyclic Drives Analysis"—by Dr. Alexander Kapelevich—was in fact the paper that actually ran. To rectify the error, the omitted paper begins on page 48 of this issue.

Gear Technology regrets the errors.

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- *Hofler HF1250/1600* ***(2009)***
- *Liebherr LC800* ***(2009)***

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- *Hessapp VDM 1200-11* ***(2009)***

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ONE "SMALL STEP" TOWARDS MARS?

In the June issue of our sister publication — *Power Transmission Engineering* — the Power Play feature (Destination Mars! — pg. 64) was devoted to NASA's Mars-oriented LDSD (Low Density Supersonic Decelerator) project. The mission: "Advance the technology of decelerating large payloads traveling at supersonic speeds in thin atmospheres (read *Mars*) to a new level of performance" for Mars landings.

(A brief re-cap of the Power Play article: To colonize Mars — indeed, we're — some of us — going — ships bearing much heavier payloads will be needed, making landing in the Red Planet's extremely thin atmosphere a dicey proposition. The LDSD project is being developed to solve that problem.)

Unfortunately, the test flight scheduled for mid-June was scrubbed. "NASA did not conduct the flight test of the agency's Low-Density Supersonic Decelerator (LDSD) during its designated launch" window, which closed June 14 due to continuing, "unfavorable weather conditions," said a NASA press release.

But Addendum is here to bring you the rest of the space saga — *and* a happy — if not perfect — ending to this early installment in achieving manned flights to Mars. This is much more ambitious than the Moon Walks, circa 1969. Different how, you wonder? Well, there are people — maybe you know some — who actually *want to live and stay on Mars* — and they don't even belong to a cult. Why the Red Planet? Scientists say after Earth, Mars is the most habitable planet in our solar system (*marsone.com*).

So having another go at it, NASA on June 28 launched the LDSD craft from Hawaii. Reports say the first part of the test went well, but the LDSD's mammoth parachute did not deploy properly.

Nevertheless, NASA and the LDSD team are satisfied with their progress. "Progress" in this project includes reaching goals such as developing and testing the biggest supersonic chute ever flown — and two saucer-like devices called Supersonic Inflatable Aerodynamic Decelerators (SIADs).

"We are thrilled about yesterday's test," said Mark Adler, LDSD project manager at NASA's Jet Propulsion Laboratory (JPLP) in Pasadena, California. "The test vehicle worked beautifully, and we met all of our flight objectives. We have recovered all the vehicle hardware and data recorders."

Both SIADS (due to their shape, the press can't resist referring to them as "flying saucers") are built to fit around the rim of atmospheric entry vehicles like the one that carried NASA's Mars Rover Curiosity in 2012, slowing them down by increasing their drag.

During Saturday's test a huge helium balloon carried the 7,000 lb. test vehicle — equipped with the big chute and the 20-foot SIAD — up to an altitude of 23 miles.

After the balloon and its load soared to roughly 23 miles high, the balloon released the vehicle and dropped to Earth, the cue for a rocket attached to the saucer to fire. The rocket propelled the saucer to four times the speed of sound, duplicating the rapid clip of a spacecraft bound for Mars. The saucer's inflatable ring, made of Kevlar, popped up, expanding to some three feet high in a fraction of a second; the ring is designed to brake the vehicle as it speeds through the atmosphere.

The balloon was to drop the craft at that point, and its onboard rocket motor to kick in — boosting it to Mach 4 (four times the speed of sound) and 34 miles up (55 km) — if all went as planned.

If the test had gone perfectly, the SIAD was to have inflated and thus slowed the test vehicle down to Mach 2.5, at which point the chute would deploy and take the craft down to a soft splashdown in the Pacific Ocean.

Instead, it's back to the drawing board

As the balloon released the test vehicle, the rocket appeared to fire properly. The SIAD seemed to inflate on cue, but the collected data later indicated that the parachute didn't deploy as planned; more information will be made available later.

Existing technology like the sky crane (used to deliver the Mars Rover to the planet's surface) can (and probably will) be used again to let payloads down on Mars. But new gear such as bigger chutes and SIADs will be used to slow down extreme payloads enough for the sky crane to finish the job.

"With the science and the technologies that we're testing here, we think we could double the (payload) that we land on Mars (up to two tons)," said principal investigator Ian Clark of JPLP, adding that the gear could also help put payloads down more accurately and at higher elevations on the Red Planet than is currently possible.

What's more, with the new technology now being tested, the successful use of multiple parachutes could mean even spacecraft of 20 to 30 tons could make a soft Mars landing, Clark said.

So if you're thinking of signing up, you'd best hurry as spots are filling up fast if internet reports are any indication. There are various for-profit outfits more than willing to take your money in return for planting your rear-end on Mars.

Then what?

(*Source: June 28 article, space.com, by senior writer* Mike Wall.)

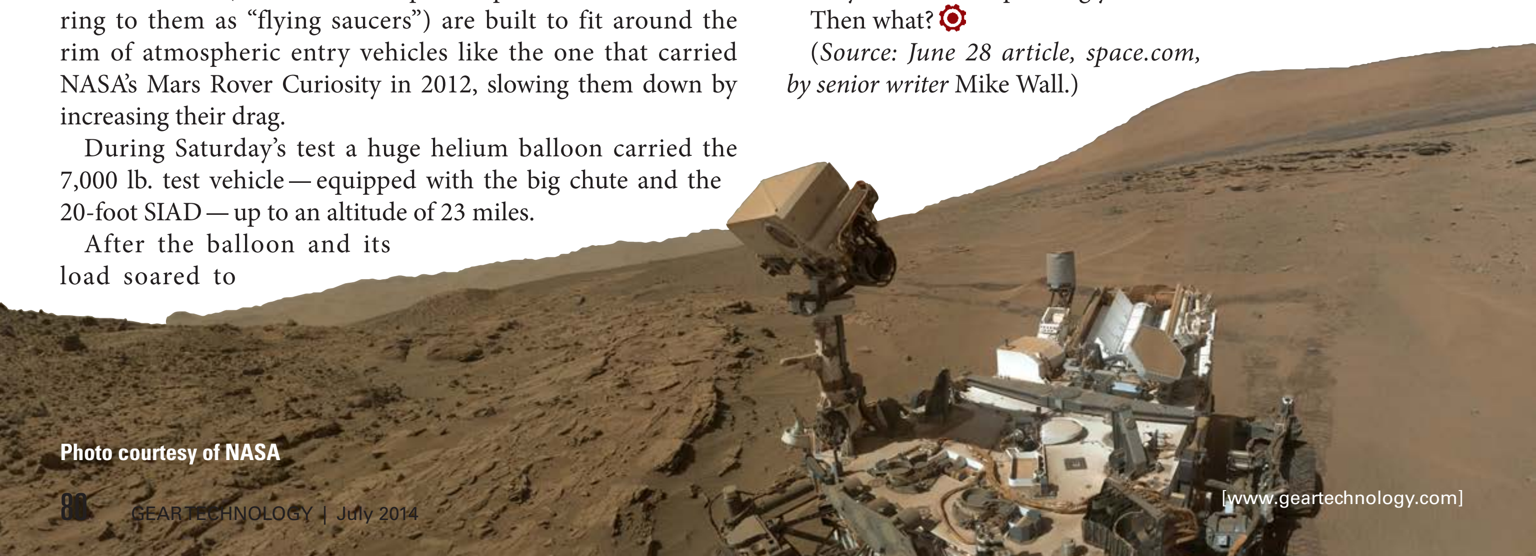

Photo courtesy of NASA