September/October 2008

GEAR TECHNOLOGY

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The Journal of Gear Manufacturing

Features

Technical Articles

Plus

THE GEAR INDUSTRY'S INFORMATION SOURCE

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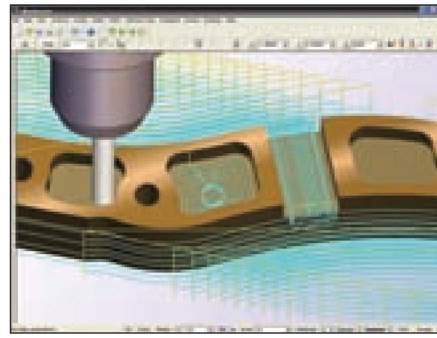

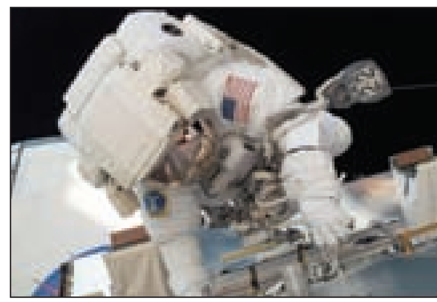

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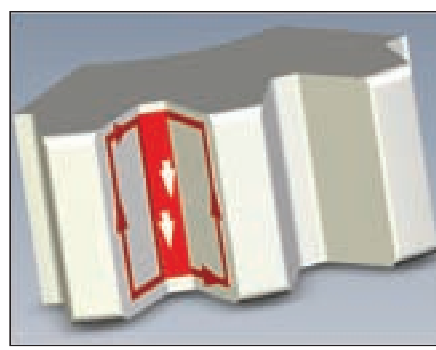

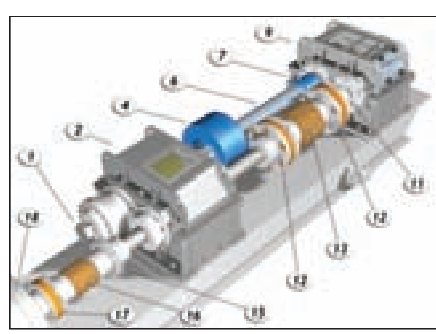

Vol. 25, No. 7. GEAR TECHNOLOGY, The Journal of Gear Manufacturing (ISSN 0743-6858) is published monthly, except in February, April, October and December by Randall Publishing, Inc., 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL 60007, (847) 437-6604. Cover price $7.00 U.S. Periodical postage paid at Arlington Heights, IL, and at additional mailing office (USPS No. 749-290). Randall Publishing makes every effort to ensure that the processes described in GEAR TECHNOLOGY conform to sound engineering practice. Neither the authors nor the publisher can be held responsible for injuries sustained while following the procedures described. Postmaster: Send address changes to GEAR TECHNOLOGY, The Journal of Gear Manufacturing, 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL, 60007. Canadian Agreement No. 40038760.

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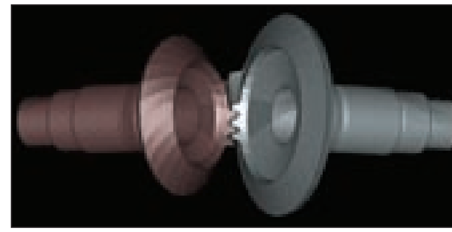

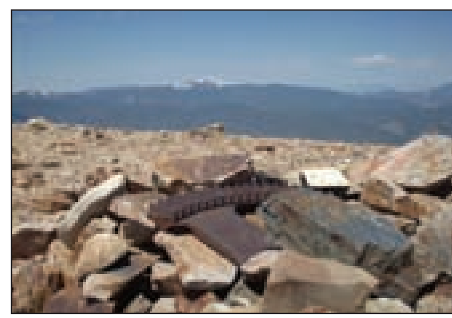

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Klingelnberg GmbH D-42499 Hueckeswagen www.klingelnberg.com

GEAR TECHNOLOGY

VOL. 25, NO. 7

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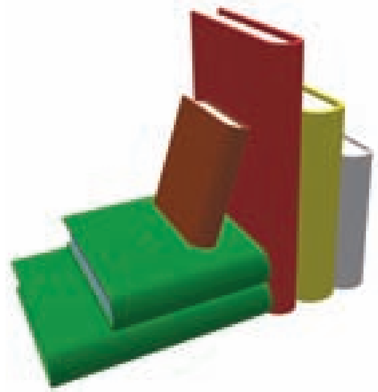
Cover photo courtesy of Gleason.



Why do YOU read Gear Technology

When I started this magazine 24 years ago, my intention was to provide a resource to the gear industry—a practical, useful reference about the highly specialized and technical niche of gear manufacturing. Our goal was to assemble a body of knowledge covering the materials, design, manufacturing, processing, heat treating, testing, and purchasing of gears and gear-related products. Our mission has always been, and remains, one of education.

Sure, there were conferences and seminars for gear manufacturers where technical papers were presented, but if you didn't or couldn't attend, you missed out. That's where we came in. We remain committed to bringing our readers the best technical information on gears from authors doing cutting-edge research and honest-to-goodness practical work, all around the world.

Over the years, we've also recognized the importance of providing you up-to-date information on industry news, new products and events. We've continued to grow and refine our news departments to help keep you abreast of the latest developments in a manufacturing world that continues to become more competitive and more global.

We're also keenly aware that you rely on us for analysis and insight, which is why we place a high level of importance and spend a lot of effort on this page and on our feature articles.

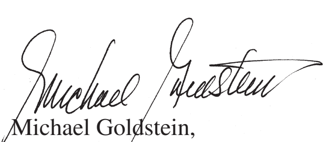
Our staff is busy planning the 2009 editorial calendar—figuring out the types of articles we should publish next year. As part of that effort, we recently sent out an e-mail survey to a random sampling of 600 of our qualified readers. It had only one question: "Why do you read *Gear Technology*?" Our intent was to make sure we understand your needs and to give us insight about our editorial efforts.

At best, we thought maybe we'd get a handful of responses that would spark an idea or two. But, in fact, we were overwhelmed not only by the volume and variety of the results, but also by how much thought went into them.

What we got back was gratifying, on most every level. We were struck by the variety of the respondents, their various duties and responsibilities, the different ways they're involved in the industry, and the variety of companies, products and geographic breadth they represent. People in all parts of the gear industry value *Gear Technology*—not all for the same reasons—but with the same level of enthusiasm.

I was especially pleased to see that many of our readers emphasized the importance of our advertisements, not just when they're looking to buy products or services, but as a resource for learning about the latest technology and ways to become more productive.

A number of respondents were gracious enough to give us permission to reprint their comments here. Overall, they serve to reinforce both the mission we began with 24 years ago and the refinements we've made along the way. We hope that you enjoy reading and reflecting on them as much as we did. I want to thank our readers, advertisers, authors, technical editors and staff for helping us make this magazine truly "The Gear Industry's Information Source."



Michael Goldstein,
Publisher & Editor-in-Chief

"I read Gear Technology *magazine to stay current with new manufacturing and heat treat processes. I particularly enjoy articles and interviews of existing manufacturers willing to share their processes. I would stress to your advertisers the importance to make their products visible even if it is only once or twice a year. New ideas are generally triggered by visually seeing pictures of other manufacturer's equipment and processes."*

—John Krainer, senior manufacturing engineer
Harley Davidson Motor Company
Milwaukee, WI

"I read Gear Technology *for the technical articles, such as 'Influence of Roughness on Gear Pitting Behavior' (6/06), 'Spiral Bevel and Hypoid Technology' (7/07), and 'Advances in Bevel Gear Blades' (10/07). I also enjoy the Publisher's Page for its insights into the industry. The various articles and presentations of advances by gear equipment manufacturers are very interesting as well."*

—Steve Burr, design engineering specialist
Caterpillar Inc.
East Peoria, IL

"I've looked forward to every issue of Gear Technology *since Mike started publishing it over 20 years ago. It is the only technical magazine I receive that I never read the contents page. I go through the entire magazine, looking at every page, because I know there will most likely be something of interest to me, and not pages of unrelated advertising. I always enjoy Mike's editorial page, and many of the technical articles are valuable reprints from FTM [AGMA's Fall Technical Meeting] and other sources."*

—Gary DeLange, engineering manager
Philadelphia Gear Corp.
Hueytown, AL

"I work in an international company as senior gear designer, and for my job the information about new developments in gear design and production is very important. On the other hand, I don't like papers in which mathematics is the most important player; the mathematical approach is necessary, but we must always

continued

remember that we are engineers, and our final scope is to produce components (gears) and not to be teachers at the Berkeley university. For this reason I like Gear Technology*; the papers are always a good compromise between theory and practice, and very often the information included can be immediately used in the work of every day."*
—Giuseppe Boni, senior gear designer
Dana Italia S.p.A.
Arco di Trento, Italy

"Basically, I read Gear Technology *to stay abreast of developments in the gear world which may be of benefit financially or technologically to my company. Currently, I am looking at our small gears with an eye toward moving some from cut gears to sintered metal based on a recent article."*
—Mike Andrew, purchasing agent
CEF Industries
Addison, IL

"We design and manufacture specialty gearboxes for most applications, primarily off-highway. The updated gear information helps us keep up on gear manufacturing, but gear applications such as wind generators and unusual gear applications are very interesting."
—Gary Hamilton, chief engineer
R. Cushman & Associates
Livonia, MI

"I always find the magazine keeps up to date on the latest technology, which helps us to keep up with the latest customer demands. I have found useful formulae that I use on a daily basis. The ads are very helpful. I have found vendors to help with certain projects. All in all it's a great gear magazine."
—Murray Sundell, engineering sales
Ideal Gear Works
Delta, BC, Canada

"Your magazine is a lot more interesting than the alternative, i.e., reading AGMA technical papers, and it provides a broad and comprehensive overview of gear design and manufacturing issues."
—Steve Schuster, transmission design engineer
Caterpillar Inc.
East Peoria, IL

"Simple reason for reading Gear Technology *is it updates on modern methodology. Research papers published are most of the time dealing with a problem actually faced by us. I still remember a write-up on modern electronic gear testers, which mentioned that such sophisticated equipment should be useful only for experienced inspection personnel and not for somebody who will only look for ACCEPT/ REJECT remarks. It was a most practical write up."*
—P.P. Mahajan, manager
Manisha Industries
Aurangabad, India

"We subscribe because GT *is a quality assured publication recognized internationally for its balance of technical articles and analytical comment. It*

continued

also helps us keep up-to-date with new developments well outside our own sphere of operation. We recognize that contributing text or advertising with GT *will guarantee a circulation amongst a wide scope of potential customers and partners, from the major players to the small enterprises such as ourselves."*
—Mike Fish, managing director
Dontyne Systems
Prudhoe, England

"I am a drive system design engineer primarily in the aerospace field. I like to see how other industries solve similar problems, and Gear Technology *is one way of getting information from around the world."*
—James B Colter, engineer
The Boeing Co.
Almondbank, Scotland

"I read GT *for several reasons: I want to know what is going on with the technical side, new production technology and design methodology. I am mostly interested in the technical articles. Also upcoming seminars and events are important since I work with both the technical side and marketing of powder metal gear technology, so I need to find venues for networking. What would be interesting is articles that have a systems approach to them—new designs of complete transmissions, for example. Most technical articles are focused on one little detail on a specific gearwheel. Nothing wrong with that, but articles showing the bigger picture are of interest too."*
—Anders Flodin, R&D engineer
Hoeganaes A.B.
Hoeganaes, Sweden

"Because I like to see the latest and greatest in gear technology for bevel gear manufacturing and inspection. Automotive and specialty products for automotive industry are my preference."
—Robert Cabrera, gear engineer
ArvinMeritor
Heath, OH

"As a long-time (32 yr.) employee of Dana's Ft. Wayne Axle Plant, gears have been an essential element of my career. As VP and Chairman of USW Local 903, keeping informed and educated about our industry is one of my highest priorities. Keeping my membership informed and educated and pursuing continuous improvement in our product and processes is critical to maintaining our productivity, profitability, and ultimately the jobs of my union brothers and sisters."
—Dave Kobiela, vice president, Bargaining Committee chairman
United Steelworkers Local 903
Dana Light Axle Products Group
Fort Wayne, IN

"I like to receive information regarding all aspects of gear manufacturing, and consequently enjoy your articles, whether or not they have relevance to our current products. Information regarding new machinery, tooling, materials, gear designs, etc., is always welcome. Keep up

the good work!"
—Bill Laflair, president
Duragear Ltd.
Scarborough, Ontario, Canada

"Because we have just started manufacturing differential gears and would like to be updated on the latest technology."
—Dr. N. Gowrishankar, director
IP Rings Ltd.
Kanchipuram, India

"I'm reading your magazine because it is related to my business actually. I like to have up-to-date and upcoming news. And I believe that I learn a lot via your magazine."
—Atilla Basulas, sales/marketing manager
Atak Madeni Yag
Istanbul, Turkey

"I read Gear Technology *because I get: current information about the state of the gear industry; technical/scientific information about trends in gear manufacturing and design; and information on how we as a forging company can suit the needs of the gear/transmission industry."*
—Hans-Willi Raedt, R&D director
Hirschvogel Umformtechnik GmbH
Denklingen, Germany

"I enjoy reading and reviewing new and different techniques used in the gearing industry that your magazine addresses."
—Ron Reeve, district sales manager
Nord Gear
Corona, CA

"The reason why I read Gear Technology *is to be updated about news regarding manufacturing of gears."*
—Stig Palmkvist, preproduction engineer
Volvo Powertrain
Skövde, Sweden

"I read this magazine for the following reasons: 1) Identify potential sources for gearbox components (primarily gears), 2) Identify new developments within the industry, 3) Keep-up-to-date on gear industry marketing trends/news."
—Jim Klubertanz, design engineer
Weasler Engineering, Inc.
West Bend, WI

"I subscribe to Gear Technology *because it gives me a window on the entire area of gear design and cutting. As a very small restorer of racing car components, I cut only the oldest designs, and some old enough to be made before the current metric standards (WW II). The articles of most interest to me are of small shops who do very intricate parts on a prototype or limited-quantity basis. The advertising that most interests me is suppliers of conventional machines and parts and rebuilding service. I am mostly interested in American-made machines: Barber-Colman, Fellows, etc."*
—Wayne Mitchell, owner & chief engineer
CMW Enterprises, Inc.
Cardiff, CA

Want to add to the discussion? We'd love to hear what you think! Tell us why YOU read *Gear Technology* by sending a message to *publisher@geartechnology.com*.

The Staying Power of Low-Pressure Carburizing

Bill Gornicki, vice president sales and marketing, ALD-Holcroft

Open any heat treating journal today and you're certain to find multiple references (articles, technical papers and/or advertisements) promoting low-pressure carburizing (LPC). The uninformed might breeze by these references thinking it's the next flash-in-the-pan, but unlike in the past, this time the process has legs.

Commonly remembered, LPC of yesterday looked much like a tar and/or soot factory and never gained the respect it has today. For roughly 10 years, acetylene has been production proven as the carburizing gas of choice due to its high-carbon flux and its relative stability under temperature and vacuum.

LPC applications are now growing for a number of very basic reasons. First being it provides measurably and provably better results. Look at the automotive sector and you'll see lighter, smaller transmissions with significantly increased power densities. These advantages are largely attributable to LPC. Look, too, at the aerospace market where "zero defects" is a mandate for obvious reasons. The requirement is grabbing hold here and suppliers are being steered to comply. Next, the wind turbine industry has looked very seriously at this technology. The holdback here is their relative component size. The overwhelming majority of LPC furnaces are designed for high-pressure gas quenching (HPGQ), and wind generation components are just too large and of too low an alloy for adequate quenching in gas. While there are some oil quench LPC furnaces, the market is certainly not flooded with them. Finally, look at the powdered metal market where there's been success in applications for vacuum carburizing with HPGQ.

A common misconception regarding the LPC/HPGQ system seen here is increased maintenance.

While there are many viable and successful exceptions, LPC has more-or-less been married to HPGQ. HPGQ is the primary reason post-heat treat machining can be eliminated (or at least very significantly reduced). This has made the combination very popular in the "vehicle gearing" market.

There is little argument that the capital investment for LPC/HPGQ is more substantial, making the justification more challenging. The economic justification comes in pieces from a number of directions, including:

- Better quality by virtue of zero intergranular oxidation (IGO) along with more uniform case depths and hardness profiles.
- The processes can provide a significant level of piece part distortion control. This is via convection heating in conjunction with dynamic and controlled directional quenching in high-pressure gas. The combination can eliminate or at least significantly reduce post-heat treat machining needs. Heat-up is more uniform, quench intensity can be varied, wind direction can be altered and quench media can be substituted, providing a host of possibilities to control quench and therefore distortion.
- A "green" process: Emissions are extremely low. Less than five percent carbon emission can be expected for less than 10 percent of the total cycle length. Of course, cycle length depends on case depth requirements. Also, when quenching with helium, 99.5 percent of this precious gas is reclaimed and recycled on a per quench basis. When considering any possible result from the coming presidential election, this should be everyone's concern. Carbon credits are not going to stay cheap,

continued

they are not likely to stay voluntary and they are certainly not going away.

• Safer, cleaner working environment. The days of belching smoke and flame don't need to continue. Vacuum-based systems are clean and quiet, and you need not fear the heat or grime when leaning up against one.

• The capability of running with a higher carbon flux (near or at saturation level) can also provide faster cycle times. This is further enhanced by the ability to run at higher temperatures without fear of increasing intergranular oxidation (IGO).

A common misconception regarding large multi-chamber LPC/HPGQ systems is increased maintenance. These theories are based on performing LPC in a standard batch vacuum furnace. True, you can perform the process in these furnaces, but it comes with a high price in maintenance.

Multi-chamber systems require roughly the same amount of maintenance as a comparable atmosphere furnace system. The big difference is the type of maintenance. Instead of approaching the problem with a brick in one hand, a bucket of mortar in the other and a trowel under your arm, you're more likely to have a screwdriver, crescent wrench and an ohms meter. It takes a different temperament to work on vacuum equipment. But with proper preventive maintenance these systems run unattended and reliably for extended periods.

Using LPC and HPGQ can also eliminate post-heat treat machining. It's currently being done in mass production every day. It can be economical to make the move to LPC and HPGQ, particularly if you can eliminate downstream operations and defer the coming requirements for "carbon offsetting." It is an exceptionally green method of heat treating in batch processes.

Given the aging condition of the bulk of U.S.-based heat treat systems that will be replaced in the coming years, there is no doubt the growth of LPC will be steady.

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to send us your opinion.


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Roto-Flo's Servo-Actuated CNC

TO DEBUT AT IMTS

Roto-Flo's Model 3251 48" horizontal servo CNC is the first of its kind for the company—a clear departure from its long history of hydraulic-driven spline and thread-rolling machines.

Most anyone that has been in the gear industry—or any machining and tooling oriented business, for that matter—is probably at least somewhat familiar with the Roto-Flo workhorse line of hydraulic-actuated spline and thread rolling machines. After all, they've been at it for decades.

But things are changing at the Detroit-based company. For starters, the Roto-Flo brand and company has since 2005 been owned by U.S. Group, and is operated by its subsidiary, U.S. Equipment Company. And now with that infusion of change comes another—the new 48" Model 3251–CNC—Roto-Flo's first CNC servo-actuated, horizontal spline and thread rolling machine. The machine debuts at this year's IMTS.

Paul Simon, Roto-Flo CEO, explains the addition of the servo-driven machine.

"The key motivating factor in developing the servo-actuated machine was bringing technological advancement to the spline rolling process. Servo-actuated machines provide productivity improvements, more predictable process control, easier machine setup and improved environmental considerations (no hydraulic fluids, electricity savings and reduced noise)."

The 3251–CNC is capable of producing "cold-formed splines, grooves, worms, threads and other part features with high precision," according to a company new-product release. The obvious difference between this servo-driven Model 3251–CNC and its predecessor, the hydraulic-driven Model 3251 (still available) is the latest technology in CNC controllers and closed-loop A/C servomotors. With those advances—feed rates of over 1,400 IPM, for example—part throughput is increased up to 20 percent.

The key is the servo technology, which allows for maximum-minimum speed modulation. This includes driving the tool rack, which allows for rapid traverse of the tooling to the part, slowing to a controlled entry rate to account for "part inertia control" and accelerating for optimum part quality and productivity.

In addition, says Simon, "By using servo motor technology with ballscrews to provide the variable and adjustable tool rack motion, rather than fixed hydraulic systems, tool life and part quality can also be increased because the servo drives allow the forming process to be fine-tuned."

It is this technology—not exclusive to Roto-Flo—that makes the hydraulic-driven machines of old a somewhat endangered species. Some of the well-documented drawbacks with hydraulic spline and thread rolling machines include:

- Once a part is rolled, the tailstock must fully retract before the slides return to their previous setting.
- Part sensing during rolling is unavailable, which in turn leaves no room for error in part sizing that can result in costly tool jams and machine crashes.
- Maintenance-intensive (fluids, filters, cylinders, etc.)
- Expensive to run, and getting more so with out-of-control energy costs.

On the other hand, other welcomed attributes of servo-controlled CNCs include:

- Energy savings. Hydraulic systems run non-stop; CNC servo motors run only when needed.
- Smaller footprint. Hydraulic systems, with their fluids, filters, cylinders and other necessary parts, require a good deal of floorspace. That all goes away with servo CNCs.
- No hydraulics = maintenance savings (see above).
- Greener. None of the above mentioned hydraulic fluids, oils, etc. to worry about or recycle. Servo motors also run cooler, which leads to savings

continued

on air conditioning.

- Quieter. AC-servo motors reduce noise by 50 percent over continuous-running hydraulic motors.
- Faster setup. The CNC control positions the racks, so an operator no longer needs to adjust stops and switches.
- Enhanced part precision. Unlike hydraulic spline rolling, servo-driven CNCs can re-roll with ease and as needed to fine-tune a specific part feature.

The Model 3251–CNC is the first out of the gate for Roto-Flo, but, says Simon, "New models are under continuing development," including a 36" version.

And for users of hydraulic-driven machines, don't despair. Roto-Flo still makes them and intends to continue doing so. In fact, Simon adds, they still represent a big chunk of the company's business.

"We have customers that still desire hydraulic-actuated machines, and we will continue to provide that model. These customers tend to be customers in developing countries that do not have the expertise in CNC technology and domestic companies with a shortage of CNC expertise in their maintenance departments."

Nothing new there, unfortunately, regarding skilled workers here at home. Which makes the fact that both the hydraulic- and motor-driven versions are easily Fanuc-automated a very good thing indeed.

See the Roto-Flo Model 3251–CNC at IMTS in **Booth 7511**.

For more information:

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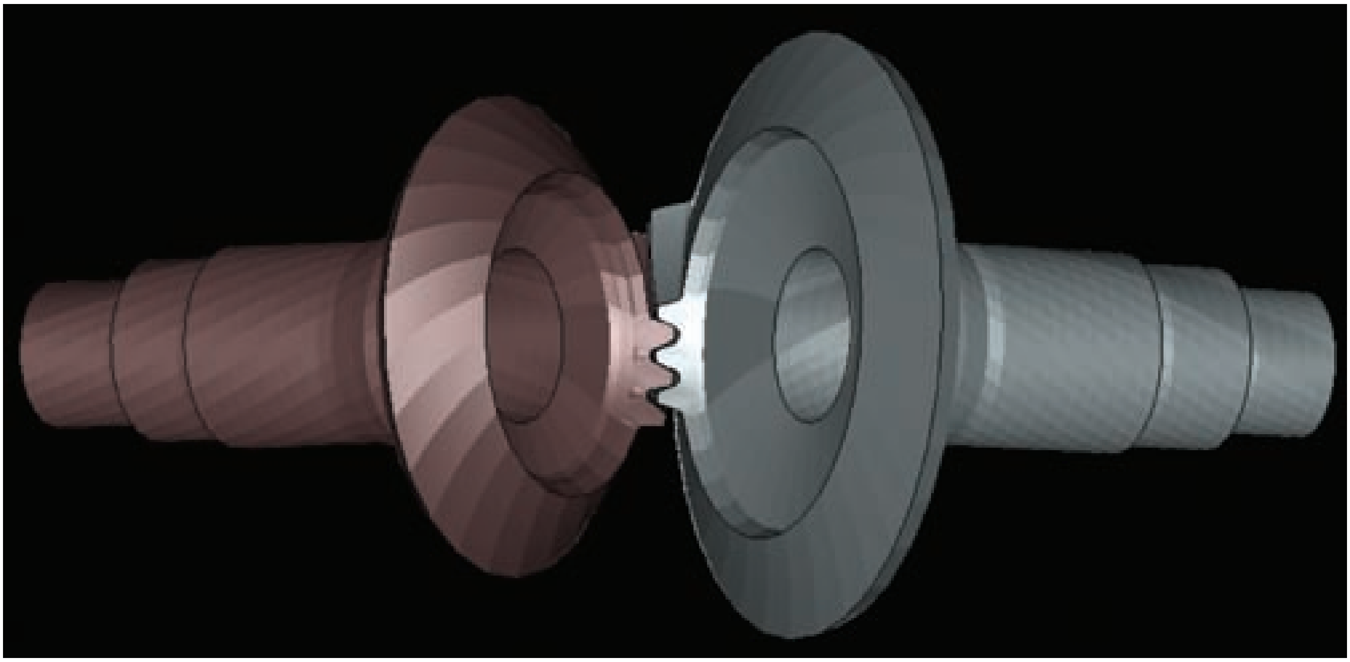
GPSys Critical to Spiral Bevel Gear Life

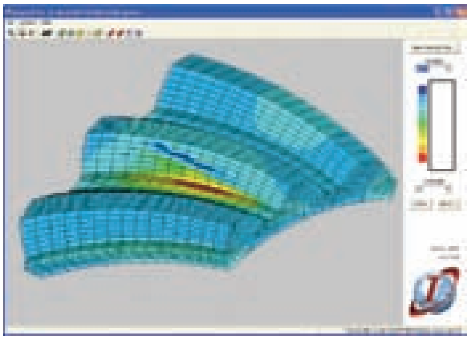
IMPACT TECHNOLOGIES CONSIDERS COMMERCIAL VERSION OF SOFTWARE PACKAGE



CAD model of a sprial-bevel gear set.

Impact Technologies delivered a software module that combines tooth contact analysis, stress analysis and fracture mechanics evaluation for spiral-bevel gears to the U.S. Navy in 2006. *GPSys* was originally developed to examine helicopter gearing.

"The ability to predict remaining useful life of spiral-bevel gearing, based on assumed initial flaws and specified mission profiles was the initial motivation behind creating *GPSys*,"



Calculated stress contours in a spiral-bevel pinion.

says Jeff Steele, manager of software and services at Impact. "For the stress analysis portion, traditional formulas in truck or automotive applications assume that the gear is very rigid and make the assumption that the flexibility is in the teeth and that the gear itself is rigid. In helicopters, this is not the case."

The software integrates advanced physics-based failure modeling, system vibration features, inspection and operational data and run-to-run testing to enable failure prediction on critical drive train components. According to the website, it automates the process for model generation, stress analysis and 3D fracture mechanics of spiral-bevel gears. The prognostic approach incorporates a probabilistic fusion process which can update damage models for component-specific damage states and remaining useful life predictions.

The developed technology and analytical approach can be applied to other systems. Because of this, Impact is now considering commercial versions of the software suite for other applications.

GPSys pulls together a number of software packages including *Gleason T900*, *ANSYS* and *Franc3D* and acts as the director for data communication between the modules.

"The initial work on the prognostic side was done nine or ten years ago, then the first modeling on failure progression started in 2002/2003," says Joel Berg, senior project engineer at Impact. "The Phase II program was initiated in 2004, looking at integrated software systems before it was delivered to the Navy in 2006."

Damage tolerant design and prognostics are the key aspects of the program, and the reason both Berg and Steele believe the software can be marketed effectively.

"We've developed some of these

things for the military over the years on other components such as bearings and parts of gas turbines," Steele says. "The unique thing here is that we're applying the outside framework to these high-performance gear drives. The *GPSys* has the ability to combine design parameters with assumed flaws and mission profiles to determine the likelihood of a catastrophic failure."

Berg says *GPSys* ties in with the new generation of military aircraft and control systems and onboard health monitoring systems where the military is looking at how to operate the equipment safely and when to operate certain profiles.

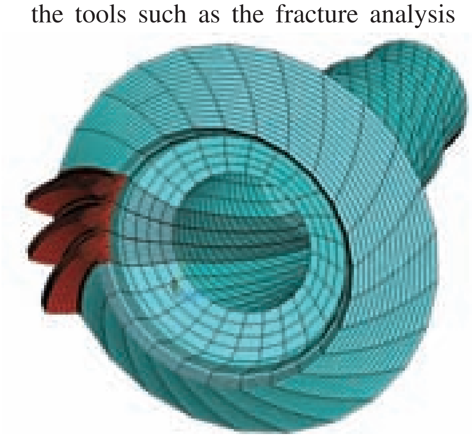
"They have the ability to predict remaining life and how they should properly operate an aircraft to get to a safe landing condition," Berg says. "With this software, pilots can plan out a safe return flight instead of losing an aircraft. That's kind of the birth of prognostics and how it is permeating through the design of these next generation aircraft."

Steele says the most important aspect of this technology is the safety of the pilots.

"They want a smart system onboard to tell the pilot to punch out, land immediately or continue the mission."

While this is prevalent in aerospace applications, Berg says the software offers plenty of flexibility and some of the tools such as the fracture analysis software do not have to be tied to gears if you have a model and load conditions.

"There are basically two systems at work here. One is an analysis tool and the other is a design tool, and both can be applied to several applications," Berg says.



3D finite element model of a spiral bevel pinion.

For more information:

Impact Technologies, LLC
200 Canal View Boulevard
Rochester, NY 14623
Phone: (585) 424-1990
Fax: (585) 424-1177
info@impact-tek.com
www.impact-tek.com

Rotary Cutting Tools

COATED WITH PDC

The V-tec series of veined rotary cutting tools from Star-SU include helical end mills and drills. They are coated with polycrystalline diamond by a high-pressure, high-temperature process that sinters the PCD coating into the veins that form in complex geometric shapes. This process effectively allows the V-tec end mills and drills to be made in solid-body helical geometries that don't have braze joints, so the tools are suitable for machining highly abrasive, advanced materials.

The V-tec helical end mills and drills have a broader application range. Non-ferrous application materials include composites, aluminum alloys, copper alloys, metal matrix composites, ceramics, graphites, carbides, friction materials, green ceramics and magnesium. Helical geometry reduces tool forces and helps improve chip removal. They exhibit less heat buildup and adhesion.

Star-SU is exhibiting at IMTS 2008 in booth **F-2238**.

For more information:
Star-SU LLC
5200 Prairie Stone Parkway, Suite 100
Hoffman Estates, IL 60192
Phone: (847) 649-1470
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com/Vtec

Chip/ Coolant Management System

MONITORS FLUID VALUES

Mayfran International's ConSep Plus and MagSep Plus are single platform chip handling, coolant recovery and monitoring systems that automatically control volume and conditions of water-soluble cooling and lubricating fluids in machine tools.

The ConSep Plus is for stand-alone machine tools and cell or FMS configurations. It handles any type of chip and can function with as many as 12 coolant tanks. An optional high-pressure coolant package includes a media-free filtering module with 10-15 micron level filtering.

The MagSep Plus handles cast iron chips and fines, and it can also be fitted with a high-pressure coolant package. Both units change belt speed to reduce coolant loss from the chip carryout by sensing the machine tool load. They are programmed to monitor the volume temperature, concentration, acidity and conductivity of the fluid in the coolant tank. The units can detect if an out-of-range variance is recognized. The systems are being displayed at IMTS at Mayfran's booth, **D-4427**.

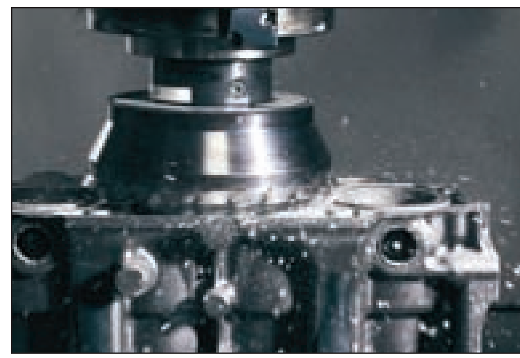
For more information:
Mayfran International
P.O. Box 43039
6650 Beta Drive
Cleveland, OH 44143
Phone: (440) 229-5449
Fax: (440) 461-0147
www.mayfran.com

Milling Cutter Technology

THREE-TIMES FASTER THAN INSERT CLAMPING

The VForce with SideLok direct-insert clamping design from Valenite is designed for high-insert density machining with increased metal removal rates. With diameters between three and 10", the SideLok technology allows more cutting teeth per revolution while feet and feed as well as material removal rates are three times faster than traditional insert-clamping systems.

Valenite incorporated three of its carbide grades and top-form geometries. The VForce can be used on a range of materials, especially cast iron, the company notes. Indexing time is minimized by releasing the insert quickly, which is enabled by one screw. There are 12 cutting edges created from a hexagonal shape.



The VForces insert cavity and locking screw are aligned and angled relative to each other, so they apply force in two directions while the screw tightens. A wedge-like condition is created by a process where the insert is pushed against pocket-side walls and pulled down to the bottom of the pocket, effectively securing the lock screw and retaining the insert.

For more information:
Valenite LLC
1675 East Whitcomb
Madison Heights, MI 48071-4628
Phone: (248) 733-6980
Fax: (248) 733-7846
www.valenite.com

Swiss Tooling Lines

Maximize Rigidity

Ingersoll Cutting Tools' integral collet tooling connects to the company's

Hi-PosMicro indexable end mills and Chip-Surfer solid carbide tipped tooling lines. Axial and radial repeatability of 0.0005" replace worn tooling in seconds. Tooling applications demonstrate improved rigidity, productivity with higher feed rates, finishes and extended tool life. The Chip-Surfer tips offer a range of carbide grades and coatings for various materials. The tooling lines are available in medium- and high-density styles with cutter diameters ranging from .250" to 2.00".

For more information:

Ingersoll Cutting Tools
Marketing and Technology Center
845 S. Lyford Road
Rockford, IL 61108-2749
Phone: (815) 387-6600
Fax: (815) 387-6337
info@ingersoll-imc.com
www.ingersollcuttingtools.com

Horizontal Machine Center

OFFERS ECONOMIC VALUE

The DMC 55 H ECO, a new product in the Ecoline series, is a compact, horizontal machining center offering XYZ axis travel of 22.1" x 23.6" x 23.6". Powered by a 26.8 hp main drive, the spindle is capable of reaching 18,000 rpm and rapid traverse to 1,970 ipm. The machine features CAT40 tooling, a 45-position tool magazine, a pallet with dimensions of 15.8" x 15.8" and a maximum load capacity of 1,102 pounds. The Ecoline machines are designed to offer a low price tag for quality machining.

The DMC 55 H ECO is one of 27 machines DMG is exhibiting at IMTS in **booth A-8501**. Other DMG machine tools being displayed are ultrasonic

continued

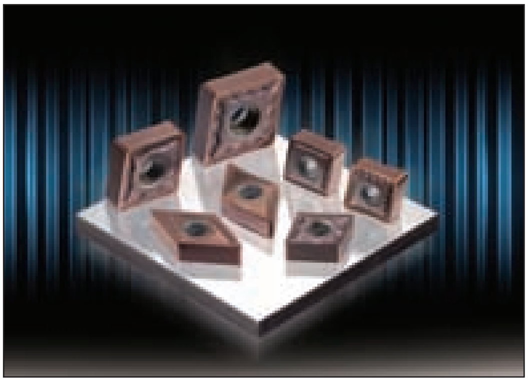
machines for the job shop, automotive, aerospace and advanced materials processing.

For more information:

DMG America, Inc.
265 Spring Lake Drive
Itasca, IL 60143
Phone: (630) 227-3900
Fax: (630) 227-3975
www.dmgamerica.com
info@dmgamerica.com

Carbide Grades

TURN EXOTIC MATERIALS



The AC510U and AC520U carbide grades are coated with a Super ZX coating, which consists of multiple thin layers of TiAlN and AlCrN to achieve higher speed capabilities and greater wear resistance. The AC510U grade is ideal for turning exotic materials, and the AC520U is intended for roughing and medium cut machining applications.

Both grades come in molded and ground insert types. The ground inserts improve accuracy and reduce the amount of scrap parts, and are used in high-precision applications. Sumitomo Electric Carbide Inc. is exhibiting at IMTS in booth **F-2668**.

For more information:
Sumitomo Electric Carbide, Inc.
1001 Business Center Drive
Mount Prospect, IL 60056
Phone: (800) 950-5202
Fax: (847) 635-9335
info@sumicarbide.com
www.sumicarbide.com

Insert Grade's Coating

INCREASES METAL REMOVAL RATES

Designed to mill hardened steels in response to demand from the die and mold industry, the GC1010 insert grade is capable of roughing and finishing. The grade combines a PVD coating with a fine-grained hard substrate to increase the rates of metal removal, improve tool life and provide both prolonged surface finish and tight tolerances.

Also from Sandvik Coromant, the Coromill 690 is a long-edge cutting tool for 2D profile milling of titanium parts, specifically complex components for the aerospace industry. It can be used for circular interpolation from a pre-drilled hole, square shoulder milling and

continued

edging and contouring. The tool resists axial forces and has four cutting edges. The insert pockets have threaded coolant holes, so high-pressure coolant is applied directly to the cutting edge, reducing chip build-up.

Both tools can be seen at IMTS in Sandvik Coromant's booth, **F-2000**.

For more information:
Sandvik Coromant Company
1702 Nevins Road
Fair Lawn, NJ 07410
Phone: (201) 794-5223
Fax: (201) 794-5217
www.coromant.sandvik.com/us

Gearmotor Line

BOASTS MORE THAN 75 STANDARD MODELS

Bison Gear and Engineering Corp. has responded to growing OEM customer demand with more than 75 standard gearmotor models designed as Von Weise Drop-in Replacements (VWDIR). The gearmotor line encompasses AC and DC parallel shaft and right angle gearmotors and is designed for a variety of commercial and light industrial applications, including food and beverage equipment; exercise, recreational and gaming machines; office and banking equipment; displays and merchandising equipment; and medical equipment.

The new Bison VWDIR gearmotors range from 1/30 to 1/2 hp, with output torques from 12–800 in-lbs. DC models include 12V and 90V permanent magnet motors as well as a 115V universal motor. AC models are available with 115V and 230V inputs in permanent split capacitor, split phase, shaded pole and universal motor design.

"Over the past 24 months, we were approached by a growing number of customers requiring shorter lead times for these types of gearmotors, and we have responded by tooling up this complete VWDIR line that is now in full production in our St. Charles, Illinois facility," says John Morehead, vice president of strategic planning and marketing at Bison.

"OEMs benefit by being able to design in a gearmotor solution that is just right and not overkill for their particular application. With increasing emphasis today on reduced cost designs it is important to be able to choose an appropriate gearmotor that is not burdened with rugged design features that may not be necessary," Morehead says.

For more information:
Bison Gear & Engineering Corp.
3850 Ohio Ave
St. Charles, IL 60174
Phone: (630) 377-4327
info@bisongear.com
www.bisongear.com

Fluid Line

CURTAILS FOAM

Milacron's HFP line of fluids features foam arrest control technology (FACT) to minimize the amount of foam produced, which improves lubricity for high volume and high fluid pressure applications. The fluids provide rancidity control, and they are compatible with most conventional waste treatment methods, according to the company's press release. The HFP line with FACT includes six fluids to accommodate different applications.

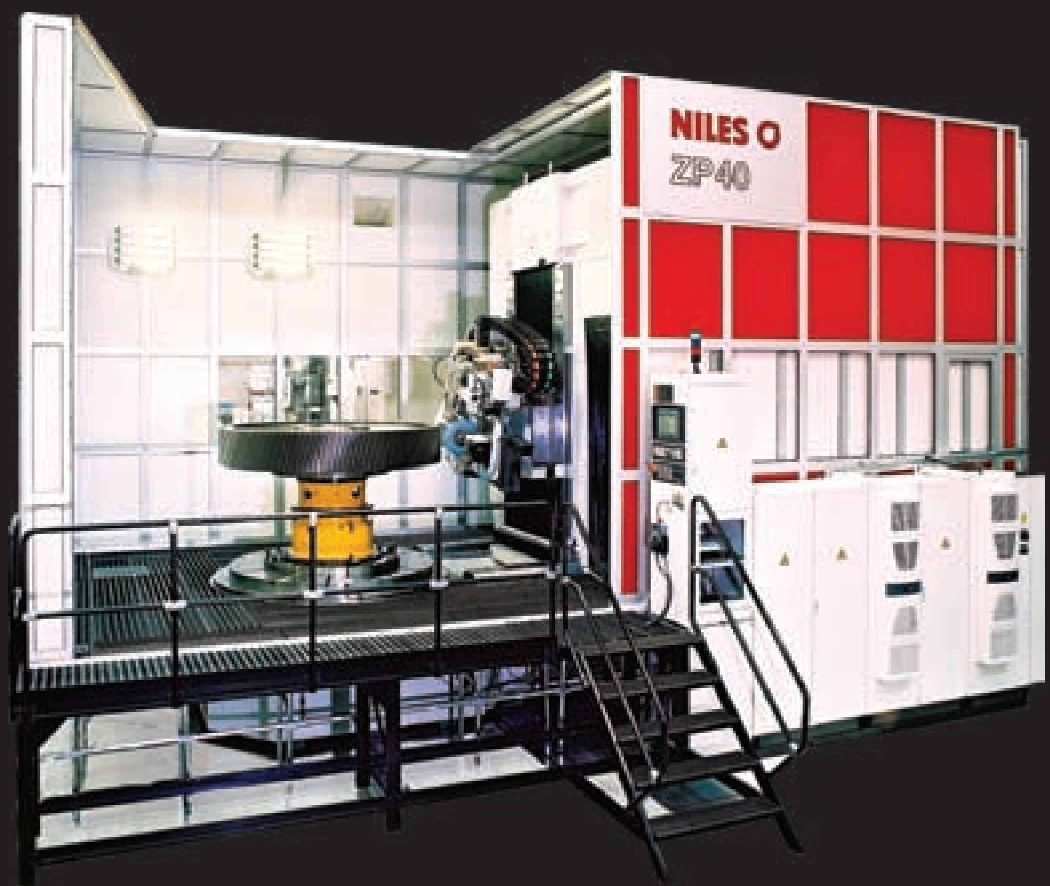
Milacron is exhibiting at IMTS in booth **B-7527**.

For more information:
Milacron Marketing Company
3000 Disney Street
Cincinnati, OH 45209
Phone: (888) 246-2665
Fax: (800) 205-3293 or
(513) 458-8298
www.cimcool.com

HAVLIK INTERNATIONAL MACHINERY

WE'VE INCREASED OUR GRINDING CAPACITY.

HAVLIK GEAR HAS AQUIRED ONE OF THE LARGEST GRINDERS IN NORTH AMERICA.



KAPP O NILES

The ZP 40 grinding machine features the ultimate in design construction with true hydrostatic guideways and rotary table. The work table is direct drive. Nodular cast iron is used for the machine beds, columns, and all sub-assembly housings, for stability. The machine accuracy is therefore assured for a long lifetime.

The ZP40 is designed to profile grind spur and helical external and internal gears using dressable corundum or sintered grinding wheels. An integrated measuring device further increases machine's flexibility. The ZP machine can be set up to accommodate application-specific requirements for maximum flexibility, high precision and optimum productivity.

It is specifically designed to accommodate shaft pinions, mating bull gears and internal ring gears.

Extended capacity for gears and profiles is:

- External grinding capability to 50 module (0.5 DP)
- Internal grinding capability to 25 module (1.0 DP)

NILES ZP 40

Tip diameter max.	4,000 mm (157.48 in.)
Distance rotary table – grinding wheel min. / max.	435 / 2.260 mm (17.13 / 88.98 in.)
Number of teeth	any
Profile depth external	100 mm (3.94 in.)
Module-External (at tooth height 2,25 x mod. max.	50 mm (0.5 DP)
Module-Internal (at tooth height 2.25 x mod)	25 mm (1.0 DP)
Helix angle max.	40 deg.
Stroke length max.	1,550 mm (61.02 in.)
Rotary table- load max.	40,000 kg (88,000 LBS)
Table diameter	2,250 mm (88.58 in)
Bore diameter x depth	1.365 x 265 mm (53.74 x 10.43 in.)
Grinding wheel- diameter max.	500 mm (19.69 in.)
Dressable diameter min.	220 mm (8.66 in.)
Width max.	130 mm (3.94 in.)
Speed max.	2,200 RPM
Driving power max.	40 kW

Connect with Global Technology at IMTS 2008

Lindsey Snyder, Assistant Editor

The International Manufacturing Technology Show has come a long way from the National Machine Tool Builders' Exposition first held in 1927. The ancestral show attracted 12,000 people and took up 63,000 square feet; a pretty impressive size even for the roaring 20s. Eighty-one years later, today's show, known as IMTS, is expected to exceed seven times the audience size of its original predecessor. IMTS 2008 is at Chicago's McCormick Place September 8–13.

It's easy to get lost at a show so large and filled to the brim with potential buyers, partners, competitors and wide-eyed machine-techies. The McCormick Place complex in Chicago may seem daunting. It is after all one of the only venues in the United States large enough for a net 1.2 million square foot show. The complex consists of nine industry-specific pavilions intended to help guide visitors through the large exhibition.

Here at *Gear Technology*, we think what better place to start your IMTS experience than the Gear Generation Pavilion located in the North Building, Hall B. Most major companies with gear-related specialties can be found there. Gear hobbers, gear shapers, shaving cutters, hobs, broaching equipment, grinding equipment and measuring equipment are found at this location. Don't forget to stop by the *Gear Technology* booth, B-7116, to meet the editors and renew your subscription.

The other pavilions include abrasive machining/sawing/finishing in the North building–Hall B; controls and CAD-CAM in the East building–Hall D; EDM in the East building–Hall D; machine components/cleaning/environmental in the East building–Hall D; metal cutting in the South building–Hall A; metal forming and fabricating/laser in the

North building–Hall B; quality assurance in the East building–Hall D; and tooling and workholding systems can be found in the West building–Hall F.

Global is the key theme at hand for modern manufacturing technology, and such is the focus of IMTS 2008. International attendees are offered free registration. Show organizers at the Association for Manufacturing Technology (AMT) felt an international theme was appropriate because IMTS appeals to members of the worldwide manufacturing community. The 2008 logo intends to communicate this idea by illustrating a globe with a spark on the horizon symbolizing new innovations, according to an IMTS press release.

"Spring-boarding off a tremendously successful IMTS 2006, this new theme and logo will set the tone for an even more exciting IMTS 2008," said John Krisko, AMT director, exhibitions. "IMTS is truly a global event during which buyers and sellers from over 100 countries exchange business and technical knowledge. The logo's symbolic contemporary globe image recognizes science and global presence. It is a futuristic, yet timeless design."

Some gear industry companies in Illinois take extra advantage of the show's proximity. Bourn and Koch is hosting an open house at its new facilities in Rockford. For information about transportation, contact Cathy Manske at *cmanske@bourn-koch.com* or (815) 965-4013 ext. 2305.

Fred Young, CEO of Forest City Gear, provides transportation to IMTS for any of his employees interested in attending. He offers this service so his employees can "look at the latest equipment, so we're aware of all the newest technology that is available in the gear world," Young says. "And so that our people have an understanding of what is available for them to help do their jobs properly. We try to involve our employees in the decision making process to evaluate new equipment that is out there to make sure we have the latest technology."

Take a look at what some gear-related companies will have on display at their booths, some of which can be found outside the Gear pavilion—for when you've exhausted yourself there.

Product Preview

Höfler

Booth B-7045

For the German company's first run at the IMTS show, two very large machines are being exhibited: the Rapid 1250— a 50-inch gear grinder—and the HF 1250 hobber/gasher.

"What's really unique about it [the Rapid 1250] is that we have our new power stroke process," says Ray Mackowsky, president of Great Lakes Gear Technology, the sales and marketing arm for Höfler in the U.S. and Canada. "It's a very high-speed grinding strategy that we use. The machines we had a year ago, we're actually producing 30–40 percent, sometimes 50 percent, faster grinding cycles.

"Now with this new power stroke strategy, we're even more productive."

The HF 1250 is equipped with carbide cutting speeds and power for heavy-duty applications, like coarse pitch. It produces gears from 15 to 1,250

continued

mm in diameter, has an axial slide travel of 1,000 mm and features an 8,000 kg table load capacity. After the show, this unit is headed to HMC Inc. in Indiana to join the Rapid 6000 (world's largest) form grinder.

For more information:

Great Lakes Gear Technology
8755 Ronda Drive
Canton, MI 48187
Phone: (734) 416-9300
Fax: (734) 416-7088
www.greatlakesgeartech.com
www.hofler.com

Gleason

Booth B-6902

Taking aim at improving bevel and cylindrical gear production, Gleason brings four new machines to IMTS.

The Genesis machines are a new series of gear production machines, and Gleason is displaying two of them. The Genesis Vertical Hobbing Machine is appropriate for dry machining. It features a small footprint and provides improved productivity for spur and helical gears up to 210 mm in diameter. The Genesis Threaded Wheel Grinding Machine is designed for high production needs in which every second is imperative.

The P 600/800 G Profile Grinding Machine offers new software for profile grinding, which reduces manual setup and other time-consuming steps.

The Sigma 475 and 1500GMM Analytical Gear Testers provide complete bevel and cylindrical gear inspection featuring a three-dimensional scanning probe head. These testers are powered by new *GAMA* native software that covers a range of gear applications.

Gleason's booth will also exhibit cutting tools and workholding systems including hobs, shaper cutters, bevel blades and heads, replatable CBN and diamond grinding and dressing wheels, plated diamond rolls and milling cutters.

For more information:

Gleason Corporation
1000 University Ave.
P.O. Box 22970
Rochester, NY 14692
www.gleason.com

Sunnen

Booth B-7200

The VSS-2 Series 2 Single Stroke Honing systems have factory-aligned spindles that surpass DIN 8635 requirements for vertical honing machines. Applications include sizing bores 3.9–50 mm diameter in stamped parts, hydraulic valve bodies, gears and sprockets, parking pawls, rocker arms, turbocharger housings and other similar parts. Materials suitable for the machines are free-cutting materials like cast iron, powdered metals, ceramic and glass graphite.

"The VSS Series 2 sets a new standard for single-pass bore sizing efficiency," says Phil Hanna, Sunnen product manager for machines. "If a part is best suited for single-pass honing, the VSS-2 provides a level of precision not available in other designs. And, with the new touch screen control, this machine is very operator friendly. No custom electronics or special training are needed, and the control is designed to interface with part handling automation systems."

Three models of the VSS Series 2 are available to serve mid- to high production. The model 84 is an eight-station, four-spindle machine, the 86 has six spindles and the 64 is a six-station, four-spindle design. The 10 hp spindle drive operates at speeds between 100 and 2,500 rpm.

The work envelope is accessible from both sides of the machine. Other standard features include an electric rotary index table and tool holder. Optional features include floating or rigid adjustable tool holders, 12- and 16-port programmable rotary air unions for index output, base coolant evacuation pump, automatic lubrication system, work area light kit, stack light, tool alignment indicator and spindle crash

continued

and tool protections.

"If a part is appropriate for single-pass honing, the VSS-2 delivers a value-priced, compact, customizable package," Hanna says.

For more information:
Sunnen Products Company
7910 Manchester Avenue
St. Louis, MO 63143
Phone: (314) 781-2100
www.sunnen.com

Jones & Shipman

Booth B-6760

A multi-wheel design and a stylized concept dressing unit are two new technologies emerging in soon to be released cylindrical and gear grinding machines on display from Jones & Shipman – Holroyd. The company is also exhibiting three other machines and two wheelhead modules.

Some future developments on display from Jones & Shipman include a concept for the grinding/dressing area of a new model that has been proposed for the Holroyd series of next-generation gear and thread grinding machines. The family of machines is aimed at the high-end aerospace, performance car and master gear industries. The dressing/grinding concept features a twin diamond disc dressing unit that includes a full two-axis control, a 500 x 107 mm grinding wheel, and it has the capacity for 350 mm x 1,500 mm components.

Jones & Shipman is introducing the Ultramat MK II series of high-precision production cylindrical grinding machines, which feature a modular wheelhead system that is on display at IMTS. The wheelhead design on display features twin grinding wheels with the capacity for components up to 500 x 100 mm and an internal grinding spindle. The grinding wheels are placed back-to-back, but there are other available external/internal wheel configuration options designed for complex machining. The Ultramat MK II machines are directed towards high-end aerospace, performance car and precision mold, tool and die industries.

The Suprema 650 Easy cylindrical grinding machine, pictured here, has a universal wheelhead and grinding capacity of 300 m x 650 mm diameter between centers. The wheelhead allows both internal and external grinding, but the machine is available with a plain straight approach and angle head option. Available table capacities include 1 m and 1.5 m. Other machines at the booth are the Dominator creepfeed series grinder and the TechMaster surface grinder family.

For more information:

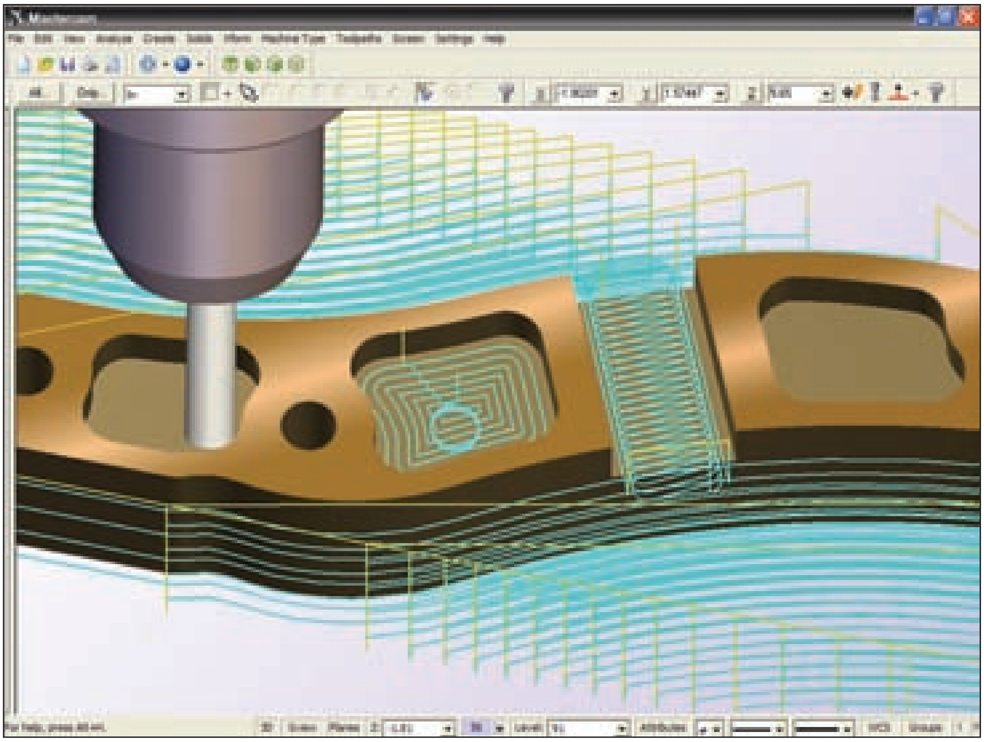
Jones & Shipman Precision Ltd.
Murrayfield Road,
Leicester LE3 1UW, UK
Phone: +(44) 116-201-3000
Fax: +(44) 116-201-3002
www.Jonesshipman.com

Mastercam

Booth D-3027

CAD/CAM software developer CNC Software, Inc., is releasing its latest software *Mastercam X3*, including Feature Based Machinining (FBM), 2D high-speed tool motion and improved toolpath generation.

The Mastercam Feature Based Machining evaluates the features of a part and automatically designs a machining strategy. Users select criteria for the type of FBM operation to employ, and the software detects the machining features. The FBM is equipped to set the correct toolpath options for closed, open, nested and through pockets, and it machines the pockets using 2D roughing, rest mill and finish operations.



FBM also provides the option to make a separate finish toolpath for floors and walls and can activate or deactivate external machining, which is identified by the software. The FBM recognizes when facing is necessary, creates drilled, tapped, counterbore and countersink holes and performs deep drilling, spot drilling, pre-drilling, tool section and tool creation if these features are required. Other controls can drill blind, through, co-axial and split holes. Users can change any toolpath at any time.

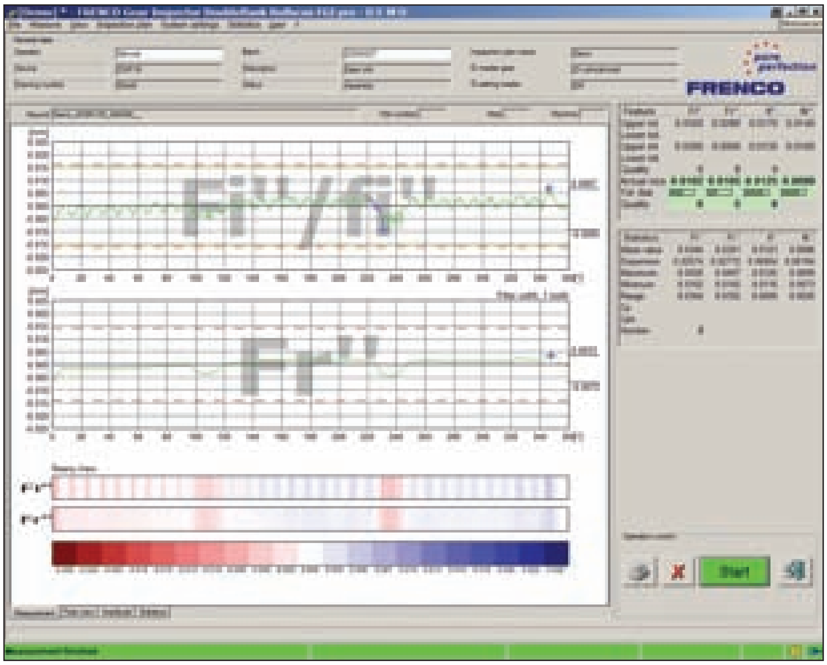
The *X3* software brings high speed capability to 2D machining. These toolpaths allow low-stress motion without a high-speed machine. The peel milling feature removes material in layers and brings constant climb milling in rotational motion when a tool is not engaged. Other 2D modes include core milling, area milling for complex shapes, rest milling that removes excess material between cuts, blend milling that alters a toolpath between two shapes and controlled engagement, which allows users more control over tool engagement.

A *Mastercam* in *Solidworks* package will be featured at the company's booth, but it won't be immediately available for another month or so. This version of the X3 software integrates the Mastercam toolpaths into *SolidWorks*. Designers that use *SolidWorks* will be able to program parts with the *Mastercam X3* strategies.

For more information:
CNC Software, Inc.
671 Old Post Road
Tolland, CT 06084
Phone: (800) 228-2877
www.mastercam.com

Frenco/Eurotech

Booth F-2310



The measurement and evaluation software *Frenco Gear Inspector/FGI Pro* has been upgraded with new features. *FGI Pro* has an application-oriented development and can be used for retrofitted Mahr and Hommel instruments.

There are several measurement evaluation display options, including a comparison for series of measurements or a juxtaposition and evaluation for freely selectable measurements within a sequence, which helps detect deviations and other errors.

Measured values can be traced to the physical workpiece, known as positioning. For global companies, the output language can be programmed separately, in which measurement reports can be displayed and assessed in English, German, French, Spanish Portuguese, Hungarian, Polish and Russian. Measuring the coating thickness of partly coated gears is one of several special applications add-ons.

For more information:
Euro-Tech Corporation
N48 W14170 Hampton Avenue
Menomonee Falls, WI 53051
Phone: (262) 781-6777
Fax: (262) 781-2822
www.eurotechcorp.com

Reishauer Corporation

Booth B-7005

The RZ 303C precision gear grinding machine is being displayed by Reishauer. The machine uses gearless planetary drives, acoustic sensing for alignment of dressing diamonds and low noise shifting—which prevents excitation on gear teeth by a random surface structure.

The chief column that carries the spindle and slide rotates 180 degrees from the grinding position, 90 degrees in order to change the wheel and another 90 degrees to dress the wheel. The wheel uses the machine axis during the dressing cycle to modify root, flanks and tip with minimum passes imparted to the gear while grinding.

For more information:
Reishauer Corporation
1525 Holmes Road
Elgin, IL 60123
Phone: (847) 888-3828
Fax: (847) 888-0343
www.reishauer.com

Hardinge

Booth A-8032

The Kel-Vita universal ID/OD grinding machine from Kellenberger, a member of the Hardinge Group, can handle workpieces as long as 1,000 mm, has eight wheelhead configurations and low-friction linear rails. Three models are offered—the Kel-Vita 600, Kel-Vita 800 and Kel-Vita 1000, with the between-centers capacity represented by the model numbers. Each version reaches a height of 175 mm.

Users can design the machine configuration using the different grinding wheelhead types. UR and URS wheelheads have a swiveling design with one internal and two external grinding wheels. In one chucking the grinder is capable of external diameters, opposed faces, bores, tapers, polygons, tapered non-rounds and thread grinding. Up to 500 mm OD grinding wheels can be used. The longitudinal axis is capable of 20 m/min rapid traverse and 10 m/min on the in-feed axis. The machine's control supports cylinders, radii, chamfers, cones, tapers, non-round ODs and IDs, contours and outlines.

For more information:
Hardinge Inc.
1 Hardinge Drive
Elmira, NY 14902-1507
Phone: (607) 734-2281
Fax: (607) 734-3886
www.hardinge.com

SMW Autoblok

Booth F-2040

The D-Chuck by SMW Autoblok is a new quick jaw change diaphragm chuck for hard turning gears. The elastic deformation of the diaphragm provides constant, adjustable clamping force contributing to greater precision, reduced maintenance and longer chuck life, according to the company's press release. The quick jaw change system utilizes the ABS Coupling, licensed from Komet, for improved rigidity and accuracy. The jaws can be changed in less than one minute, offering fast changeover between jobs. Matched jaw sets can also be used on different D-Chucks. In order to compensate for

continued

the centrifugal force caused by the jaws during operation, counter balance weights connected to the clamping jaws are mounted underneath the diaphragm.

"The D-Chuck combines the characteristics of flexibility and accuracy for a combination not matched by any other diaphragm chuck," says Sidney N. Roth, president of SMW Autoblok. "The diaphragm has been tested for several million actuations with no failures."

For more information:

SMW Autoblock Corp.
285 Egidi Drive
Wheeling, IL 60090
Phone: (847) 215-0591
Fax: (847) 215-0594
gdowns@smwautoblok.com
www.smw-autoblok.com

Drake Manufacturing:

Booth B-7407

With several machines onboard, Drake Manufacturing is promoting its grinding and gear processing technology. Drake engineers are available to discuss solutions to specific grinding and gear production challenges. Some of Drake's machine and software solutions include gears and cutting tools, e-steering, threaded parts and ballscrews.

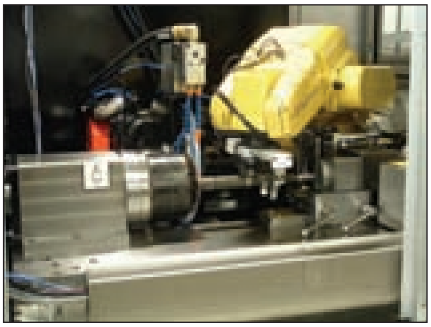
The machines on display include the Linear Motor External Thread Grinders, which grind threads, splines, key slots, rings and other forms in one setup. It has auto load/unload features and 180 degrees power helix.

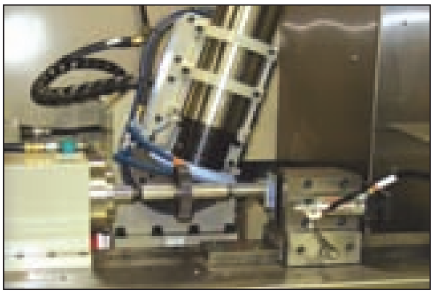
The Linear Motor Internal Thread Grinder grinds threads on internal diameters of parts such as ball nuts, steering nuts and spindles. It offers size control to +/– 0.0002 inches. The Linear Motor Worm Grinders grind single and multi-start worms—ZK, ZI, ZN, SA or free form. These grinders are capable of six arc second indexing.

The Linear Motor Profile Gear Grinders CNC finish grind gears to AGMA 14 with one setup and have a fast changeover. This machine handles small batch production well. Steering Rack Milling Machines will also be on display. This auto-load production cell machine can mill racks in 35 seconds to a 0.4 Ra finish.

For more information:

Drake Manufacturing
4372 North Leavitt Road
Warren, OH 44485
Phone: (330) 847-7291
Fax: (330) 847-6323
www.drakemfg.com
info@drakemfg.com





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Advantage AGMA

Technical Committees

Build Knowledge & Experience in Gear Industry

Matthew Jaster, Associate Editor

The world is full of acronyms. At work, the inbox reveals e-mails from the AWEA, SAE, MPIF and AMT. On the weekends, Saturday mornings are consumed by activities involving the AYSO, PTA, YMCA or DMV. It's a struggle to determine what organization does what and why we should care in the first place.

Members of the Epicyclic Enclosed Drive Committee in the fall of 2007 included from left to right: (Seated): Terry Klaves, the late Don McVittie, Chuck Schultz and Dick Schunck. (Standing): Charlie Fischer, John Amendola, Vanyo Kirov, Octave LaBath, Johannes Picard and Tom Miller.

There are certain acronyms for certain people. If you're trying to save a rain forest, you're probably interested in the EPA. Want to play third base for the Yankees? Try the MLB. If you're in the business of gears, it might not hurt to know a thing or two about AGMA.

"For an individual starting out in the gear industry, AGMA can offer individual education programs that will aid them in developing expertise in areas such as gear design, manufacturing and failure analysis," says Dave Ballard, corporate manager at SEW-Eurodrive, Inc. and vice chairman/treasurer of the AGMA board of directors. "For me personally, during the course of my career in this industry, I have interacted with AGMA in furthering my knowledge of gear failure, interpreting standards, sales and supplier networking and marketing evaluations."

Members also have an opportunity to participate in AGMA's various technical committees. For some, volunteering provides a chance to address key issues, stay informed on current events and become an active participant in the industry. Many business professionals try a variety of strategies to get ahead in their careers. They look for mentors, update resumes and network over the phone or Internet. They sometimes forget the most valuable tool they have to offer is their time.

Shortening the learning curve. AGMA was created in 1916 by nine U.S. gear companies with the objective of advancing, improving and promoting the gear industry. Today, more than 400 companies worldwide participate in the organization. One of the key aspects to AGMA's success is the people that volunteer their time and services to work on the various technical committees.

When Phil Terry joined Lufkin Industries, Inc. in 1996, he made it a priority to get involved with AGMA immediately. "My new co-workers recommended becoming active with AGMA as soon as I arrived and described the way in which their own introduction to gear technology had been accelerated by their involvement," Terry says. "I was able to get an understanding of the special material requirements, the specific gear terminology and establish a network of contacts."

Lufkin found his own experience to be invaluable when meeting with customers, certifying authorities or trainees about standards and similar documents. "There is nothing quite so convincing as saying, 'I helped write the standard' when a detailed technical point from a document is questioned or there is a subtle nuance in a clause."

His work on both the Metallurgy and Materials Committee and the Technical Division Executive Committee significantly shortened the learning curve and gave him the necessary skills to further his knowledge of the gear industry.

"In the early days of the development of the AGMA 923 document, I acted as secretary and had to get all the words and terms correct. A specific question about heat treatment response in large section parts arose and through the in-house facilities available at my own company, I was able to perform actual trials to confirm the recommendations I was proposing. The power of scientific data on the table was clear."

Robert Wasilewski, chairman of the Bevel Gearing Committee, also started out as secretary when he first got involved with AGMA.

"While this is often seen as a thankless task, it really is vital. As secretary, you control the meeting. You have to understand what is going on or you can't describe it. Learning to be a good secretary builds the foundation you need to write a better standard by learning how to describe the committee's intention. This is the perfect job for the new member."

Wasilewski's experience on the Computer Programming

continued

Committee is beneficial because every detail has to be covered in order for the program to function. "There is no better way to understand how to use a technical standard than to try and program it," Wasilewski says.

Wasilewski has devoted countless vacation days to his work on AGMA. Most members he knows do the committee work on their own time. No matter how chaotic it might get, he's always found something positive in the experience.

"Most of the committee members volunteer to do tasks because they want to work on a particular material. Either they're familiar with it, or they want to be. I look at it as learning. Take time at work to learn and take time after work to learn. You should only stop learning when you're dead!"

For George Lian, senior project engineer at Amarillo Gear Co., work on the Bevel Gearing, Helical Gearing and Programming Committees has helped his full time job immensely.

"Committee work has given me advanced knowledge in AGMA standards related to the gear product for my company. Consequently, I was able to make better judgments in designing gears and improving manufacturing processes."

Lian states that the work he's done on the Programming Committee is a far different experience than anything else he's worked on.

"The members would meet in a city with nice scenery, but would be in the hotel writing codes the entire time. The sessions would usually continue late (past midnight). Members are usually easy-going, but they're dead serious when writing codes. At times, however, a member could be influenced to write code in a certain way by tempting them with chocolate."

As far as the workload is concerned, Lian says it's not difficult when the work is interesting and you have an understanding family. "Although many hours are used doing committee assignments, there's still ample time to be with family and friends."

Technical difficulties. The most challenging task for AGMA is recruiting new members for the technical committees. According to Wasilewski, sometimes potential members are not given support from their upper management.

"Committee participation is looked at as an expense, not as an education. Management must understand that good engineers need continuous learning and exposure to contemporaries. These companies need to realize that if you send a new engineer to the committee, you start to build the developed engineer you'll need in the future. If nothing else, they should remember that having a participant gives them a voice in the standards that affect their products and helps protect their interests."

Lian believes the recruitment process should be addressed at AGMA annual meetings or other functions where attendees can influence companies to send employees to technical

continued

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committees. He also thinks new members could be recruited by running advertisements in gear-related publications.

Lukfin says recruitment is a continuous process. “All committee members are continually searching for new members, and the full time staff of AGMA always discusses technical committee work with potential new member companies and during visits to existing company members.”

While there are many benefits to technical committee work, not everyone sees committee work as an advantage to an individual’s career goals. Michael T. Robinson has been in the semiconductor industry for 30 years and is the founder of a website called *www.careerplanner.com* that helps people build more fulfilling and rewarding careers.

Robinson explains that sometimes management sees standards committees as a necessary evil and expense until there is something they need done by the committee.

“These include influencing standards, hearing new trends and changes within the industry and getting an advanced look at technical papers,” Robinson says.

Another cause for concern for Robinson is the amount of time some volunteers take if they hold a chair position or head an annual technical conference. The work it takes to volunteer for such activity may have an adverse effect on their full-time jobs. The key for Robinson is to be an active participant at your full-time job and make sure whatever you do outside the office, it gets back to the office first and foremost.

“It’s critical to attend technical conferences in your field, hear the questions, review the papers and see what your competitors are talking about. When you get back to the office, you should give a presentation on everything you’ve learned.”

While there are definite obstacles in trying to balance your full-time job with your volunteer work, Wasilewski believes the positives far outweigh the negatives. He will continue to support the various committees he serves.

Wasilewski frequently tells people that he “brings home more from an AGMA meeting than he brought to it.” Typically, the people working on a particular project share similar or complementary responsibilities in the gear industry.

“Often, they relate some experience that you can use in your position, either now or in the future. They, in turn, can learn from even the newest person. Each member company is unique, and each has experiences to share. Meetings are often an open dialog full of these experiences,” Wasilewski says.

“Where else can an individual go today and work with a room full of mentors?”

(See sidebar next page.)

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What Does AGMA Offer?

So what are your options when considering participation in an AGMA technical committee? It all depends on your area of expertise and your various interests. Here's a breakdown of the committees currently available online at *www.agma.org*.

Technical Division

Technical Division Executive Committee: This committee supervises the development of AGMA standards and organizes the Fall Technical Meeting as well as technical education seminars throughout the year.

Academic, Research & Technical Liaison Committees

Academic Committee: Supports the American academic community in the education of the gear industry.*Computer Programming Committee*: Facilitates standards using computer software.

International Standards

ANSI Technical Advisory Group: Contributes to the development of international gearing standards.

Specialty Standards

Data Exchange Protocol Committee: Develops a system of storage and retrieval of digital gear metrology and related data for cylindrical gears.

Fine-Pitch Gearing Committee: Evaluates design considerations, tooth forms and other aspects that must be treated in a different manner for fine-pitch gears and face gears.

Nomenclature Committee: Develops definitions, symbols, terms, etc., for all types and elements of gears.

Plastics Gearing Committee: Evaluates materials, design, rating, manufacturing, inspection and application of molded or cut-tooth plastic gearing.

Powder Metallurgy Gearing Committee: Evaluates materials, design, rating, manufacturing, inspection and application of powder metallurgy gearing.

Manufacturing & Inspection

Calibration Committee: Develops methods of calibration for equipment used in the manufacture or inspection of gears.

Cutting Tools Committee: Evaluates tools for producing gear teeth, such as hobs, shaper cutters, etc. (Committee maintains liaison with organizations involved directly with such tools and prepares AGMA standards only when the need is not being met).

Gear Accuracy Committee: Develops classification system covering dimensional accuracy of gears and associated measurement methods of equipment.

Sound & Vibration Committee: Evaluates sound and vibration specifications and methods as applied to gearing, generally to enclosed gear drives.

Rating Standards

Bevel Gearing Committee: Evaluates all aspects of bevel gearing, except inspection.

Helical Gear Rating Committee: Determines strength and durability rating of spur and helical gears.

Lubrication Committee: Covers the description and application of lubrication of open and enclosed gear sets.

Metallurgy & Materials Committee: Evaluates gear materials and heat treatment.

General Product Standards

Enclosed Drives for Industrial Applications Committee: Evaluates design, rating and application of enclosed drives in which helical, herringbone or spiral bevel gears are the principal form of gearing.

Epicyclic Enclosed Drives (Planetary) Committee: Evaluates design, rating and application or enclosed drives employing epicyclic gear arrangements.

Flexible Couplings Committee: Evaluates design, rating and application of mechanical connectors for transmitting torque without slip and for accommodating misalignment between axially oriented rotors.

Wormgearing Committee: Covers all aspects of cylindrical and globoidal worm gearing, including design, rating and application of enclosed drives, and inspection.

Specialty Product Standards

Aerospace Gearing Committee: Determines special considerations required for gears used in manned and unmanned aircraft, rockets and missiles, and for the guidance and data systems used for control.

Helical Enclosed Drives High Speed Units Committee: Evaluates design, rating and application of enclosed helical gear drives where the pitch-line velocity exceeds 5,000 fpm, or pinion speed exceeds 3,600 rpm.

Helical Enclosed Drives Marine Units Committee: Evaluates design, rating and application of enclosed drives in which helical gears are the principle form for propulsion and/or ship service generator sets.

Mill Gearing Committee: Evaluates special considerations required for helical and herringbone gears used to drive cylindrical grinding mills, kilns, dryers and metal rolling mills.

Vehicle Gearing Committee: Evaluates special considerations required for gears used on vehicles propelled along the ground.

Wind Turbine Gear Committee: This is a joint committee with the American Wind Energy Association (AWEA) that develops gear standards used in the production of wind energy.

NASA
GETS DOWN AND DIRTY FOR SARJ SOLUTION

Jack McGuinn, Senior Editor

This recent spacewalk from the ISS included collection of grit from the faulty SARJ rotary joint for further analysis on the ground upon the latest mission's return to earth.

For more than 10 months, NASA ground engineers and International Space Station (ISS) astronauts have been struggling with a perplexing malfunction of one of the station's two solar array rotary joints (SARJ). The SARJ in question, on the starboard side, has since last October been inoperative to the extent that it can only be rotated manually towards the sun, from which it derives power in support of the ISS. The problem exists in the solar array's truss segment—or rotary joint—which was designed to rotate the array's panels sunward.

There has been progress, however, in that NASA has identified the problem to be a roller surface failure in one of the trundle bearing assembly (TBA) raceways and rings. More specifically, the "culprit," as Johnson Space Center's Kevin Window—SARJ Recovery Team Leader—calls it, is a concentration of metallic grit, or debris, in the raceway that is causing undue vibration and is impinging upon the joint, preventing its free movement. As for the root cause of that, it remains a mystery, although Window's team believes it is on track to solve it. To do so, they have been relying on very high-resolution photos and grit samples from ISS team members in order to conduct their testing. One testing drawback, however, is the inability to replicate on the ground what is going on in space. But progress is being made, nevertheless.

"The vast majority of debris we found (in the samples) was nitrided 15-5 (steel)," says Window. "What that tells us at this point in time is that something caused us to crack (or spall) that top layer (outer-canted surface) of the raceway."

There was some confusion at one point in which one of the ISS astronauts, after an in-space inspection, referred to the grit-affected area as a "raised surface," as opposed to a "depression," which it was originally thought to be by personnel on the ground.

"That gave us concern, because a depression is a whole lot different than a raised surface," says Window. "We had a large contingent of folks that expected it to be a depression, but it is a raised surface on the raceway surface. It is concerning because what we discovered during our (pre-mission) testing is that nitride 15-5 is very hard, but it is also very brittle once you start cracking it."

In order to try and minimize the grit issue short term, an ISS astronaut applied a lubricant to the affected surface. The result was less unwanted friction in the raceway surface, but that led to discovery of another problem—misalignment in the trundle bearing.

"We believe there may be a bit of mistracking in our trundle bearing that is causing an edge load," Window says. "Our tests have shown that when the coefficient of friction gets to a certain level, the bearing itself will tip on-edge. In ambient (environments) it doesn't, but when you put it in a vacuum—or space—the roller will tip on-edge. We're still

continued

doing some analysis and testing to determine what that means and how it fits into our root cause."

But, much like unraveling a string that never seems to end, another issue was identified—the bearings, which are not lubricated but, rather, gold plated. Further inspection discovered some delamination occurring with the bearings.

"There is a potential—and it is still a leg of our fault tree that is still open—that the gold plating was potentially not applied properly on some of the trundle bearings and that could be the cause or contribute to the cause of the failure," Window explains. "We do have paperwork that shows that we did have some issues with delamination of the gold plating. (Prior to the mission) there wasn't much thought that it might cause a problem or could contribute to such a failure that we have today."

So where does that leave things?

Summing up, the "fault tree" Window refers to has 10 remaining "legs" left open in the yellow category, yellow being a "maybe" in determining root cause. Of those 10 there's some overlap, as might be expected.

"Three of (the yellows) are FOD—foreign object debris—that's gotten into the race ring. It all boils down to where the FOD came from. One is magnetic attraction of FOD from the SARJ—something broke off within the SARJ and came onto the surface. Another is magnetic attraction of FOD from outside the SARJ, and a third is that FOD was left during processing on the ground; somebody dropped a piece of debris, and it was left on that area.

"Then we have another set of yellows that we'll call materials and processing. One is that the materials in the surface treatment were incorrectly chosen, so on the design side we shouldn't have been using nitrided 15-5 or gold plated 440C. Two is that the nitride was incorrectly applied to the race ring surface. Then we have a set of yellows called roller traction kinematics. And that is that the gold was inadequately applied and thus the increase in friction. That leads to excessive friction between the drive lock assembly and the race ring, as well as between the trundle bearing assembly and the race ring. And, finally, we have misalignment of the drive lock assembly rollers and the trundle bearing assembly rollers."

That may seem—and in fact it is—a lot to deal with in determining a root cause and corrective action. But "pruning" of the fault tree continues.

"We believe that we will work this out," says Window. "We don't know that we'll actually be able to nail down the root cause until we get some more of our hardware down. We won't know until we get it down and look at it. So far, we've been able to supply the power to perform our mission, based on the analysis we've performed.

"We're putting all the plans in place to try and understand the root cause and fix whatever we need to fix to prevent it from ever happening again."

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Induction Hardening of Gears and Critical Components

Dr. Valery Rudnev

Management Summary

Induction hardening is a heat treating technique that can be used to selectively harden portions of a gear, such as the flanks, roots and tips of teeth, providing improved hardness, wear resistance, and contact fatigue strength without affecting the metallurgy of the core and other parts of the component that don't require change. This article provides an overview of the process and special considerations for heat treating gears. Part I covers gear materials, desired microsctructure, coil design and tooth-by-tooth induction hardening. Part II, which will appear in the next issue, covers spin hardening and various heating concepts used with it.

Introduction

Over the years, gear manufacturers have gained knowledge about how technology can be used to produce quality parts. The application of this knowledge has resulted in quieter, lighter and lower cost gears that have an increased load-carrying capacity to handle higher speeds and torques while generating a minimum amount of heat and noise.

Gear performance characteristics (including load condition and operating environment) dictate the required surface hardness, core hardness, hardness profile, residual stress distribution, grade of steel and the prior microstructure of the steel.

In contrast to carburizing and nitriding, induction hardening does not require heating the whole gear. With induction, heating can be localized to only those areas in which metallurgical changes are required. For example, the flanks, roots and tips of gear teeth can be selectively hardened.

A major goal of induction gear hardening is to provide a fine-grain martensitic layer on specific areas of the part. The remainder of the part is unaffected by the induction process. Hardness, wear resistance, contact fatigue and impact strength increase.

Another goal of induction gear hardening is to produce significant compressive residual stresses at the surface and in a subsurface region (Refs. 1–4). Compressive stresses help inhibit crack development and resist tensile bending fatigue.

Not all gears and pinions are well suited for induction hardening. External spur and helical gears, worm gears and internal gears, bevel gears, racks and sprockets are among the parts that are typically induction hardened (Refs. 1, 2). A sampling of parts can be seen in Figure 1. Conversely, hypoid gears and noncircular gears are rarely heat treated by induction.

Importance of Gear Material and Its Condition

Gear operating conditions, the required hardness and cost are important factors to consider when selecting materials for induction hardened gears. Plain carbon steels and low-alloy steels containing 0.40 to 0.55% carbon content are commonly specified (Refs. 1, 5). Examples include AISI 1045, 1552, 4140, 4150, 4340, and 5150. Depending on the application, tooth hardness after tempering is typically in the 48 to 60 HRC range. Core hardness primarily depends upon steel chemical composition and steel condition prior to induction hardening. For quenching and tempering, prior structure core hardness is usually in the 28–35 HRC range.

When discussing induction hardening, it is imperative to mention the importance of having "favorable" steel conditions prior to gear hardening. Hardness pattern repeatability is grossly affected by the consistency of the microstructure prior to heat treatment (referred to as microstructure of a "green" gear) and the steel chemical composition (Refs. 1, 5).

"Favorable" initial microstructure consists of a homogeneous, fine-grain, quenched and tempered, martensitic structure with hardness of 30–34 HRC; it leads to fast and consistent metal response to heat treating, with the smallest shape/size distortion and a minimum amount of grain growth. This type of initial microstructure results in higher hardness and deeper hardened case depth compared to the ferritic/pearlitic initial microstructure.

If the initial microstructure of a gear has a significant amount of coarse pearlite, and most importantly, coarse ferrites or clusters of ferrites, then these microstructures cannot be considered "favorable," because gears with such structures will require longer austenization time and/or higher austenizing temperatures to make sure that diffusion-type processes are completed and homogeneous austenite is obtained.

Ferrite is practically a pure iron and does not contain the carbon required for martensitic transformation. That's why large areas (clusters) of free ferrite require a longer time for carbon to diffuse into low-carbon regions. Actually, clusters of ferrites act as one very large grain, which often is retained in the austenite. What can result after quenching is a ferritic/pearlitic network and/or a complex ferritic/martensitic structure with scattered soft and hard spots (Ref. 1).

Steels with large carbides (i.e., spheroidized microstructures) have poor response to induction hardening

Figure 1—Typical induction hardened gears and critical components.

and also require prolonged heating and higher temperatures for austenization. Longer heat time leads to grain growth, appearance of coarse martensite, data scatter, extended transition zone and essential gear shape distortion. Coarse martensite has a negative effect on tooth toughness and impact strength, and it creates favorable conditions for cracking.

As opposed to other heat treating techniques, heat treatment by induction is appreciably affected by variation in metal chemical composition. Therefore, "favorable" initial metal condition also includes tight control of the specified chemical composition of steels and cast irons. Wide compositional limits cause surface hardness and case depth variation. Consequently, tight control of the composition eliminates possible variation of the heat treat pattern resulting from multiple steel/iron sources. Microstructurally or chemically segregated structures and banded initial microstructures of "green" gears should be avoided.

All commercial grades of steels contain limited amounts of additional chemical elements that "happened to be" in steel as traces or residual impurities in the raw materials or were added to the melting pot for the creation of certain conditions during the steelmaking process. Excessive amounts of these elements, their heterogeneous distribution and presence of appreciable-size stringers can result in stagger hardness and gear strength degradation. For example, presence of large stringers of manganese sulfide inclusions can act as stress raisers, resulting in inter-granular cracking. Sulfur level and nitrogen contents should be closely controlled.

The surface condition of the gear is another factor that can have a pronounced effect on gear heat treating practice. Voids, micro-cracks, notches and other surface and sub-surface discontinuities as well as other stress concentrators can initiate cracking during hardening when the metal goes through the "expansion-contraction" cycle; thermal gradients and stresses can reach critical values and "open" notches and micro-cracks. Conversely, a homogeneous metal structure with a smooth surface free of voids, cracks, notches, etc., improves the heat treating conditions and positively affects important gear characteristics, such as bending fatigue strength, endurance limit, impact strength, gear durability and gear life.

Medium and particularly high frequency have a tendency to overheat sharp corners; therefore, gear teeth should be reasonably chamfered if possible for optimum results in the heating process.

The first step in designing an induction gear heat treatment machine is to specify the required surface hardness and hardness profile (Ref. 1).

Insufficient hardness as well as an interrupted ("broken") hardness profile at tooth contact areas will shorten gear life due to poor load carrying capacity, premature wear, tooth bending fatigue, rolling contact fatigue, pitting, spalling and can even result in some plastic deformation of the teeth (Refs. 5, 6).

A through-hardened gear tooth with a hardness exceeding 62 HRC is typically too brittle and will often experience a premature fracture. Hardened case depth should be adequate to provide the required gear tooth properties.

Figure 2 shows examples of some induction hardening patterns. An evaluation of those patterns and their effect on gear load carrying capacity and life is discussed in Reference 1.

Coil Design and Heat Mode

Depending upon the required hardness pattern and tooth

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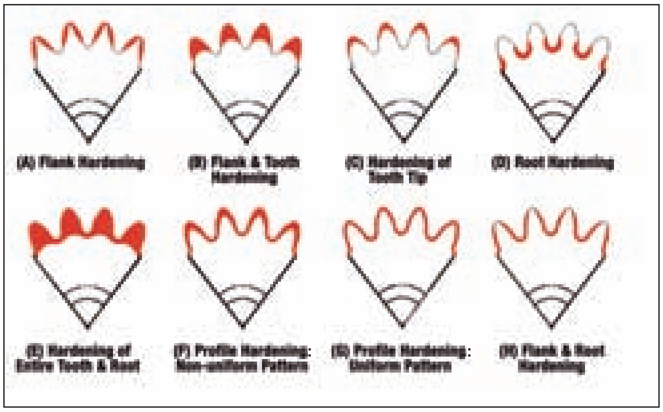

Figure 2—Induction hardening patterns.

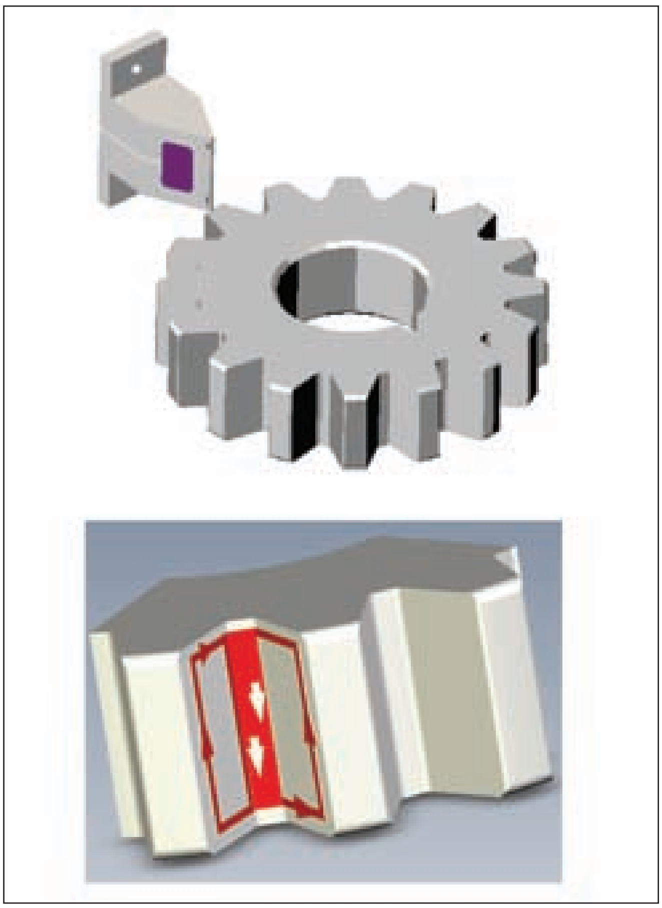

Figure 3—Gap-by-gap induction hardening.

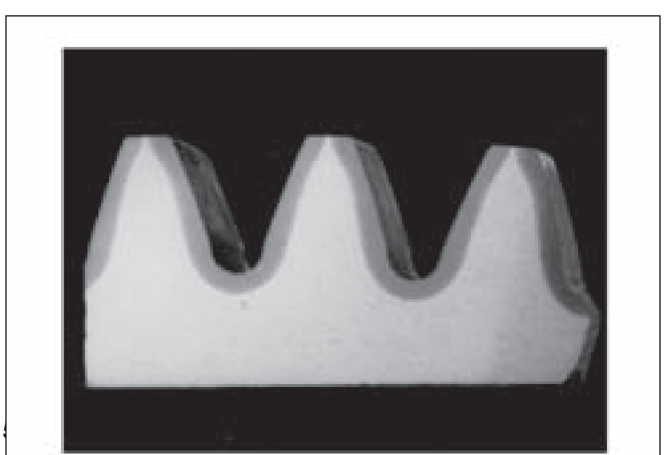

Figure 4—Typical gap-by-gap hardness pattern.

geometry, gears are induction hardened by encircling the whole gear with a coil (so-called "spin hardening of gears") or, for larger gears, heating them tooth-by-tooth with either gap-by-gap or tip-by-tip hardening (Refs. 1–4).

Tooth-by-tooth techniques—tip-by-tip and gap-by-gap hardening. These techniques can be applied using either a single-shot mode (the entire tooth or gap all at once) or by scanning. Scanning rates can be quite high, reaching 15" per minute and even higher. Both tip-by-tip and gap-by-gap techniques are typically not very suitable for small- and fine-pitch gears (modules smaller than 6).

Coil geometry depends upon the shape of the teeth and the required hardness pattern. For the tip-by-tip technique, an inductor encircles the body of a single tooth or is located around it. Such an inductor design provides patterns B and C (Fig. 2). At present time, this technique is used only for a limited number of applications.

The gap-by-gap technique is much more popular than the tip-by-tip concept. It requires the inductor to be symmetrically located between two flanks of adjacent teeth (Fig. 3). Inductors can be designed to heat only the root and/or flank of the tooth, leaving the tip and tooth core soft, tough and ductile (Fig. 4). There are many variations of coil designs applying these principles. Two of the most popular inductor designs are shown in Figure 5. Gap-by-gap inductor design was originally developed in the 1950s by the British firm Delapena.

As one can see from Figure 3, the path of the induced eddy current has a butterfly-shaped loop. The maximum current density is located in the tooth root area (the center part of the butterfly).

In most applications, the root is the most critical area of a gear because that is where the maximum concentrations of both residual and applied stresses occur. As a result, fatigue cracks and distortion occur primarily in the root area. In order to provide required heating/hardening of the root area, it is necessary to compensate a "cold sink" effect there. There is a significantly larger mass of un-heated ("cold") steel located under the gear root compared to the tooth tip or the base circle. Therefore, in order to provide a uniform heating, it is necessary to compensate an appreciable cooling effect that takes place due to thermal conduction of the massive sub-root region. A "butterfly-type" eddy current pattern does just that, allowing substantial increase of the heat sources in the gear root region and partially compensating a "cold sink" effect.

In order to further increase the power density induced in the root, a magnetic flux concentrator is applied. A stock of laminations or powder based magnetic materials is typically used as flux concentrators here. Laminations are oriented across the gap. The phenomenon of magnetic flux concentration is discussed in Reference 1.

Although the eddy current path has a butterfly shape, when combined with a scanning mode, the temperature is distributed within gear roots and flanks quite uniformly. At the same time, since the eddy current makes a return path through the flank and, particularly through the tooth tip, proper care should be taken to prevent overheating the tooth tip. Inductor design peculiarities and application of Faraday rings help to avoid overheating.

Gears heat treated by using the gap-by-gap techniques can be fairly large, having outside diameters of 100" or more, and can weigh several tons. This technique can be applied to external and internal gears and pinions. However, there is a limitation to applying this method for hardening internal gears. Typically, it is required that the internal diameter of the gear exceed 8" and, in some cases, 10" or more.

Both tip-by-tip and gap-by-gap hardening are time-consuming processes with low production rates. Power requirements for these techniques are usually relatively low and depend upon the production rate, type of steel, case depth and tooth geometry. Modest power requirements can be considered an advantage, because if spin hardening is used for large gears, it could require a substantial amount of power that can diminish the cost-effectiveness of the hardening.

Applied frequencies are usually in the range of 1–30 kHz. At the same time, there are some cases when a frequency of 70 kHz and even as high as a radio frequency of 450 kHz are used.

Pattern uniformity is quite sensitive to coil positioning and its symmetrical location in a gap between two teeth. Non-symmetrical coil positioning results in a non-uniform hardness pattern. For example, an increase in the inductor-to-gear air gap on one side will result in a reduction of hardness and shallower case depth there. Shallow case depth can diminish the bending fatigue strength of the gear. Excessive wear of the working (contacting) side of the gear tooth can also occur.

Inappropriate reduction of the air gap can result in local overheating or even melting of the gear surface. Some arcing can occur between the inductor and the gear surface. Precise inductor fabrication techniques, inductor rigidity and careful alignment are required. Special locators are often used to ensure proper inductor positioning in the tooth space. Thermal expansion of metal during heating should be taken into consideration when determining the proper inductor-to-gear tooth air gap.

There can be an appreciable shape/size distortion when applying gap-by-gap technique (Refs. 1, 6). Shape distortion is particularly noticeable in the last heating position. The last tooth can be pushed out 0.1–0.3 mm. In some cases, hardening every second tooth or tooth gap can also minimize distortion. Obviously, this will require two revolutions to harden the entire gear. Therefore, final grinding is often required. There is a linear relationship between the volume of required metal removal and grinding time.

Both carburizing and nitriding operations require soaking of gears for many hours (in some cases up to 30 hours or longer) at temperatures of 850ºC to 950ºC. At these temperatures the large masses of metal expand to a much greater extent compared to a case when only the gear surface layer is heated. The expansion of a large mass of metal during heating/soaking and its contraction during cooling/quenching after carburizing results in much greater gear shape distortion compared to the distortion after induction hardening.

In addition, large gears being held at temperatures of 850ºC to 950ºC for many hours have little rigidity; therefore they can sag and have a tendency to follow the movement of their supporting structures during soaking and handling. During induction hardening, areas unaffected by heat serve as shape stabilizers and lead to lower, more predictable distortion.

However, due to small inductor-to-gear air gaps (0.5–1.5 mm) and harsh working conditions, these inductors require

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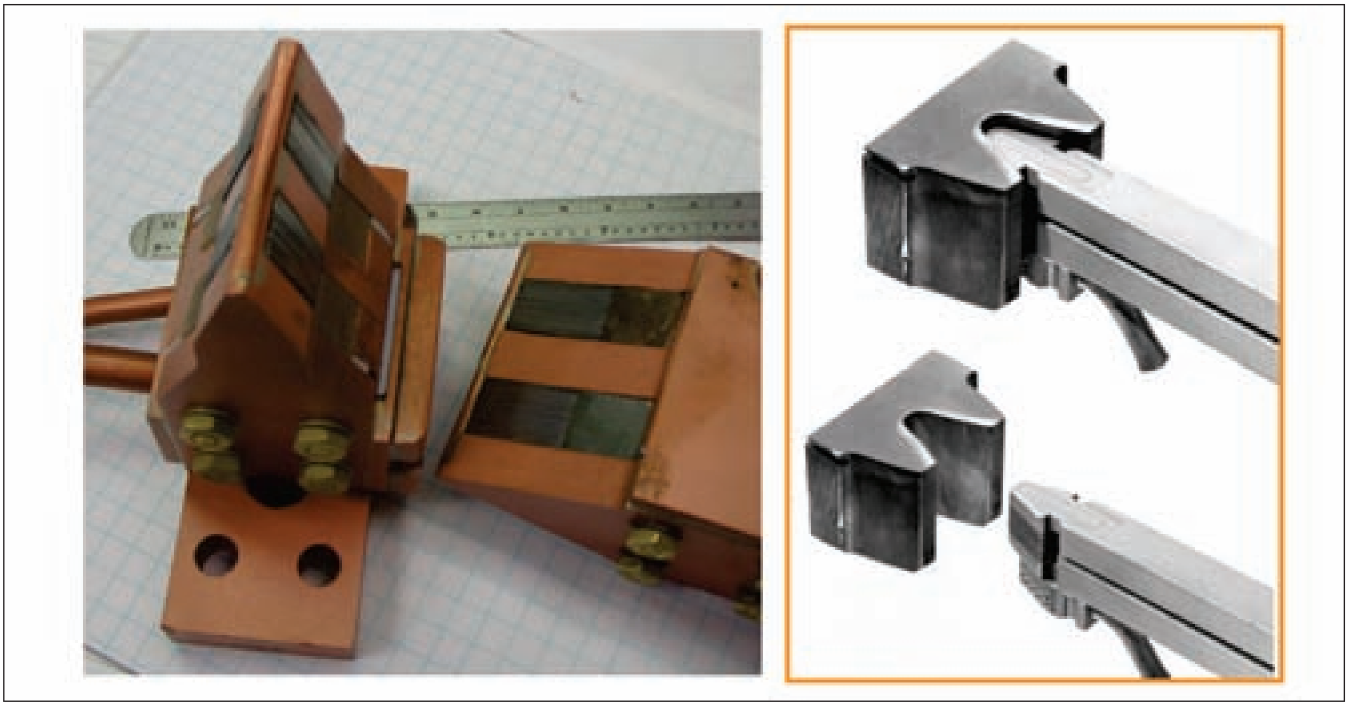

Figure 5—Gap-by-gap inductors.

intensive maintenance and have shorter life compared to inductors that encircle the gear.

Inductor copper overheating is one of the most common causes of gap-by-gap coil failure. Improper design and relatively small required inductor-to-gear gaps can lead to appreciable thermal radiation from the heated surface. This factor in combination with a limited space allowed for water cooling of the inductor can result in copper overheating, particularly when the scanning mode is used for hardening.

The gap-by-gap technique can be used in submerged hardening, where the gear is submerged in a temperature-controlled tank of quenchant. This was the basis of the original Delapena induction gear hardening process. In this method, quenching is practically instantaneous and both controllability and repeatability of the hardness pattern as well as shape stability are improved, although extra power is required. In addition, the quenchant doubles as an inductor coolant, eliminating overheating of inductor copper. In many cases of submerged hardening, an inductor does not have to be water-cooled.

Generally speaking, submerged techniques can be used in tip-by-tip hardening as well. However, as discussed above, there are a very limited number of applications requiring patterns produced by the tip-by-tip method.

Inductor failure can also be related to flux concentrator degradation (Refs. 8, 9). Laminations are exposed to harsh working conditions that could lead to their premature failure:

- High electrical currents and small space available for flux concentrators result in high power densities that could lead to a magnetic saturation of laminations and their overheating (Figure 6). The corners and end-faces of laminations tend to overheat due to electromagnetic end and edge effects (Ref. 1). Special lamination design features can be incorporated to reduce the risk of overheating.
- Laminations are sensitive to aggressive environments such as quenchants. Rust and degradation can result.

Understanding of the subtleties of tooth-by-tooth hardening allows avoiding unpleasant surprises related to premature inductor failures and allows the design of repeatable and long-lasting inductors.

When developing gap-by-gap hardening, particular attention should be paid to electromagnetic end/edge effects and the ability to provide the required pattern in the gear face areas (gear ends) as well as along the tooth perimeter.

When a single-shot mode is used, an active coil length has approximately the same length as the gear width. A single-shot mode is more limited in providing a uniform face-to-face hardness pattern compared to scanning mode.

When applying the scanning mode for hardening gears with wide teeth, two techniques can be used. The first technique represents a design concept where the inductor is stationary and the gear is moveable. The second concept assumes that the gear is stationary and the inductor is moveable.

For the scanning mode, the inductor length is typically at least two times shorter than the gear thickness. In order to obtain the required face-to-face temperature uniformity, it is necessary to use a complex control algorithm: "Power and Scan Rate vs. Inductor Position." A short dwell at the initial and final stages of inductor travel is often used. Thanks to preheating due to thermal conductivity, the dwell at the end of the heat cycle is usually shorter, compared to the dwell at the beginning of travel.

Undesirable Tempering Back

One typical concern when applying tip-by-tip or, in particular, gap-by-gap hardening techniques is the problem of undesirable heating of the areas adjacent to the hardened area (tempering back). Concern of a tempering back is particularly pronounced for Patterns A, D and I when using gap-by-gap hardening (Fig. 7a). There are two main reasons why an undesirable tempering back can take place (Ref. 1).

The first reason deals with the external magnetic field coupling phenomena of the inductor. The application of magnetic flux concentrators to the inductor results in a drastic reduction of the external magnetic field. In cases with medium-sized tooth gaps, the allocation of concentrators can be difficult due to space limitations. Applying thin copper shields can also reduce the undesirable heating of adjacent teeth.

The second reason deals with thermal conductivity phenomena. Heat is transferred by thermal conduction from a high-temperature region of the gear towards a lower-temperature region. According to Fourier's law, the rate of heat transfer is proportional to the temperature difference and the value of thermal conductivity. Most metals have relatively good thermal conductivity. During hardening, the surface temperature reaches a relatively high value and exceeds the critical temperature A_{c3}. Therefore, when heating one side of the tooth, there is a danger that the opposite side of the gear tooth will be heated by thermal conductivity to an inappropriately high temperature, which will result in undesirable tempering back of previously hardened areas.

Whether a hardened side of a tooth will in fact be softened due to tempering back depends upon the applied frequency, gear module, tooth shape, heat time and hardness case depth. In the case of shallow and moderate case depth and large teeth, the root of the tooth, its fillet and bottom of the tooth flank are typically not overheated due to a thermal conductivity. The massive area below the tooth root serves as a heat sink, which helps to conduct excessive heat and protects the hardened side of the tooth from tempering back.

Conversely, the tooth tip and top of the tooth flank can be considered "troubled areas" as far as tempering back is concerned (Fig. 7a). This takes place because there is a relatively small mass of metal at the tooth tip. In addition, heat has a short distance to travel from one (heating) side to the other (already hardened) side of the tooth.

In order to overcome the problem of tempering back, additional cooling blocks can be used. Additional cooling protects already hardened areas while heating unhardened areas of the gear (Fig. 7b). Even though external cooling is applied, depending on the tooth shape and process parameters, there still may be some unavoidable tempering back. This tempering back is typically insignificant and acceptable.

If submerge hardening is used, the fact that a gear is submerged in quenchant helps to prevent tempering back problems as well.

Conclusions

Induction hardening of gears is an important heat treating technique that can be applied to a wide range of gears and other parts, especially internal and external spur, helical and bevel gears, allowing manufacturers precise control over case depth and microstructure for increased load carrying capacity and other properties.

For best results in induction hardening, manufacturers must ensure the proper initial condition of the gear material, including chemical composition and microstructure.

Tooth-by-tooth (tip-by-tip and gap-by-gap) methods are often used for larger gears. The methods were described, along with various process and inductor design subtleties.

Part II of this article, which will appear next issue, will discuss spin-hardening of gears and gear-like components, in which the inductor coil encircles the gear. Part II will also cover various process concepts that can be employed with spin hardening.

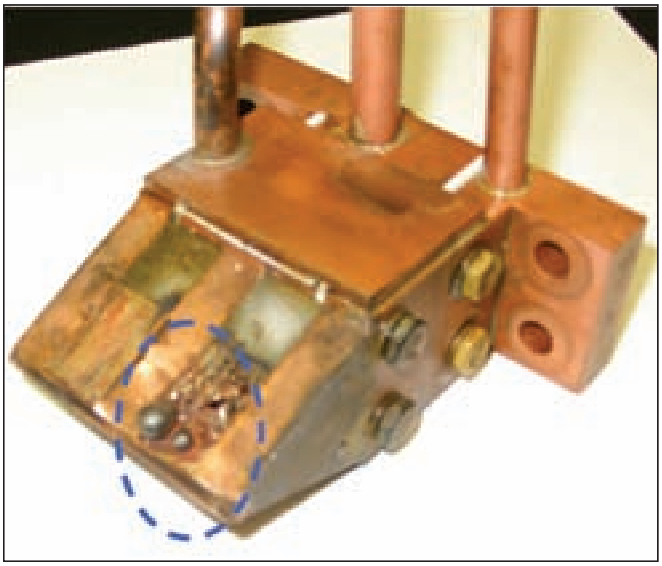

Figure 6—Typical coil failure of a gap-by-gap inductor.

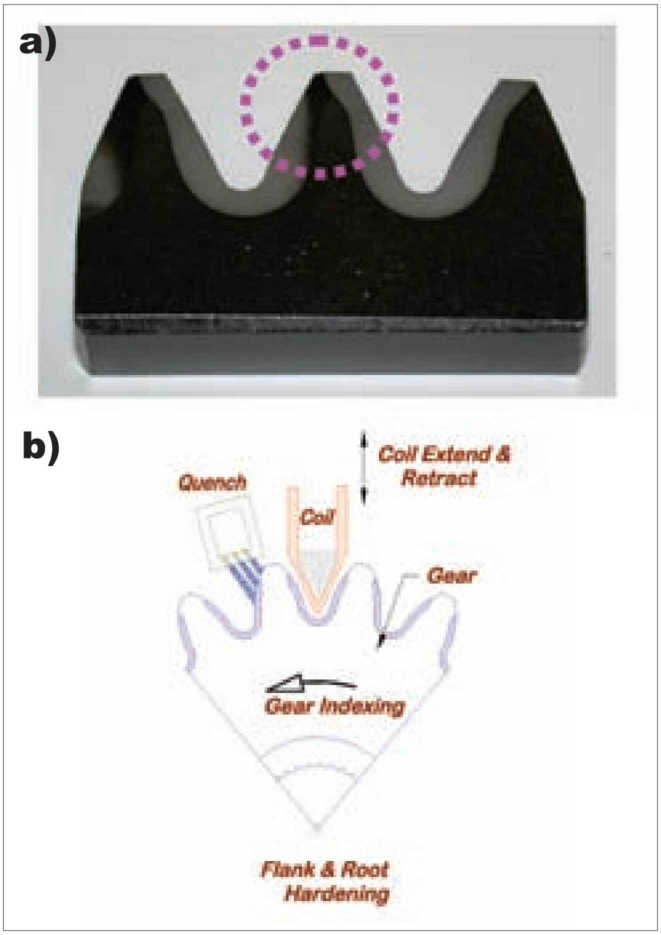

Figure 7—Tempering back effect and its control. a) Undesirable tempering back; b) To overcome undesirable tempering back of previously hardened tooth, cooling blocks are added.

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Innovative Analysis and Documentation of Gear Test Results

Pavel Žák and Vojtěch Dynybyl

Management Summary

In this paper, a method is presented for analyzing and documenting the pitting failure of spur and helical gears through digital photography and automatic computerized evaluation of the damaged tooth flank surface. The authors have developed an accurate, cost-effective testing procedure that provides an alternative to vibration analysis or oil debris methods commonly used in conjunction with similar test-rig programs.

Introduction

Modern industrial gearboxes often use nonstandard gear profiles to achieve reduced vibration and noise and to extend gear life. In this study, gearboxes and gear tooth designs were developed using the finite element method to predict gearbox deformations, shaft deflections and gear tooth deflections. Tooth profiles were optimized by simulation of gear mesh rotation, taking into account the aforementioned deformations and deflections.

To verify the design, a universal experimental test stand was developed. The test stand was designed for shortened gear life, and tests were run for more than 2 million cycles. Factors analyzed included vibrations, torque and temperature, and the optimized gears were compared against samples designed using the DIN 3990 standard, method B.

After failing to develop a precise, time-saving and inexpensive method for confirming gear damage evaluation using various vibration methods (Refs. 1–2), a new method was developed based on visual analysis of the tooth surface.

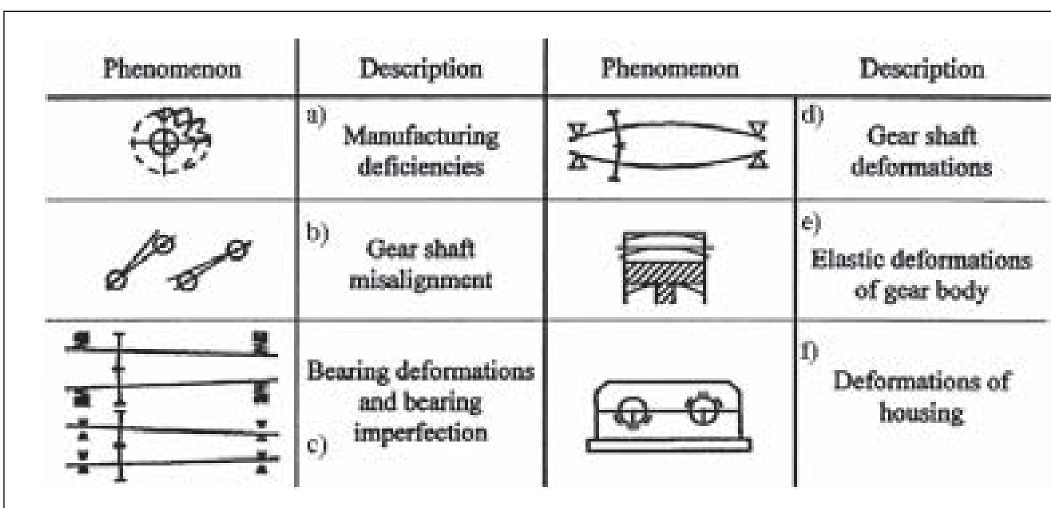

Figure 1—Main causes for the deviation of gear contact from the ideal line (Ref. 3).

Gear Design Methodology

Initial conditions. Gearbox design and structure generally include shafts, gearwheels and bearings. All of these components have in their manufacture a defined, geometrical shape, which in turn influences the final three-dimensional position of the gearing.

Various geometric factors, including manufacturing deficiencies and tolerances of the bearings, shaft and housing can affect the positioning of gear teeth (Fig. 1). Every component has a specific stiffness, and its shape changes when a load is applied. The shaft (Fig. 1d) and gearbox (Fig. 1f) have considerable influence on the calculation procedure, as they can have the greatest effect on gear tooth contact. Although deformations in the bearings (Fig. 1c) and gear teeth (Fig. 1e) are less significant, they also must be considered.

In every mechanism where power is transmitted, mechanical loss changes to heat, which influences the structure and spatial configuration. Most affected by heat is the gearbox housing (Fig. 1f), but it is not the sole area warranting inspection; the whole system should be taken into account.

Design procedure. A modeling and calculating procedure (Fig. 2) derives from the possibility of partial task separation. Output parameters taken from previous steps can be used as next-step input parameters. Furthermore, those results can be incorporated into previous steps with the aim of design optimization. This method is presented in five separate steps in order to better accommodate user-friendly software.

1. *Calculation of gearbox housing deformations*. FEM mesh comes from CAD design, but actual manufactured dimensions are included. This mesh is virtually loaded by external forces created by reactions in bearing houses and force reactions from connection to ground frame. Also, deformations are influenced by the heat dilatation of the housing material. Calculation results are point positions, which characterize shaft positions.

2. *Calculation of shaft deformations*. The positions of shaft support points, calculated in Step 1, are used as input parameters. Another input is FEM mesh with respect to manufactured dimensions. The shaft mesh is virtually loaded by external forces supplied via gear meshing reactions. Calculation results are point positions, which characterize the position of shafts. The result is a spatial configuration of shafts.

3. *Calculation of gear deformations*. In this step, the gear and gear tooth deformations are calculated. The gear geometry and shaft positions are included in the calculation.

4. *Profile optimizing*. Simulation of gear mesh rotation is a part of this step. Mesh rotation is accomplished by rotation of the deformed gear on the deformed shaft. With the constant pressure method or spatial volume collision method, the modified tooth profiles

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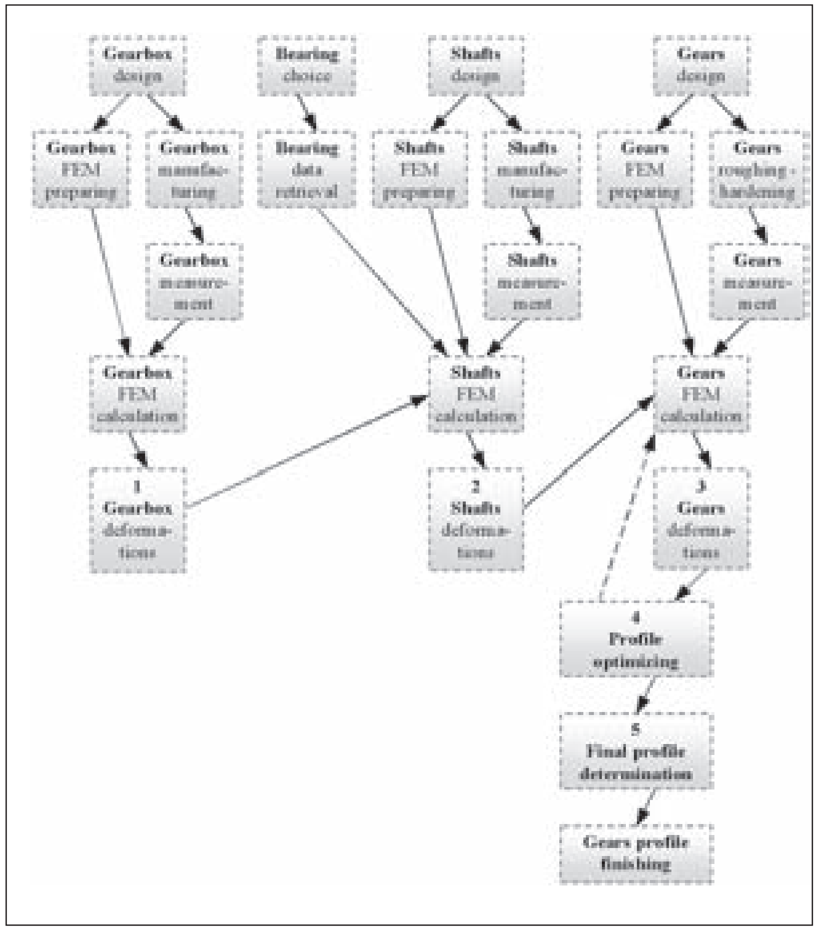

Figure 2—Methodology of gear design.

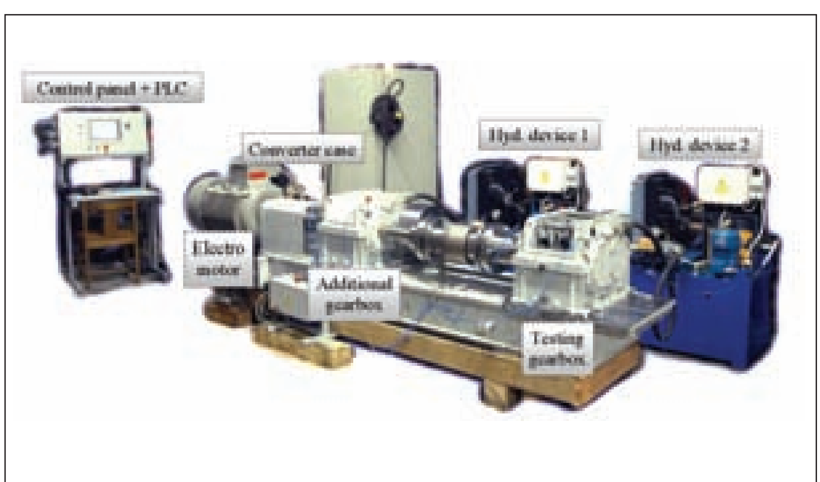

Figure 3—Photo of the complete experimental test rig.

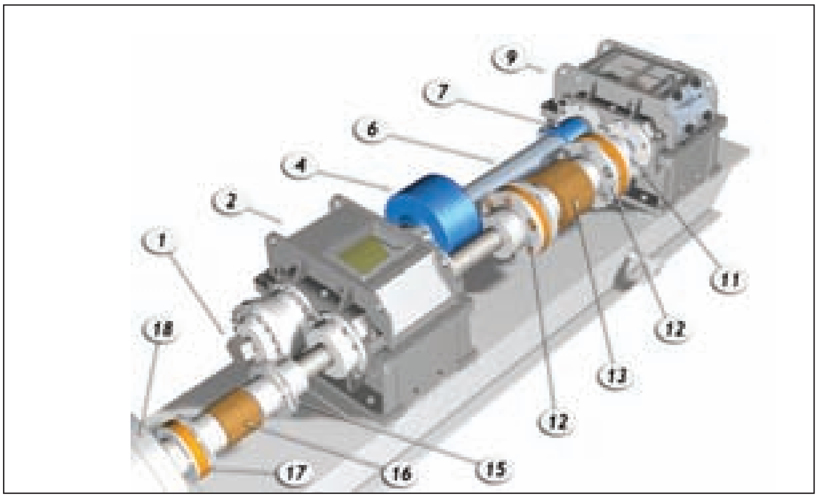

Figure 4—Visualization of test circuit (Ref. 5).

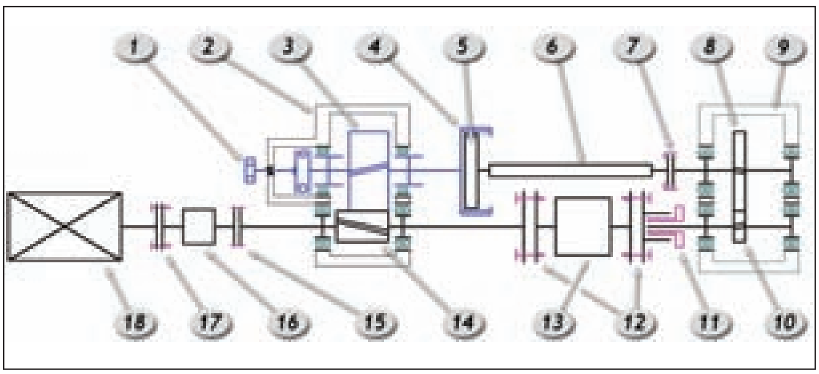

Figure 5—Schema of test circuit (Ref. 5).

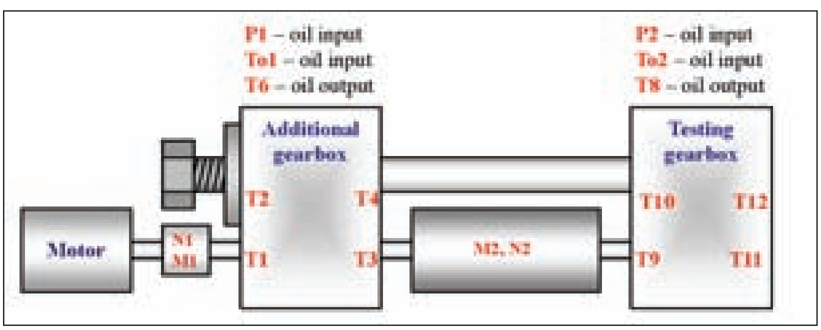

Figure 6—Placement of sensors.

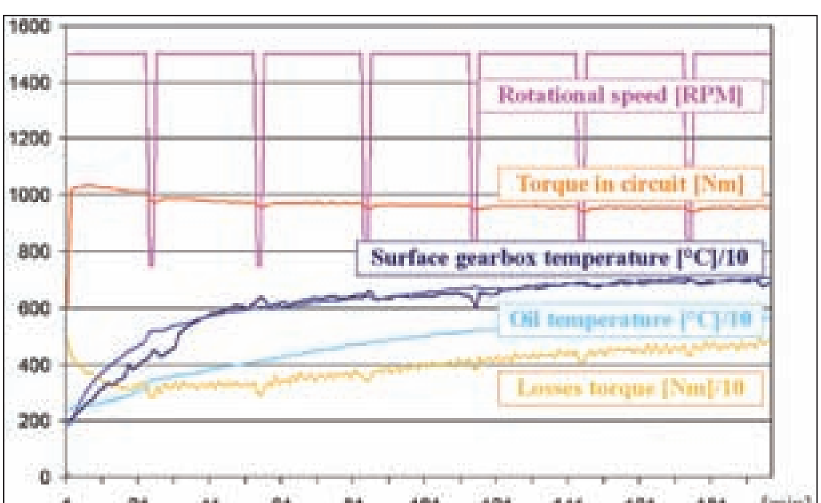

Figure 7—Illustrating test diagram.

are determined and ready for repeating of gear deformation calculations.

5. *Final profile determination*. Upon satisfactory results, the profile is converted to practicable technology for gear finishing, keeping in mind the corresponding tolerances.

Description of Experimental Stand

Niemann's back-to-back circuit is more energy-efficient than open loop. The testing circuit consists of measuring and additional gearboxes, driving motor, loading equipment, and sensors of torque, rotational speed, vibration and temperature. The torque in the circuit is established during stand operation. The test-rig is adjusted for possibility of geometry change for testing of pitting and tooth bending.

Testing conditions of gears and their assembly should be similar to actual operational conditions. To reduce testing duration, it is necessary to select a higher torque than would be used in industrial operation. In our case, we are limited by the torque sensor in the circuit, which allows torque up to 5,000 Nm. At 1,500 rpm, the circuit is dimensioned for maximum virtual power of 785 kW. Testing is mostly run on one load level for better results comparison. The complete test-rig with PLC, control panel, converter and hydraulic devices is shown in Figure 3. A schematic of the back-to-back circuit is shown in Figure 4, with a description of important elements in Figure 5.

Circuit loading equipment. Loading equipment must ensure readily available torque in the circuit, which is realized by axial movement of the gearwheel (Fig. 5, Pos. 3) with a helical gear in mesh with the pinion in the additional gearbox (Fig. 5, Pos. 14). This system is similar to that used at the NASA Glenn Research Center Spiral Bevel Gear Facility (Ref. 4). The tensioning screw gives rise to axial force that causes reaction (tangential force) in the gearing.

The tensioning screw moves the gearwheel that is fixed to the additional gearbox's low-speed shaft through an axial bearing. Axial freedom of movement occurs in the radial bearing with a long, nonstandard inner ring and in the gear coupling (Fig. 5, Pos. 4–5). The gear coupling is designed with a large diameter in order to decrease friction and contact stress among coupling teeth. At maximum torque, the axial force at the screw can be greater than 50,000 kN. This force is caused by friction between moveable contact surfaces.

It is possible to preset or slightly correct the torque to the demanded value during the running period. The driving motor (Fig. 5, Pos. 18) is controlled by a frequency converter and only serves to provide for lost circuit power. The motor must be dimensioned for high running-up power.

Torque sensors and other circuit parts. Power losses and virtual power in the circuit during running are recorded by two rotational speed sensors and two torque sensors (Fig. 5, Pos. 13 and Pos. 16). As there is no live observation during the testing, an overload safety is needed. Torque sensors are mechanically secured against overload. Tooth root break can occur during testing of tooth bending fatigue, and the inertia moment can exceed the torque sensor's permissible overload during an unexpected gear failure. Maximum overload is 150% of nominal torque.

Breakable screws, which are parallel with the coupling axis, are used for security against torque sensor damage. The test gearbox is divided in two parts for easier test gear change. A coupling of involute splines (Fig. 5, Pos. 7) and ETP-Techno coupling (Fig. 5, Pos. 11) is used for securing the simple connection of the gearbox to the circuit.

Automation of Control and Measurement Data Storage

Process loading of gearwheels. The process load used for testing is determined by the expected gear loading during its expected lifetime. It consists of different limited time periods, according to these operating phases: run-up, steady regime, braking, run-out, idle regime, overloading, etc. The loading regime has to be determined in advance, with specific torque and rotation speeds for set periods of time. To control these actions, automation is needed.

For controlling rotation speed, we used a motor converter controlled by PLC. As mentioned, the torque in the circuit (Fig. 6 - M2) can be changed during operation by the axial screw. Although the authors used a wrench to adjust the axial screw, the design of the device allows for an automatic solution using an additional PLC-controlled motor and worm gearbox.

At the start of the test, it is possible to set up desired automatic periods through the use of a touch screen interface.

Measurements of global values. Measurement of torque (Fig. 6 - M1, M2), rotational

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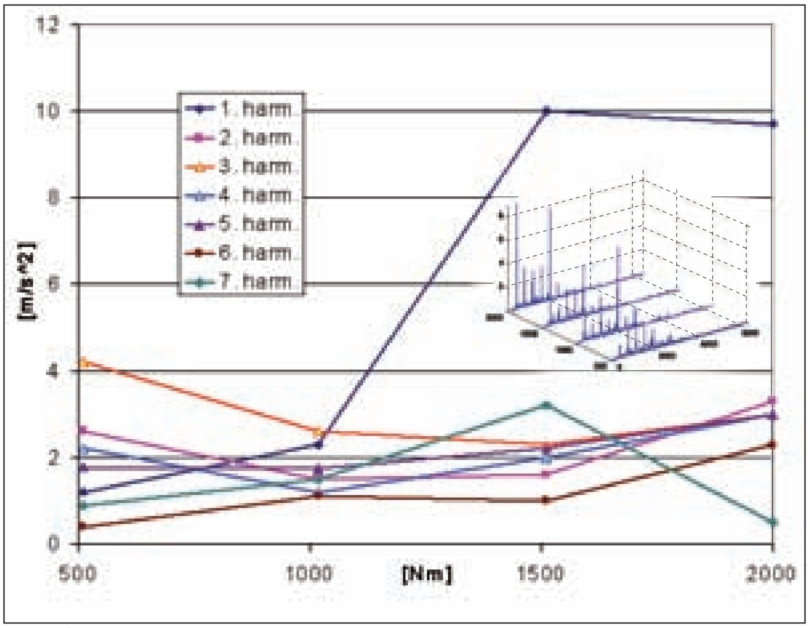

Figure 8—Relation between vibrations and moment in circuit.

Figure 9—Scuffing.

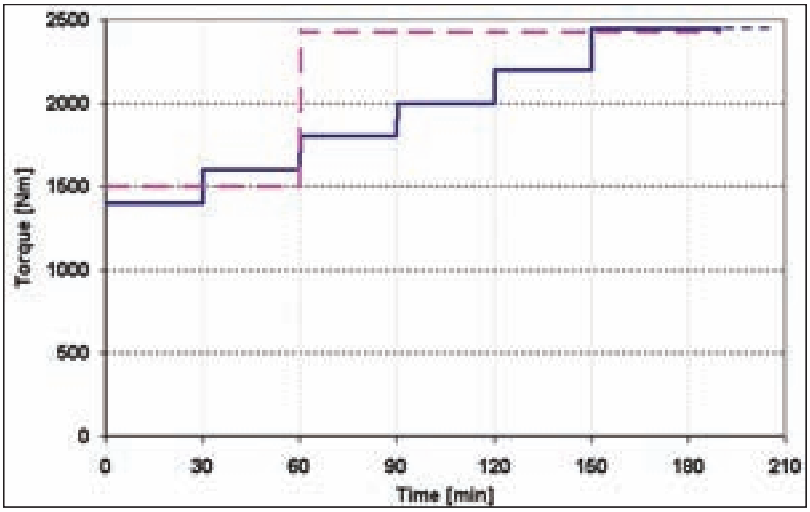

Figure 10—Two types of gear run-in.

speed (N1, N2), temperature and oil pressure (P1, P2) can be considered as global values.

The torque scanning between motor and additional gearbox (M1) is used for determining the whole circuit efficiency. This value corresponds to losses in gear assembly, bearings, coupling, etc.

Fourteen thermocouples are incorporated with the test stand, with four of them used for measurement of oil temperature in the input and output (To1, To2, T6 and T8). These values are needed for the calculation of oil heat transfer; the remaining thermocouples are magnetically fixed near the bearings.

Measured data transferred by transducers are processed by PLC, shown on a control panel screen and saved into flash memory. The PLC system also assesses adjusted value limits and, in case of its overrun, stops test processing. A good deal of important information on tested gears is provided by the measured data (Fig. 7).

Vibration diagnostic. It has been presumed that the application of spectral vibration analysis provides a primary indicator of pitting progress. Generated vibrations in the test gear mesh are transferred through the shaft and bearings to the gearbox, and they are measured on outer surfaces; the analyzer can be started by PLC.

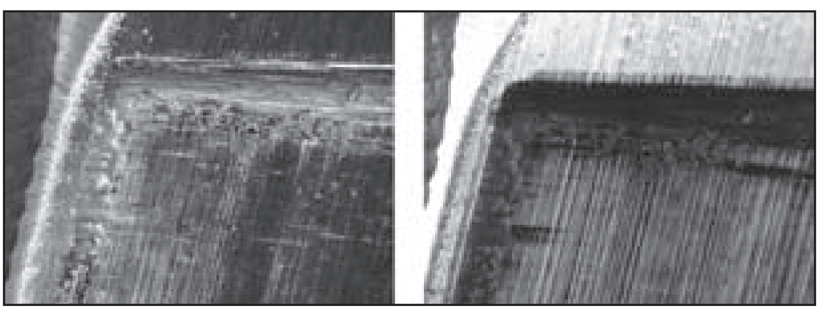

Figure 11—Comparison of two different lighting angles in picture of edge scuffing.

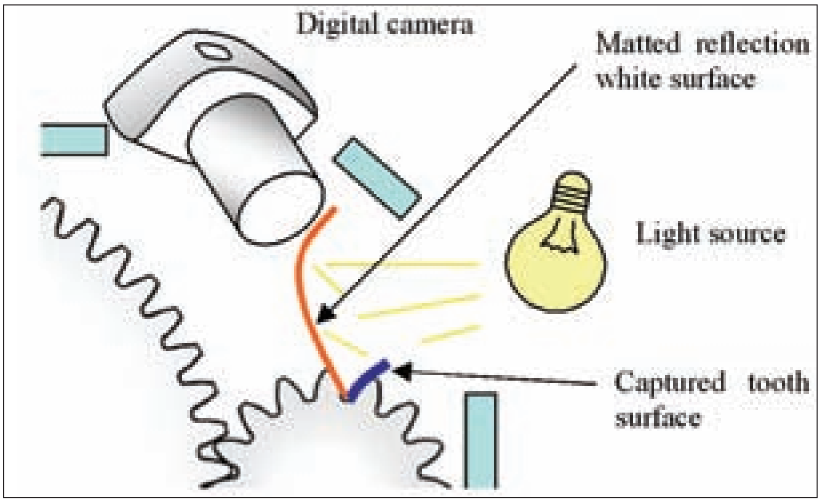

Figure 12—Suitable organization in pitting capture.

A great deal has been written (Refs. 1–2) concerning these issues. For that reason, only the diagram (Fig. 8) that originates from investigating of test rig behavior is presented.

Scuffing Problem

Scuffing occurred at the outset of testing (Fig. 9). As scuffing influences the pitting lifetime, its elimination was necessary.

Scuffing arises when certain conditions are influenced by size of tooth line load, tooth geometry, sliding, lubrication, temperature and other factors. Test requirements did not allow changes in oil, temperature, geometry or load, etc.; eventually, a way to eliminate scuffing was determined.

With each scuffing occurrence, duration and technique of gear run-in was registered. In Figure 10, the process of run-in loading is shown. The dashed line represents the gear run-in that was used for initial research tests. In those tests, the gear run-in took one hour at normal working load and then was immediately increased to full testing load. These tests experienced scuffing. The example of tooth with scuffing failure is in Figure 9a.

The second (solid) line in Figure 10 represents a longer, more gradual run-in. The load starts on the same level and then rises by 200 Nm every half-hour, up to load testing. This probably accounts for the peaks effacement and better meshing condition, as demonstrated in Figure 9b.

Flank Failure Evaluation

To determine the size and progress of flank damage, it is necessary to measure the damaged area objectively. In the past, the failure area was evaluated by use of a magnifying glass or macro-photography, which took too long. For that reason it has become necessary to find newer, faster and more modern methods. Vibration analysis methods may not be optimal for every application, and interpretation of results may not be exact.

Therefore the authors have developed a digital photographic method to monitor pitting expansion and pitting size, micro-pitting and scuffing failure. Its main advantages are low cost and quick turnaround.

By choosing a suitable optical system, it is possible to make an enlargement 1:200 at little cost. A disadvantage of high magnification can be a small depth and a small stop aperture setting. In order to provide maximum predictive ability, it is necessary to choose an optimal lighting angle. Two photographs of the same pinion tooth at different lighting angles are shown in Figure 11. On this gear we studied the effect of temperature on scuffing.

Photo Method for Pitting Evaluation

The method is based on the digital processing of captured tooth images.

Method technique:

- Capture of every tooth on analyzed gear
- Image files saved to directories with sample label and test time
- Program start
- Graphical evaluation

Pitting record. Pitting expansion can only be monitored if the exact distance, orientation, exposure and lighting conditions are maintained. Access openings on gearboxes must allow observation of the gear condition, picture taking and lighting; automatic evaluation is possible only with well-exposed pictures.

Generally, the capturing of a rounded metal surface, and particularly of a helical gear tooth surface, is very difficult; frequent burnouts or non-uniform lighting occur. A possible configuration is demonstrated in Figure 12.

The evaluation software developed by the authors assesses pixels with high contrast as damaged. It creates a summation of damaged and undamaged pixels and writes to a database. When an entire gear is captured and processed by the program, the database is ready to determine pitting evaluation.

Program for image processing. Except for image load, all program steps are automated, ensuring quality results. Even though the images are processed automatically, they can be graphically supervised by the operator (Fig. 13).

Image processing technique:

1. Image load.
2. Compensation of image deformation caused by lens optic. (Reference grading is needed.)
3. Horizontal and vertical tooth alignment.
4. Crop the tooth surrounding.
5. Image conversion to grayscale and automatic contrast and brightness change of tone curves. This step is adjusted for best pitting dimple recognition.
6. Detection of pitting dimple edges. The Sobel method (Ref. 6) is used. It returns edges at those points where the gradient of image is a maximum. Ignored are all edges that are not stronger than a value which is extracted from previous step. Calculation returns a binary image, with 1s where the function finds edges in image and 0s elsewhere.
7. Operations for dimple edge uniting. Controlled dilating, hole filling, image eroding, image border cleaning and removing of small objects are carried out.
8. Pits exterior boundaries trace.
9. Boundaries drawing into cropped original image (Fig. 13).
10. Pitting areas counting and area center positioning.
11. Save results in database.

Outputs. The main supervised output values are the total pitting damage area on one tooth A_{ij} counted in Equation (1a) and on the whole gear A_j (1b) where index j is the number of teeth and i is the number of pitting dimples. Those are required for lifetime determination. In the DIN 3990 standard, the determined value for one

continued

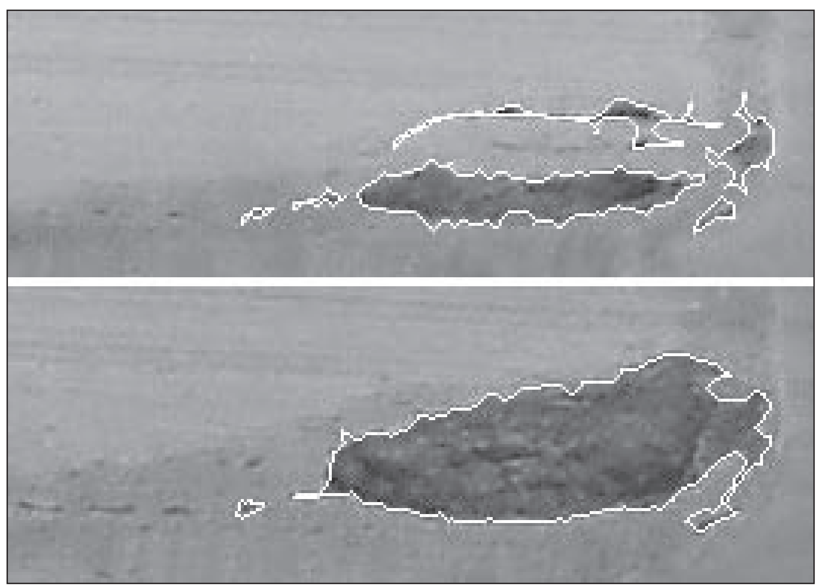

Figure 13—Example of program graphical results of two pitting stages on the same tooth.

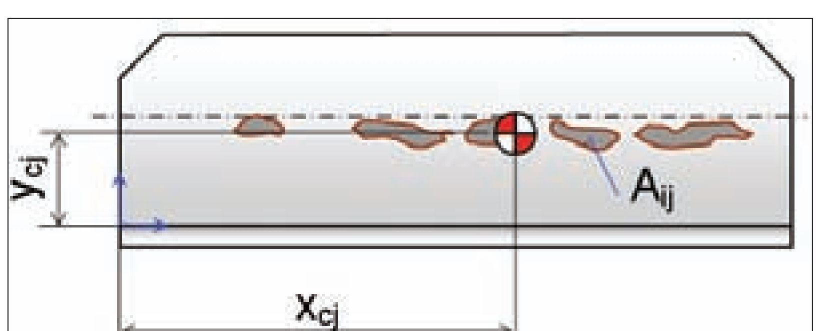

Figure 14—Center of total pitting area.

tooth is 4% surface failure of the tooth area on one tooth and 1% on the whole gear.

$$A_i = \sum A_{ij} \;,\; A = \sum A_i \qquad (1)$$

The next useful value is the center of the pitting area, which serves for assessment of transverse modification suitability. Values are obtained with Equation 2 that are described in Figure 14. Those values can be converted to a percentage figure.

$$x_{ci} = \frac{\sum A_{ij} \cdot x_{ij}}{A_i} \;,\; y_{ci} = \frac{\sum A_{ij} \cdot y_{ij}}{A_i} \qquad (2)$$

The relation between the total number of pitting dimples and their size can be expressed with a histogram.

Advantages and use. The method results are nearly exact thanks to direct measurement of the failure surface. By compliance with the aforesaid exposure demands, 6 megapixel camera and 50 mm tooth width, the resulting uncertainty is about 0.05 mm^2.

Counter to perceptions, gear photo documentation is not time-consuming. For example, photo preparation and taking pictures of a gear with 16 teeth takes five minutes. Image processing is done in two minutes if a modern computer and 6 megapixel pictures are used. Compare this to the film photography and magnifying glass methods (Ref. 7), which usually take more than half-an-hour and with less precision.

It is possible to obtain a number of time-divided results in whole lifetime; the results can be statistically evaluated and the trend of pitting dimple growth can be observed in every tooth. This method is very cost-effective in comparison to vibration analysis or oil debris mass (Ref. 8) methods. It is used for specific gear lifetime determination on fatigue surface failure. Comparison of vibration or oil debris gear damage detection methods applied to pitting damage with this method is offered. The photo pitting evaluation can be applied to spur and helical gears.

Conclusions

A gear design methodology was developed for use in the production of high-end industrial gearboxes. This method takes advantage of well-known manufactured dimensions, FEM analysis and non-standard gear profiles (especially tooth modifications).

An experimental test rig was used for testing the shortened lifetime of gears with various geometry, material and heat processing. Vibration and a newly developed photographic method were used for pitting evaluation. The developed photographic method is helpful in the evaluation of surface failures on helical and spur gears.

Acknowledgments

This work was supported by IGS CTU0711212 and MPO FT-TA2/017 grants.

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This article first appeared in the Proceedings of IMECE 2007, the 2007 ASME International Mechanical Engineering Congress and Exposition, Nov. 11-15, 2007, Seattle, WA.

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Lapping and Superfinishing Effects on Surface Finish of Hypoid Gears and Transmission Errors

Jack Masseth and Mohsen Kolivand

(*Proceedings of the ASME 2007 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, IDETC/CIE 2007 September 4–7, 2007, Las Vegas USA*)

Management Summary

This presentation is an expansion of a previous study (Ref.1) by the authors on lapping effects on surface finish and transmission errors. It documents the effects of the superfinishing process on hypoid gears, surface finish and transmission errors. There are several geometric and process parameters, besides offset, that affect hypoid gears' efficiency—spiral angle, pressure angle, lubricant type, temperature and surface finish serve as good examples. In this paper, a study on measurement of surface finish of both ring gear and pinion will be presented. Moreover, the effects of lapping and superfinishing on surface finish will be addressed. Surface finish measurements were done on several experimentally produced hypoid gear pairs. Results are shown of measurements taken before and after superfinishing.

Introduction

Hypoid gears are widely used in the automotive industry to transfer rotation between non-intersecting axes in rear-wheel drive and 4WD vehicles. Compared to other gear types (such as straight and spiral bevel gears) that are geometrically capable of transferring power between perpendicular axes, hypoid gears have more advantages that allow this type of bevel gear to dominate in automotive axle applications. In general, two basic, yet different, cutting processes are used to generate hypoid gears—face milling (FM, or single indexing) and face hobbing (FH, or continuous indexing)—which have their own advantages and disadvantages over each other. However, face hobbing is dominant in automotive industry applications, mostly because it requires shorter cutting time compared to face milling (Refs. 2–4). With hypoid gears' non-intersecting axes, a higher sliding velocity between contact surfaces exists; as a result, sliding friction is one of the main power loss sources, in addition to rolling friction. Therefore, hypoid gears lose considerably more mechanical power during gear mesh than intersecting types of bevel gears and are, as a result, less efficient. In a study on gear surface finish effects on friction (Ref. 5), by comparing frictional losses of conventionally ground (Ra = 0.4 μm) teeth with superfinished (Ra = 0.05 μm) teeth, it was shown that with the same load and speed, this surface finish improvement will decrease friction by around 30%, in addition to decreasing tooth surface temperature. Moreover, based on Xu's proposed model for hypoid gear efficiency prediction (Refs. 6–7), which uses an EHL model with contact data provided by an FEA-based modeling software (Ref. 9), and depending on lubricant temperature at inlet, a change in surface finish from Ra = 0.2 μm to Ra = 0.6 μm may decrease hypoid gear efficiency around 0.5%. As a result, improving surface finish can be one way to increase efficiency. In this study a set of measurements was done to see how superfinishing and lapping will change the surface finish of hypoid gear sets. The aim of this study is to investigate the effects of superfinishing and lapping on the surface finish of hypoid gears to gain insight into the effects of these processes on surface finish. Moreover, it will be experimentally shown how superfinishing and lapping may change transmission errors (up to the first two harmonics for lapping and the first harmonic for superfinishing).

First, the surface finish measurement procedure will be explained, followed by sample results of measurements using this procedure. In this study, superfinishing effects on surface finish and transmission errors will be explained as a complement to a previous study by the authors. This study will not cover theoretical issues related to this phenomenon (effects of superfinishing and lapping on surface finish and transmission errors) at this step. Rather, the goal here is to discuss the issue experimentally, with the hope that future experiments and theoretical studies will help in investigating the superfinishing and lapping effects in more detail.

Surface Finish Measurement Procedure/Hypoid Gears

The surface finish measurements were performed on nine hypoid gear sets before and after lapping. All gear sets were the same and had 11.5" outer diameter; their geometric parameters are as mentioned in Table 1. To measure surface finish, a CNC form-measuring machine (Fig. 1) equipped with *FormTracePack* software was used to analyze measured data to extract surface finish. Table 2 shows an example data sheet of surface finish measurement with several surface finish parameters—Ra, Ry, R_{zDIN}, etc.) and settings.

There are several measuring parameters which need to be set before beginning measurement that are mentioned in Table 2. The machine is equipped with both pinion and gear fixtures in order to keep parts securely in place while measurements are performed. The software is capable of removing surface curvature from data and calculating pure surface finish for curved surfaces. (It should be mentioned here that all measurements were done with 0.8 mm sample length [length of taking data cut-off]). Measuring the surface finish quality in different locations on gear and pinion shows

continued

Table 1. Hypoid Gear Set Geometric Parameters

Geometric parameters	Pinion	Gear
Number of teeth	11	41
Diametral Pitch	---	3.57"
Face width	2.13"	1.78"
Pinion offset	2.00"	
Shaft Angle	90°	
Outer cone distance	5.36"	6.46"
Pitch diameter	---	11.50"
Pitch angle	25D 23M	62D 50M
Mean spiral angle	49D 59M	27D 38M
Hand of spiral	LH	RH
Generation type	Generated	Non-Generated
Depthwise tooth taper	FH	

Figure 1—Form measuring machine setup.

Table 2. A Sample of Measurement Parameters

Parameter	Results	Parameter	Results
Ra	1.24255 μm	Rp	3.49220 μm
Ry	6.54780 μm	R_{zDIN}	6.54780 μm

Evaluate Condition List<<Profile=R – Section=[1]>>		Measurement Condition	
Standard	OLDMIX	Measurement Length	1.6mm
Kind of Profile	R	Column Escape	5.0mm
Smplg Length (lc)	0.8 mm	Auto-Leveling	Off
No of Smplg(nle)	1	Speed	0.0mm/s
Lc	0.8mm	Over Range	Abort
Kind of Filter	Gaussian	Pitch	0.5 μm
Evltn Length(lm(	0.8 mm	Machine	
Pre-Travel	0.4 mm	Detector	
Post-Travel	0.4 mm	Polar Reversal	Off
Smooth Connection	Off	Arm Compensation	Off
Mean Line Compensation	Off	Auto-Notch(+)	Off
		Compensation Method	Off

Table 3. Pinion surface finish (at center) before and after lapping for drive and coast sides

	Drive side				Coast side			
	Before Lapping		After Lapping		Before Lapping		After Lapping	
No.	Ra	R_{zDIN}	Ra	R_{zDIN}	Ra	R_{zDIN}	Ra	R_{zDIN}
1	0.53	3.78	1.88	15.0	2.75	12.92	1.79	12.24
2	1.52	10.4	1.47	11.8	2.30	18.24	2.37	15.71
3	1.35	5.23	1.59	9.54	2.18	16.69	1.93	11.58
4	1.26	9.35	1.31	10.1	1.86	9.07	1.63	10.13
5	1.88	8.54	1.21	7.61	2.11	13.98	1.78	12.39
6	1.92	7.10	1.03	8.09	2.34	14.50	1.66	12.29
7	0.56	3.13	1.00	9.49	1.48	10.47	1.72	12.23
8	1.40	7.87	0.97	9.46	2.42	13.27	1.93	16.04
9	1.48	10.2	1.44	11.6	1.84	15.02	1.77	11.30
Ave.	1.32	7.29	1.32	10.3	2.14	13.8	1.84	12.66
Var.	0.24	7.27	0.09	5.02	0.14	8.07	0.05	3.84

Table 4. Gear surface finish (at center) before and after lapping for drive and coast sides

	Drive side				Coast side			
	Before Lapping		After Lapping		Before Lapping		After Lapping	
No.	Ra	R_{zDIN}	Ra	R_{zDIN}	Ra	R_{zDIN}	Ra	R_{zDIN}
1	0.93	9.92	1.45	11.6	0.78	6.07	1.54	10.86
2	1.21	7.83	1.75	13.9	1.22	8.79	1.71	10.90
3	0.83	6.61	1.78	12.3	1.16	6.32	1.27	8.04
4	0.53	3.70	1.84	13.9	1.14	8.54	1.71	13.78
5	0.77	7.27	1.53	11.0	0.87	7.09	1.70	13.17
6	0.26	2.69	1.14	8.00	0.96	6.79	1.26	8.77
7	0.71	5.32	1.77	13.0	0.90	8.38	1.80	10.91
8	2.01	13.14	1.85	18.3	1.46	7.02	1.27	9.30
9	0.91	7.54	1.55	9.81	1.03	8.39	1.65	11.07
Ave.	0.907	7.113	1.629	12.4	1.06	7.49	1.55	10.76
Var.	0.93	9.92	1.45	11.6	0.04	1.08	0.05	3.57

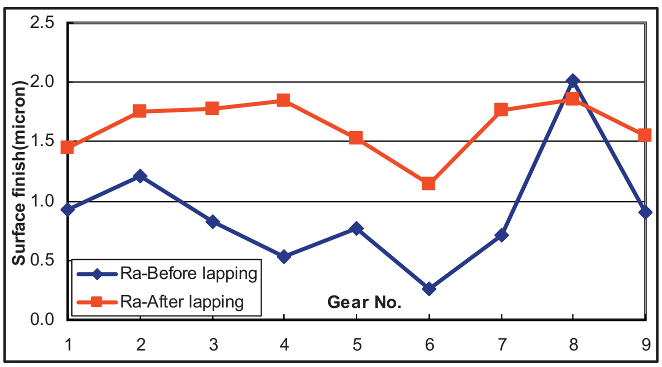

Figure 2—Gears drive side surface finish: before and after lapping (Ra).

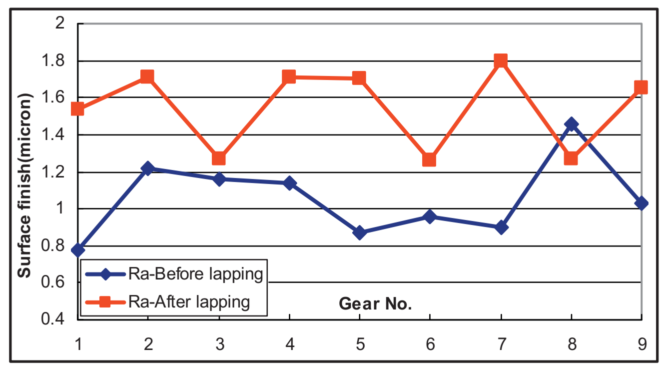

Figure 3—Gears coast side surface finish: before and after lapping (Ra).

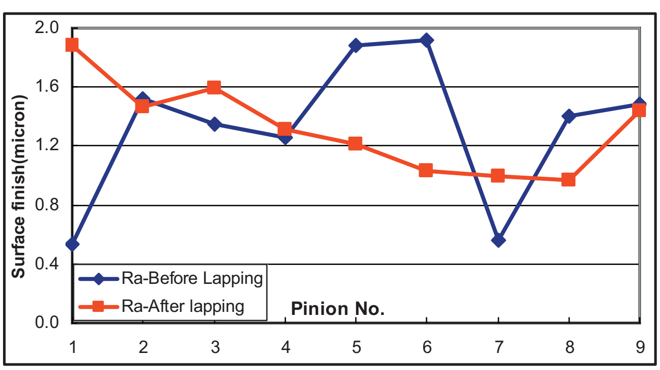

Figure 4—Pinions drive side surface finish: before and after lapping (Ra).

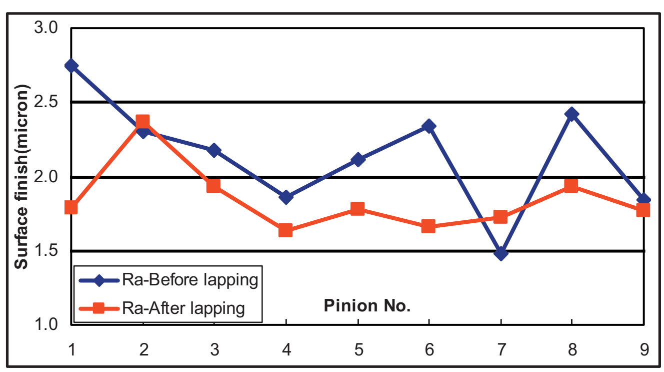

Figure 5—Pinions coast side surface finish: before and after lapping (Ra).

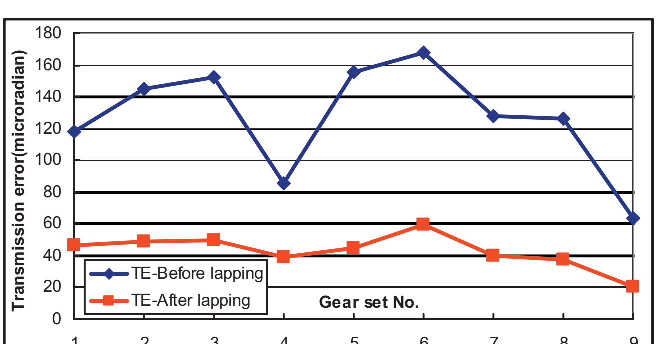

Figure 6—First-harmonic (drive side) transmission error.

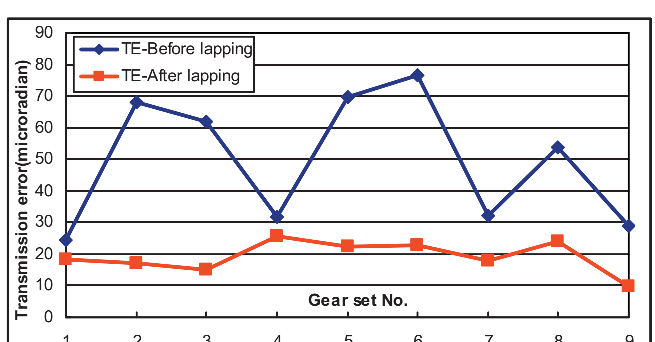

Figure 7—First-harmonic (coast side) transmission error.

that it varies considerably in both lengthwise and profile directions. To have consistent surface finish data to compare results before and after the lapping process, data should be taken from the same location on the flank, i.e., lengthwise (from toe to heel) and profile (from top to root) location of measuring spot should be consistent for all measurements.

In order to check the surface finish variation on pinion flank, a pinion surface was divided into nine regions—three divisions from toe to heel and three divisions from top to root—and surface finish was measured in the middle of each region. The results show that surface finish improves from top to middle and then worsens, continuing further to the root in the profile direction. In addition, the surface finish will improve from toe and heel toward the center (in lengthwise direction). Although it may not be a general rule, it is a consistent result for most of the measured pinions.

Lapping Effects on Surface Finish and Transmission Errors

Lapping is one of the processes used for gear finishing. While for many types of gears grinding may at times be economical—for bevel and hypoid gears, lapping is the most applicable and economical process (except for some aerospace applications). Lapping also smoothes the surface through increasing mesh between pinion and gear, which in turn serves to reduce noise levels (Refs. 3–4). As for hypoid gears in automotive applications, their large production volumes preclude grinding with currently available machine technology, thus making lapping the best choice.

The main advantage of lapping over grinding in large-volume production is that lapping requires less time and employs price-friendly machinery (Ref. 8). Depending on the hypoid gear geometry (especially the amount of offset), the sliding velocity and contact pressure will be changed during mesh cycle. As a result, sliding distance caused by the combination of sliding velocity and contact pressure on every contact point (or spot) results in surface wear. Therefore, the complex physical quantity of sliding distance on each surface point forms a surface wear distribution over the gear flank. To experimentally measure how much lapping will affect surface finish, some sets of experiments have been performed.

In order to check lapping effects on surface finish, a set of measurements was performed to evaluate surface finish (namely Ra and R_{zDIN}) on both gears and pinions. All measurements were done on the same area in all gears and pinions (at the center of lengthwise and profile directions). For all gear sets, the same lapping settings were used, and all were lapped with the same abrasive (silicon carbide) lapping compound. The lapping procedure was conducted under a light brake load, with about 10 Nm torque on the gear shaft, and pinion speed was kept at 2,300 rpm.

For all gears and pinions, measurements were performed on both drive and coast sides before and after lapping. The results in each of these four sets—Pinion/Drive, Pinion/Coast, Gear/Drive and Gear/Coast sides—are shown in Tables 3 and 4 (all measurements were performed on the same tooth).

Moreover, the average and variation of each column of data are shown at the end of Tables 3 and 4. To have a graphical view of the surface finish changes by lapping, the measurement results for the gear drive and coast sides before and after lapping are seen in Figures 2 and 3. As is shown, the surface finish of all gears is higher (rougher) after lapping, when compared to before lapping. In addition, surface finish changes for the drive and coast sides of the pinion before and after lapping are shown in Figures 4 and 5. In these graphs, Ra was used; however, R_{zDIN} also was measured (see Tables 3 and 4) and the same trend was observed. As for the

continued

Table 5. Transmission Errors: (first, second and third harmonics) for drive side before and after lapping

	Transmission Errors							
	Drive side				Coast side			
	Before Lapping		After Lapping		Before Lapping		After Lapping	
No.	DM01	DM02	DM01	DM02	DM01	DM02	DM01	DM02
1	118	14.7	46.83	9.51	24.4	8.44	18.35	3.71
2	145	13.7	48.94	8.63	68	16.9	17.29	6.34
3	153	11.5	49.4	7.72	62	12.1	15.21	4.14
4	85.9	10.1	38.97	7.22	31.8	12.1	25.68	6.14
5	155	15.3	44.93	8.74	69.8	10.5	22.21	2.5
6	167	10.7	59.8	11	76.8	9.63	22.7	3.2
7	128	15.1	40.05	8.47	32.3	26.8	17.88	7.14
8	126	17.7	37.82	7.38	53.6	9.57	24.2	4.07
9	63.6	15.4	20.04	3.09	29	11.4	9.61	1.54
Ave	126.9	13.78	42.98	7.97	49.74	13.04	19.24	4.31

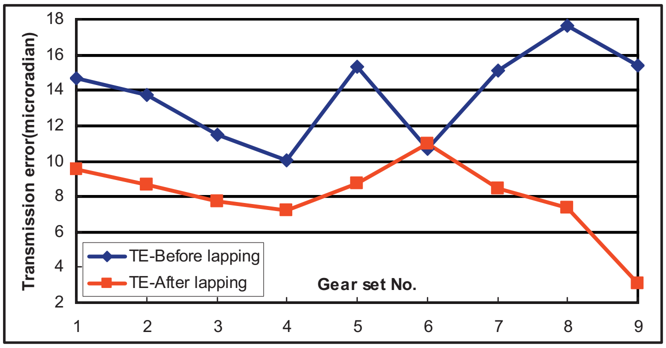

Figure 8—Second-harmonic (drive side) transmission error.

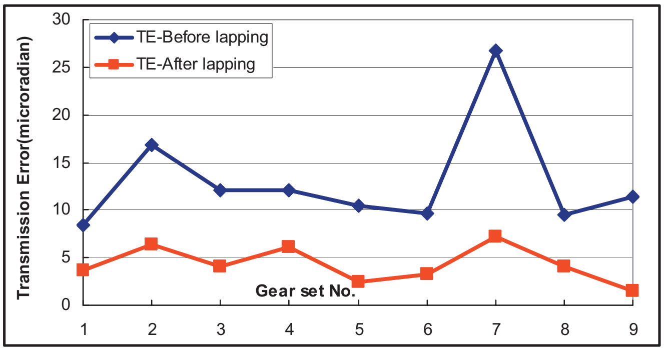

Figure 9—Second-harmonic (coast side) transmission error.

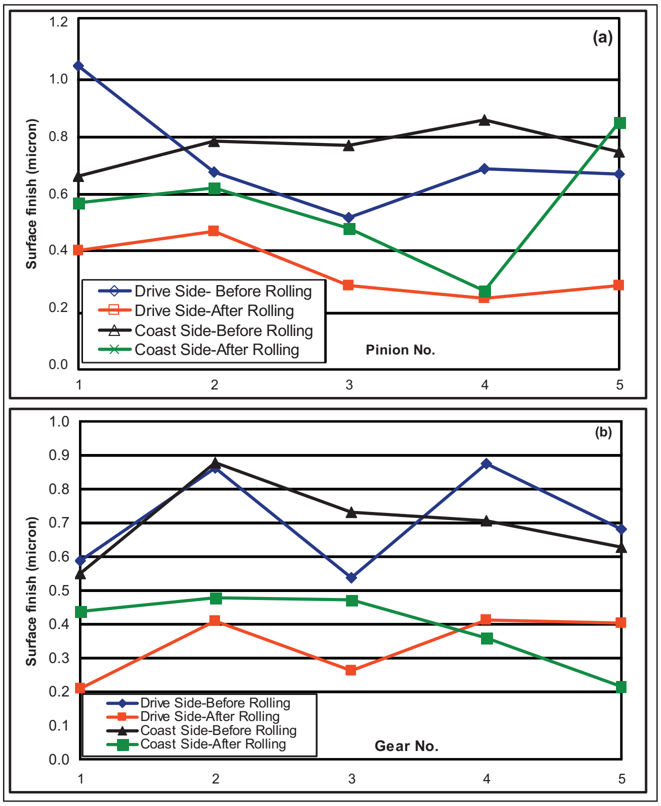

Figure 10—Surface finish changes after rolling for: a) pinion; b) gear.

Figure 11—Gear set photo before superfinishing process.

Figure 12—Gear set photo after superfinishing process.

pinion, there are no consistent changes, and lapping effects on surface finish vary from part to part. In addition, to see how other hypoid gear characteristics may be affected by lapping, transmission errors of the gear sets were measured (by Gleason SFT machine) and the measurement results are shown in Table 5 for both drive and coast sides, respectively. The results of Table 5 are graphically shown in Figures 6–9 for the first two harmonics, for both drive and coast sides. As can be seen in the graphs, lapping decreased both harmonics for both drive and coast sides.

Also, to see the effects of rolling of lapped pinions and gears on surface finish, the roughness of five gear sets—before and after rolling—was measured. The results for Ra on both drive and coast sides of pinions and gears are as shown in Figures 10a and 10b.

Rolling was performed by an SFT machine under 17 Nm brake load on a gear shaft at 100 rpm for pinion speed, and lightweight oil (SAE 30W) was used for lubrication for the entire hunting tooth cycle time. As can be seen, rolling gear sets together after lapping will improve surface finish slightly. Although these figures (Fig.10a and 10b) are for Ra, surface finish improvement with the same results was observed for R_{zDIN} as well.

Superfinishing Effects on Surface Finish and Transmission Errors

Isotropic superfinishing (ISF) is an abrasive type of finishing process. It is a chemically accelerated vibratory finishing that has the capability to finish surfaces with (Ra) < 3 μ-inch. A smooth work surface is produced by simultaneously loading an abrasive stone against a rotating workpiece surface and oscillating (reciprocating) the stone (Ref. 12).

To see how superfinishing will affect the surface finish of hypoid gears, a set of hypoid gears after lapping was superfinished, and both pinion and gears were measured, as in the previous example. Figures 11 and 12 show the gear sets before and after superfinishing. The results of the surface finish measurements for the pinion and gear are in Table 6. In this table, row 1 shows the surface finish before superfinishing; row 2, after superfinishing; and row 3, after rolling.

This Table 1 sample result is for one gear set. However, measurements were also done on eight additional gear sets, and surface finish changes were completely consistent among all parts.

As such, superfinishing significantly improved the surface finishing quality, the surfaces now appearing much smoother. However, after rolling (with the same rolling condition mentioned for rolling after lapping), the smoothness of this gear set has decreased. The measurement results after rolling the gear set together are in the third row (marked by 3) of Table 6 for pinion and gear (all measurements were performed on the same tooth).

Moreover, to graphically see the surface finish changes before superfinishing, after superfinishing, and after rolling, the results are shown in Figures 13 and 14 (for both Ra and R_{zDIN}) for the pinion and gear for both drive and coast sides.

Also, to see the effects of the superfinishing process on transmission errors, single flank tests were done on those original eight gear sets, and the results for both drive and coast sides are shown in Figures 15a and 15b.

It is shown that, although superfinishing improves surface finish drastically, it doesn't affect first-harmonic transmission error. Moreover, the results for SFT show that superfinishing does not have any considerable or consistent effect on 2nd- or 3rd-harmonics.

For an example of surface quality before and after superfinishing, and after rolling, Figure 16 shows all of the steps in the same graph for both the pinion and drive side.

Conclusions

In this paper, a study on measuring the surface finish of both ring gear and pinion was presented. Moreover, the effects of superfinishing and lapping on surface finish and transmission errors were discussed. Surface finish measurements were done on several experimentally produced hypoid gear pairs that are manufactured at the GearLab of American Axle and Manufacturing Inc., using an accurate form-measuring machine. Despite the fact that lapping was expected to improve surface finish, measurement results show that gear surface finish becomes worse after lapping, while no consistent or definitive results for pinion surface finish were observed. In addition, it can be seen that lapping decreases surface finish variation among gear sets. However, it was shown that lapping decreased the first three harmonics of transmission errors for both drive and coast sides. Also, further studies need to be done to check the effects of lapping on higher harmonics. And last, this paper presented the effects of the superfinishing process on hypoid gear set surface finish and transmission errors.

continued

Table 6. Surface finish data for pinion; 1) After lapping, 2) After superfinishing, 3) After rolling

	Pinion				Gear			
	Drive		Coast		Drive		Coast	
	Ra	R_{zDIN}	Ra	R_{zDIN}	Ra	R_{zDIN}	Ra	R_{zDIN}
1	2.03	12.34	1.72	10.90	2.00	15.29	2.12	14.70
2	0.14	1.492	0.31	0.86	0.29	2.00	0.31	3.34
3	0.30	1.563	0.43	3.08	0.33	4.38	0.36	3.69

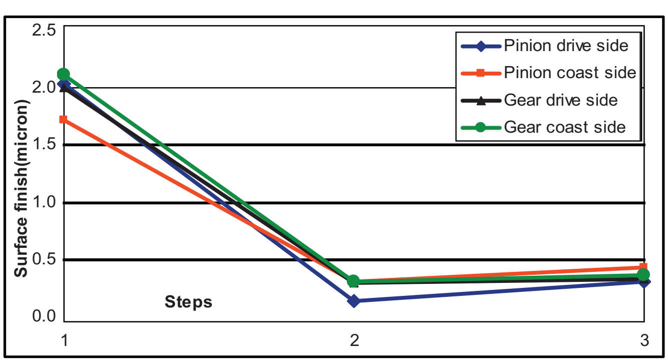

Figure 13—Ra for pinion and gear: 1) after lapping; 2) after superfinishing; 3) after rolling.

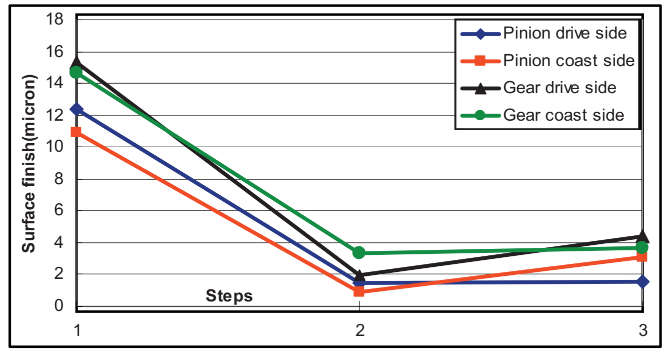

Figure 14—R_{zDIN} for pinion and gear: 1) after lapping; 2) after superfinishing; 3) after rolling.

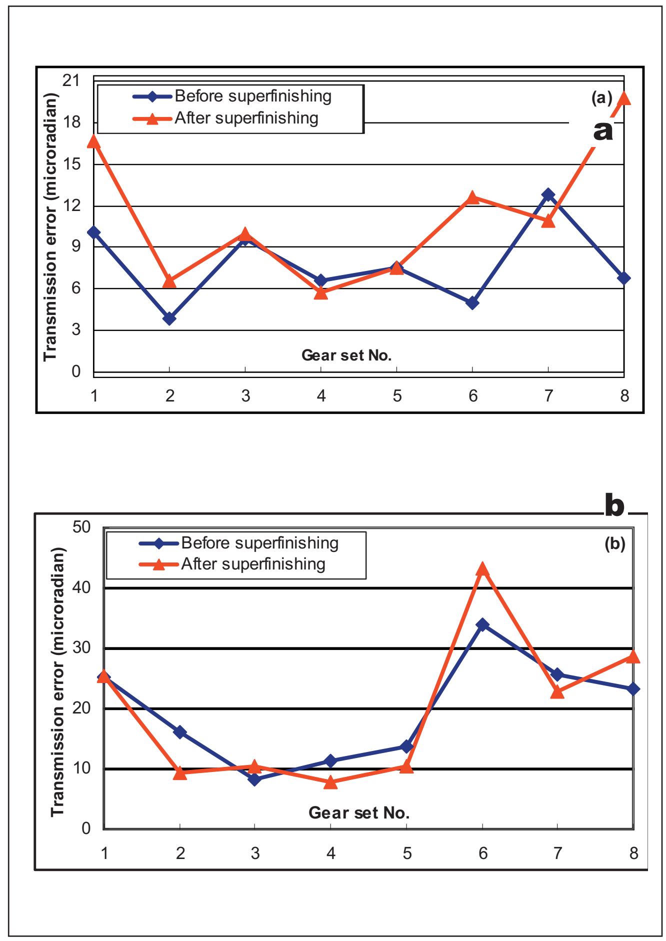

Figure 15—First-harmonic transmission error of gear sets before and after superfinishing: a) drive side; b) coast side.

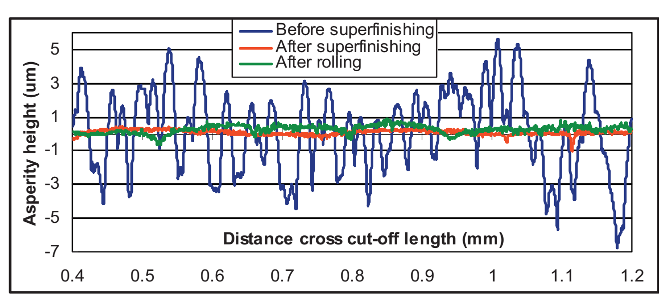

Figure 16—The effect of a different surface finish process on surface finish quality for pinion: drive side.

This study shows the results of measurements taken before and after superfinishing. Although superfinishing dramatically improves surface finish, it was also shown that the surface finish quality achieved by superfinishing decreased markedly when gear sets were rolled together. Moreover, the results for single flank testing showed that superfinishing does not have any considerable or consistent effect on transmission errors.

Acknowledgment

The authors thank American Axle and Manufacturing Inc. for providing use of its machines and equipment.

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Celebrate National Manufacturing—All Week Long

Chicago is trade show central during September. If your manufacturing senses don't overload at the IMTS show, National Manufacturing Week should help fill every last need. Brought to Rosemont, IL by trade show organizer Canon Communications, nine shows are co-located: Design Engineering, Plant Engineering, Industrial Automation, Enterprise IT, Assembly Technology Expo, Electronics Assembly Show, PLASTEC Midwest, Medical Design and Manufacturing Midwest and Green Manufacturing Expo.

Between these shows, 40,000 manufacturing professionals and more than 2,000 suppliers are expected in areas like aerospace/aviation, transportation/motor vehicle, defense, electronics, medical/pharmaceutical, computer/communications, food and beverage, industrial/agriculture and household appliances. Over the course of three days, buyers will have 400,000 square-feet of products and services to browse on the show floor, providing opportunities to accommodate important specifications and requirements.

Some familiar names to catch include Bosch Rexroth, Hitachi America, Stock Gears Inc., Heidenhain Corp., Parker Hannifin, Baldor Electric, Process Equipment Company and the Metal Powder Industries Federation. Last, but not least, you can find *Gear Technology* and sister-publication *Power Transmission Engineering* in booth 5211.

Lean and green manufacturing are two related topics that appear overwhelmingly as conference session subjects. A show-opening keynote panel discussion entitled "So the Grass *Is* Greener on the Other Side: How Industry Leaders are Practicing Sustainability and Increasing Tomorrow's Profitability," is being held Tuesday, September 23 at 9 a.m. Four panelists representing Philips Healthcare, Hewlett-Packard, Best Buy and Exelon Corp. will discuss how their respective companies have developed environmentally sound policies. Attendees will hear how design and manufacturing practices can embrace sustainability efforts, how supply chains can be reversed and how energy-efficiency programs can save energy and money. Bottom line cost-savings, end-of-life product design and corporate social responsibility will be covered.

There's more on the global manufacturing subject with several sessions discussing the issues in outsourcing. One of these sessions aims to help small- and mid-sized manufacturers establish wholly owned enterprises in China. The "China option" will be covered in regards to benefits and risks as well as the different steps along the way, such as contracting with a sourcing company and relationships with contract manufacturers. The session will identify five phases of implementation, from concept to operational audits. A separate session on outsourcing is titled "An Often Overlooked Resource for Efficient Outsourcing," in which attendees will learn how to reduce the various risks involved at different levels.

Professionals in the plastics industry can participate in the National Plastics Design Competition organized by the Society of the Plastics Industry's (SPI) Alliance of Plastics Processors (APP). The competition has been held for 36 years, but this is the first time it is co-located with PLASTEC Midwest. "Placing the APP's 2008 competition at PLASTEC Midwest will showcase the plastics industry's innovative designs and emerging technologies to a more diverse array of end-market industries and a much greater number of people than ever before," says William Carteaux, SPI president and CEO.

National Manufacturing Week takes place September 23–25, conference beginning Sept. 22, at the Donald E. Stephens Convention Center, a few miles outside of Chicago in Rosemont, IL.

Visit

***Gear Technology* and**

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September 23–25—MFN Shot and Flap Peening Workshop, Houston Marriott North at Greenspoint, Houston. Three different-level classes are held on three separate, subsequent days that cumulatively cover 19 topics. The FAA-approved courses provide hands-on training for flap peening. The courses are intended for operators, supervisors, process and maintenance engineers, buyers and trainers. Some topics include peening intensity, masking solutions, specifications and standards, air and wheel peening, hole peening, residual stress and laser peening. An optional examination at the end of each course provides a certificate of achievement, which includes the FAA identification. Each course is $790, but group discounts are available. For more information, visit *www.mfn.li/workshop*.

October 7–8—AmCon Minneapolis, Minneapolis Convention Center, Minneapolis. AmCon is a contract manufacturing expo for all job shops and contract manufacturers that provide custom metal, plastic, rubber or electronic parts and related manufacturing services to OEMs. Attendees include top level purchasing, engineering and production managers who are directly involved in buying custom contract manufacturing services. Representatives from companies of all sizes attend from a range of industries, often with blueprints in hand. The AmCon shows occur regionally throughout the year. Other fall shows include Fort Lauderdale, FL September 23–24, Phoenix October 14–15, Houston October 29–30 and Greensboro, NC November 18–19. For more information, visit *www.amconshows.com*.

October 21–25 EuroBLECH 2008, Exhibition Grounds, Hannover, Germany. The international technology exhibition EuroBLECH is for designers, buyers, production, quality managers and all other specialists in sheet metal working technology. Attendees and exhibitors represent every corner of the sheet metal working technology chain including semi-finished and finished products, handling, separation, machine elements, tube/section working, joining/welding, surface technologies, tools, process and quality control systems, CAD/CAM applications and R&D. The 2006 exhibition attracted over 64,000 visitors from 73 countries. The 2008 theme is "Quality, Flexibility, Productivity," which will highlight innovative solutions to rapidly adapt fabrication processes to global market requirements. For more information, visit *www.euroblech.com*.


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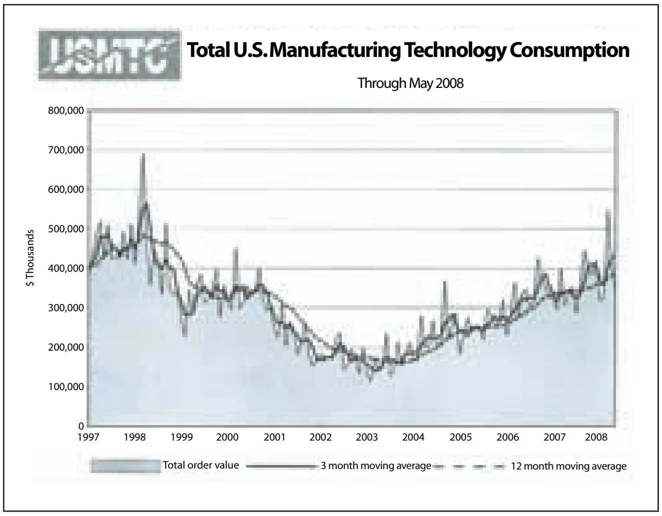
May Manufacturing Technology Consumption

INCREASED FROM 2007



U.S. manufacturing technology consumption totaled $341 million in May, reports the American Machine Tool Distributors' Association (AMTDA) and the Association for Manufacturing Technology (AMT). The figure from May is down 16.4 percent from April, but up 2.2 percent from the number reported in May 2007. The year-to-date total for manufacturing technology is $1,942.37, which is 17.2 percent higher than the total for 2007.

"The May machine tool consumption numbers again demonstrated continued strength and growth in many markets across the country, except in the automotive sector in the upper Midwest," says Peter Borden, AMTDA president. "However, the concerns about energy and commodity prices, along with the traditional summer and pre-IMTS buying slowness, may in the next few months reduce the gains that we have seen thus far this year to bring the orders closer to the forecasts."

The USMTC report, put together jointly by the AMTDA and the AMT, reports on U.S. manufacturing technology consumption in five geographic breakdowns.

The Northeast region experienced a rise in manufacturing technology consumption to $48.8 million, which is 4.7 percent higher than the previous month, but 16 percent less than in April 2007. The year-to-date total for the Northeast is $269.89 million, 0.1 percent less than the total from May 2007.

In the Southern region, manufacturing technology consumption was down 11.6 percent from April and down 19.0 percent from May 2007. This year's total for May was $43.47 million, and the year-to-date total stood at $314.75 million, which is 47.2 percent higher than the 2007 total was in May.

With a May total of $119.31 million, manufacturing technology consumption in the Midwestern region was 26.2 percent less than the total was in April 2007; however, the May 2008 amount was 20.8 percent higher than it was in May 2007. The year-to-date total is $662.98 million, an increase of 42.6 percent from 2007.

At $91.15 million in May, the Central region's manufacturing technology consumption was up 7.5 percent from April this year and 3.4 percent higher than the total was in May 2007. The year-to-date amount is 2.9 percent higher than the figure was a year ago, at $447.29 million.

In the Western region, manufacturing technology consumption, at $38.78 million, was 41.5 percent less than April's total but up 9.2 percent from May 2007. The year-to-date total is $247.47 million, which is 0.2 percent less than the total from 2007 at the same time.

Forest City Gear

RECEIVES MEDICAL DEVICE CERTIFICATION

A medical device certification, ISO 13485, was issued to Forest City Gear, joining the company's ISO 9001:2000 and aerospace accreditations. FCG sought out the certification in order to add to its other quality standard certifications. "Since we do a small amount of medical devices, we thought it would help bring in some more work for us," says Pat Keeley, quality manager.

Keeley's job is to ensure the company adheres to its quality standards. After receiving the aerospace accreditation, there were only a few additions to their quality procedures manuals to implement because requirements overlap between the two quality certificates. Some medical applications FCG has produced gears for include surgical instruments that put screws in bones, kidney dialysis machines and heart pumps.

The accreditation was something CEO Fred Young really wanted to strive for, according to Keeley. Young comments, "We historically have always done some stuff in the medical

continued

field from X-ray and CAT scan equipment, medical positioning tables to portable ventilators; a variety of different things.

"Our registrar has told us that he believes we are the only gear company in the United States with our medical certification."

Fette

BOOSTS INVESTMENT IN GERMAN PLANT

While celebrating its 100th anniversary, precision tool and machine manufacturer Fette GmbH opened an innovation and training center at its Schwarzenbek, Germany plant, and the Leitz Metalworking Technology Group subsidiary plans on investing 30 million euros into the production site by 2010. The facility provides tool technology and tabletting press users with testing and improvement tools on machinery under production conditions.

The innovation center is part of a global network linking the LMT corporate headquarters in Oberkochen, Germany to key markets. At the official opening event, Dr. Michael Heinrich, LMT managing director, said, "Here, in Schwarzenbek, we want to create yet another location within the Group where experts can meet and discuss machines, tools, materials and processes and jointly develop new solutions for industrial production through collaborative research and experimentation."

The center provides the opportunity for customers to test and improve tools and machines under production conditions. Five modern processing centers are available in the tool

technology sector. The equipment, designed to cover the complete tool deployment process chain in a modern product system, ranges from clamping systems and tool measuring and adjustment to automated tool dispensing.

Fette also announced a 30-million-euros investment in the Schwarzenbek production site by 2010. The funds will be distributed evenly across the toolmaking and compacting business divisions to increase and modernize the production facilities. Funding for research and development of resource-efficient tool systems is also being increased.

"With this investment we are strengthening the Schwarzenbek site and offereing Fette the opportunity to continue to play a leading role in the LMT Group," Heinrich says. "Our services as tool specialists are in great demand worldwide in all key markets and industries of the future. As a network of specialists we want to utilize these opportunities for growth. That also entails a targeted strengthening of the Group's different sites."

Höfler

EXPANDS SERVICE FACILITIES

A service support facility in China was opened by Höfler GmbH in June in response to the company's large growth in machine installations in China. The Yantai facility is a full-service office with a manager, secretary and service engineers. In the future, Höfler plans to expand this facility with more staff and service customers in nearby Korea. The service and parts center will help in the worldwide support of Höfler's CNC form gear grinders and CNC gear hobbers, according to

continued

Harald Jung and Dirk Kukelhahn, Höfler president and service manager respectively, unveil the service support facility in China.

Ray Mackowsky of Great Lakes Gear Technologies, which provides sales and marketing representation for Höfler in the United States and Canada.

Höfler is planning a second North American Service and Application facility in Milwaukee to complement the two existing North American facilities. The Milwaukee location will help serve Höfler customers by bringing more application and service engineers to the region, and it will serve as a spare parts depot for Höfler machines sold in that territory.

GE Marine Gear Lines

BOUGHT BY PHILADELPHIA GEAR

The Philadelphia Gear Corporation (PGC) purchased the majority of General Electric Corporation's marine gear product lines. PGC acquires intellectual property, equipment and transition assistance in order to broaden its capabilities to manufacture main reduction gear assemblies, upon completion of the transaction.

GE is a primary supplier to the U.S. Navy and other foreign navies including the main reduction gears for the Arleigh Burke Class DDG destroyer and prototypes for the LCS ship class, according to a PGC press release.

The GE facility in Lynn, Massachusetts will complete the backlog of business that exists through 2009. PGC, headquartered in King of Prussia, Pennsylvania, will manufacture new product lines at its own manufacturing sites, and the company will not take over any operation at the Lynn facility.

Carl Rapp, CEO and president of PGC comments, “We are very pleased to announce this transaction. The GE assets that we are purchasing complement our existing military program business.”

Moventas

EXPANDS IN CHINA

A Moventas Competence Center was established in Suzhou, China, supporting the expansion of operations and growth strategy for industrial and wind gear businesses. The facility will mostly serve the industrial gear business and its significant local customer base.

The center will bring sales and service support to local customers in the area. Services include technical support, limited assembly operations and resources for purchasing and logistics.

Moventas’ Shanghai Competence Center will continue current operations and support customers in the fiber, paper and minerals industries. Moventas plans to establish a limited liability company with 100 percent foreign ownership in China, and the Shanghai and Suzhou centers will operate under the new enterprise.

Excellence in Metalforming Awarded

The annual Awards of Excellence in Metalforming were presented by the Precision Metalforming Association (PMA) at an April 1 ceremony during PMA’s 2008 Regional Metalform trade show in Birmingham, Alabama. The awards acknowledge members of the metalforming industry with high

continued

achievement standards in the areas of design, safety, training and education, process control, quality, productivity and product development.

Each winning company received a special plaque, commemorative flag and a cash prize. The 2008 winners were ITW CIP California, E&E Manufacturing Co. Inc., SKD Automotive Group–Brampton Division, Penn United Technologies, OKAY Industries Inc. and E.J. Ajax & Sons Inc. Details of each award-winning entry are available at *www.pma.org/pressrm.*

Applied Process Inc.

BRINGS AUSTEMPERING TO INDIA

HighTemp Furnaces Ltd., of Bangalore, India is now a licensee for Applied Process Inc. This partnership allows both companies to cater to the Indian manufacturing sector. "With Appled Process' experience in the application of austempering to steel and iron components, and HighTemp's reputation in the Indian market for quality, reliability and innovation, the combination offers a powerful synergy of strengths," says John R. Keough, CEO of Applied Process.

Gopal Mahadevan, managing director for HighTemp, says, "This collaboration will bring efficient, technology-based austempering services to our customers, offering them high-performance, cost-effective material/process alternatives. We will also be able to support our customers with research, technical marketing and design consultation relative to the application of austempered materials. This relationship expands our process portfolio in our core strength of heat treatment and forms part of our aggressive expansion plans within India."

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CLASSIFIED SECTION

GEAR MANUFACTURING

HEAT TREATING

A look at large gear remnants on Mt. Baldy. But how did they get there?

Gear on a mountain, you say? How can that be? Someone must be stricken with a bad case of altitude sickness to create that sort of delusion. What's next, gears in space? On a glacier?

Despite overwhelming skepticism, sure enough, pieces of a large metal gear were happened upon by an avid *Gear Technology* reader on his ascent of Mt. Baldy, the second-highest peak in the Cimarron Range of mountains in northern New Mexico. With a flurry of these questions accumulating in his brain, the reader thought it best to leave this bizarre mystery to the experts.

We could hardly believe our eyes. Surely there must be a very logical explanation behind this unusual discovery. Although admittedly perplexed, the Addendum staff dusted off its archeologist caps and came up with its best bets.

Mining Mutiny: In the second half of the 19th century, Mt. Baldy was a booming site of copper and gold mines; an estimated 70 miles of mines exist in the crag. Mining workers were increasingly disgruntled by the poor and dangerous work conditions and minimal income they endured day-after-day. Their sentiments were ignored by the fat-cat mining management, and their dissatisfaction grew into anger and an insatiable thirst for revenge. Striking out against authority, the starving miners destroyed the mine and scattered its pieces as far apart as possible to prevent any simple chance for reconstruction.

The Truth is Out There: Geographically, Mt. Baldy is longitudinally linked to Roswell, NM, a few hundred miles to the south of Colfax County. By way of atmospheric drift, this gear was part of an extraterrestrial vessel wreck. The aliens were collecting Earth artifacts to help write the story of human life when the ill-fated voyage occurred.

Beep! Beep!: Upon close inspection of the gear, you notice "Acme Co." inscribed into the metal. This gear was once a critical component to one of Wile E. Coyote's complex contraptions. Despite his unending clever attempts and admirable determination, the Roadrunner got the best of his plans.

The Lost City: These are obviously gear remnants from the lost city of Atlantis from the netherworld. Probably from some sort of diabolical torture device. After millions of years, they are just now beginning to come to ground from thousands of miles beneath the earth's surface.

Return to Gear Mountain: Archeologists recently discovered the last remnants of the Gear World Adventure Park in New Mexico. This gear-themed amusement park, conceived by Walt Disney, was rumored to feature the Spiral-Bevel Mine Ride, The Helical Mystery Mansion and It's a Manufacturers World. It opened in the early 1950s to lukewarm reviews and closed three days later due to waning public interest. Walt would go on to create another amusement park venture despite objections from friends and family members. On a cool New Mexico night, residents say the ghosts from Gear World can be seen roaming the former park grounds in large gear-related costumes looking to hug kids and sign autograph books.

Think you have an idea as to how this gear ended up on the mountain? Help us crack the mystery by e-mailing *publisher@geartechnology.com*. Don't be shy, and we'll devote an upcoming Addendum to your theories.

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