

gear

TECHNOLOGY®

NOV/DEC
2012

STATE OF THE INDUSTRY

GEAR INDUSTRY TRENDS
OUR ANNUAL GEAR INDUSTRY SURVEY
THE "MANUFACTURING MIDDLE CLASS"
—WHAT HAPPENED?

TECHNICAL

**Predicting Scuffing to Spur/
Helical Gears in Commercial
Vehicle Transmissions**

Morphology of Micropitting

Ask the Expert:

Gleason Machinery Setup

ADDENDUM

**Paper
+
Scissors
(No Rock)
=
Gears!**

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Star's PTG-1 sharpens both straight and spiral gash hob designs up to 8" OD x 10" OAL. Additionally, it sharpens disk, shank and helical type shaper cutters and a wide range of round tools, making it a versatile tool room machine.



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Designed to grind shaving cutters and master gears, the GS 400 sets new standards for precision, reliability and ease of use. An integrated measuring unit automatically checks the quality of the first tooth ground without unclamping the workpiece.



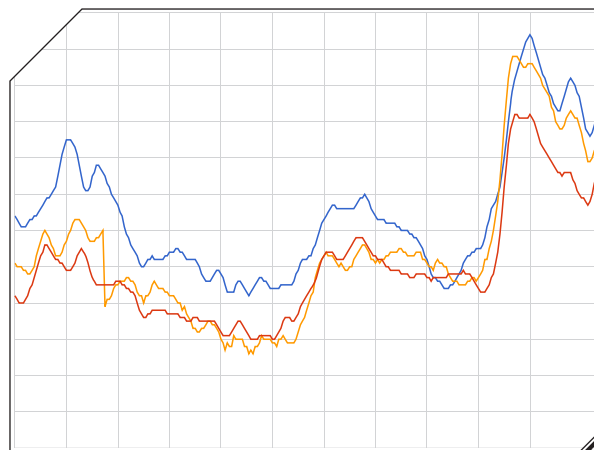
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Scuffing risk predictions for spur/helical gear sets in commercial vehicles: SAE Class 3—Class 8.

Customers Say it Best



Ontario Drive and Gear Limited has maintained its competitive advantage by investing in state-of-the-art technology, including three Kapp KX 300P grinding machines. ODG chose Kapp because of their reputation for quality and ingenuity. ODG utilizes the full of array of the KX300 P's capabilities to form, generate, topological and sub spindle grind. *"We are extremely pleased with the flexibility and sophistication of the machine solutions from Kapp. We plan to continue to grow our business thanks in part to Kapp."*

Joel Wright, General Manager, ODG.

Ontario Drive and Gear Ltd. is a high quality custom gear manufacturer that offers design, manufacture, assembly, and test services from their 60,000 sq. ft. facility in New Hamburg, Ontario. ODG celebrates its 50th anniversary this year.

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Paper + Scissors (No Rock) = Gears!



Cover Design by David Ropinski

Power Skiving – A Milestone in Gear Manufacturing

IMTEX Bangalore, India
Hall 3A Booth B 108
24.-30. January 2013



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► Learn more about Power Skiving at www.klingelInberg.com

THE GEAR INDUSTRY'S INFORMATION SOURCE

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How to Conduct a Heat Treat Audit

Do you know how well your current heat treat provider is doing? Are you shopping for a new provider? Then you don't want to miss the article by Daniel H. Herring ("The Heat Treat Doctor") that appeared in our November 2012 e-mail newsletter. The online article describes what you need to do to ensure your heat treated parts are getting the attention they deserve.

www.geartechnology.com/newsletter/1112.htm



Gears on Mars!

Forest City Gear employees talk about their work manufacturing gears for the Mars Rover Curiosity in a short documentary web series by Pablo Korona.



Star SU Plant Tour

Take a virtual tour of the Star SU Federal de Mexico Service Center, a modern plant for sharpening and reconditioning tools for gear manufacturing.

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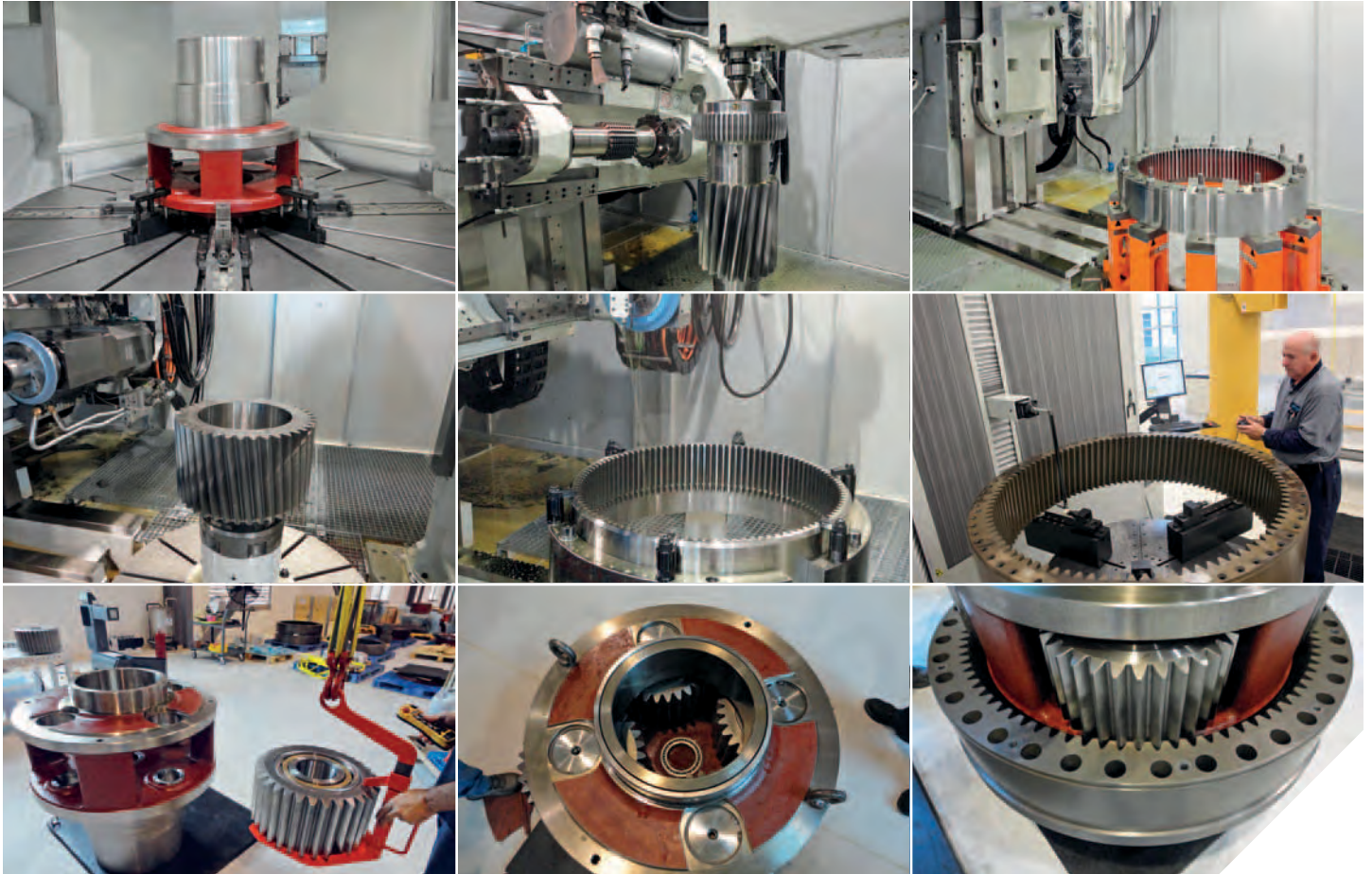
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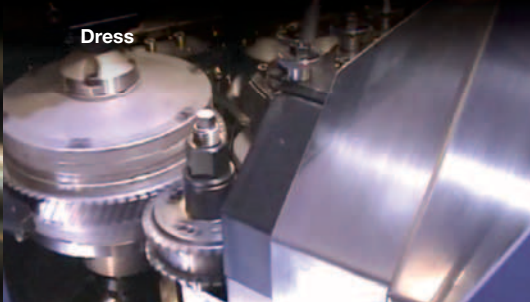
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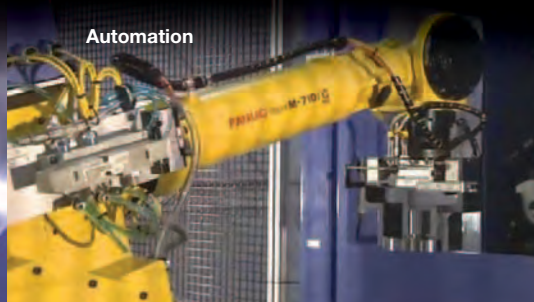
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The Results Are In



Publisher & Editor-in-Chief
Michael Goldstein

The past several months have been filled with uncertainty. Everyone wanted to wait and see who would be our next president and how the political landscape might change. Now the elections are over, and the polls are all closed, so we should all be getting back to business, right?

Well, not so fast. We've still got that huge budget deficit to worry about. The fiscal cliff looms. And the balance of power in Washington remains pretty much as it was before the elections. So there's still a lot of uncertainty out there. If we do go over the cliff, the impact will be worldwide, and the gear industry will be affected along with all other industries.

But it isn't *all* bad news. We've been doing some polling of our own, in the form of our annual State-of-the-Gear-Industry survey, and the results are presented beginning on page 32. As expected, those results reflect the overall economic uncertainty facing our country and the rest of the world, and they point out many of the serious challenges manufacturers face today. But overall, the business of gear manufacturing remains steady, with our respondents reporting significant optimism about the future.

No matter what else is going on in the world and the economy, gears are still being made. Gear manufacturers continue to invest in technology, improve their quality, increase their productivity and grow their businesses.

Before you jump right into the statistics, I encourage you to read through Jack McGuinn's article on the manufacturing middle class (p. 22) and Matt Jaster's article on current trends in the industry (p. 28). These articles include interviews with a number of industry leaders, who help put the raw numbers into better perspective.

In addition to the questions we ask about business conditions, sales, production, capital spending, and so on, we also use the survey as an opportunity to ask our readers what subjects they're interested in and what types of articles they'd like to read more of. I find some of these results to be the most interesting and insightful regarding our marketplace.

For example, more than half of our respondents indicated they'd like to see more articles on gear inspection and gear grinding—by far the most popular subjects. Heat treating, cutting tools, bevel gears and lean manufac-

turing were also highly ranked, with more than 40% of respondents indicating they'd like to see more articles on those subjects.

We also asked our readers to rank (on a scale from 1-10) the types of articles that are of most value to them. Not surprisingly, technical articles received the highest ranking, with a median score of 8. This has always been the bread-and-butter of *Gear Technology*, and the area where we spend the most effort to ensure that our content is accurate and useful. Our "Ask the Expert" feature scored almost as high, at 7.4. But our staff-written feature articles are also highly valued, with a median score of 7.2. Providing the kind of in-depth coverage we give you every issue in all of these areas requires us to maintain a much larger, more experienced editorial staff than most magazines our size. It's rewarding to know that you value our commitment to the industry.

Clearly we seem to be doing something right. According to the survey, 80% of our readers spend 20 minutes or more with each issue of the magazine, and almost 25% of you spend more than an hour. In a time when attention spans are hard to come by, that really means something.

It also gives us a good road map for the future. With your continuing support and interest, we'll keep producing the highest quality content possible on the subjects you care about most.

P.S. While our survey gives us very good insight into what our readers like and don't like, we'd still like your feedback. If there are gear-related topics you'd like to see covered more, please tell us at publisher@geartechnology.com.

Romax Technology

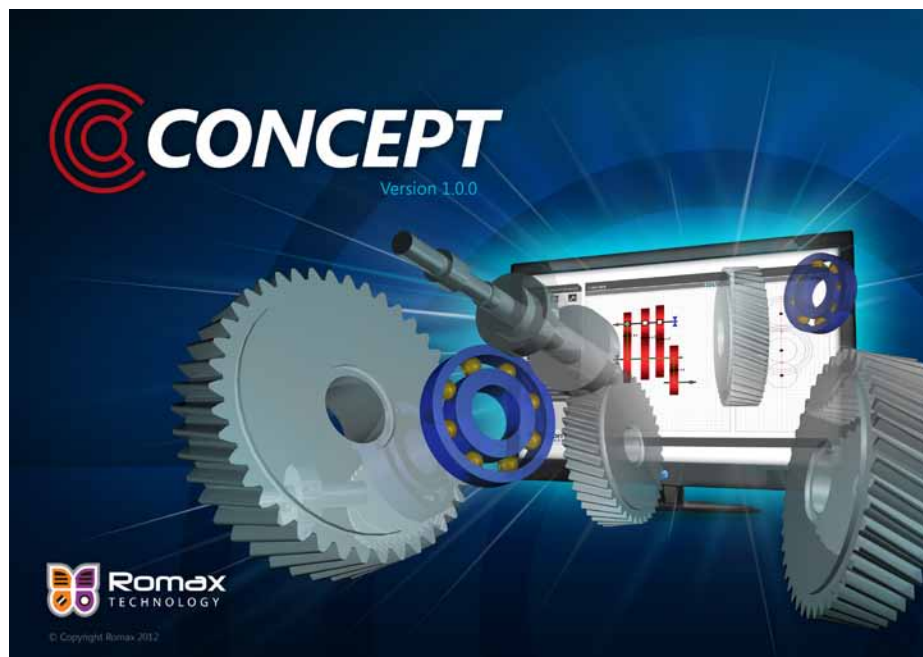
LAUNCHES GEARBOX AND DRIVELINE DESIGN SOFTWARE PACKAGE

Romax Technology, the gearbox, bearing and driveline engineering specialist, has launched a new design software package that will increase speed, quality, creativity and innovation when designing gearboxes and drivelines. Called *Concept*, the new product delivers on the Romax vision of streamlining the end-to-end, planning-to-manufacture process with open, easy to use software solutions. It has been developed in close collaboration with engineers in the largest ground vehicle, wind energy and industrial equipment companies around the globe.

The result is a highly intuitive drag-and-drop design environment enabling rapid creation of concept models. It provides semi-automated sizing, definition and rating of gears, shafts and bearings, with advanced 3-D visualization capability allowing evaluation and manipulation of key parameters. As a result, it promotes creativity as new design ideas can be evaluated rapidly.

Concept also utilizes Romax's analytical capabilities to enable initial NVH assessments, as well as preliminary mechanical design assessments of alternative concepts.

It is applicable for any gear, shaft and bearing system application, from power tools to mining equipment and from complex automotive planetary automatic transmissions to the largest wind turbine gearboxes. The new software not only enables creativity, effectiveness and efficiency, it also promotes a seamless workflow, either as a stand-alone solution or



used in conjunction with other CAD packages.

Its innovative, easy-to-learn interface allows new users to become productive extremely quickly, which means both graduate designers and experienced gearbox and driveline design teams can use it. Romax Technology product manager Dr. Jamie Pears, who is heading up the product launch, believes concept design is one of the most important aspects of the gearbox and driveline product development process.

"Early decisions can be crucial in shaping product performance, robustness and durability, as well as minimizing manufacturing and operating costs,"

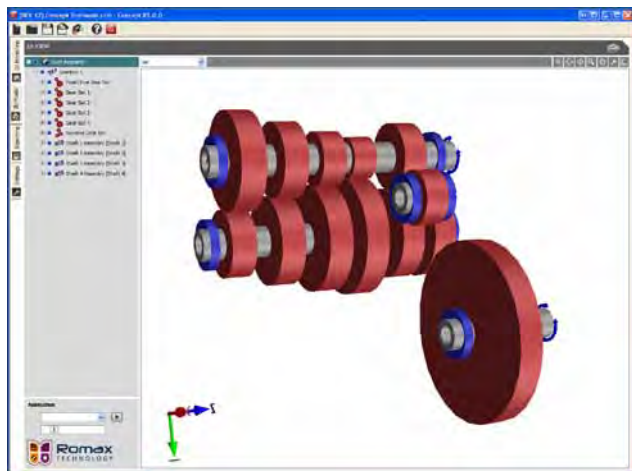
he said. "However, this stage of development can be expensive and time-consuming too, meaning that many engineered products fail to reach their full potential. This next-generation design package, which incorporates many of our advanced analytical algorithms,

helps users to pull forward new concepts into robust and highly optimized designs capable of subsequent, detailed development. It not only saves development time and cost but also improves the quality and robustness of the finished product."

Also supporting Romax's vision of streamlining end-to-end, planning-to-manufacture processes is another significant, new capability in the company's flagship product offerings for detailed design and analysis—*RomaxDesigner* and *RomaxWIND*. This enhanced capability for improved manufacturability of end-products includes a comprehensive suite of tools that enables the gear manufacturing process to be considered part of the gear design and analysis process. Romax announced *Concept* in October and will be shipping the software in December.

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Phone: + (44) (0) 115 951 8800
www.romaxtech.com



ITAMCO

OFFERS INDUSTRIAL BLUETOOTH TRANSMITTER

Indiana Technology and Manufacturing Companies (ITAMCO) has released iBlue—the first handheld bluetooth transmitter that gathers crucial production data and sends it to bluetooth-enabled smartphones, tablets and computers. iBlue replaces several tools, including hardness testers, micrometers and temperature readers. When iBlue is paired with a bluetooth-enabled device, it gathers, records and sends data through its three ports: a K-type thermocouple port—iBlue comes with a K-type thermocouple probe; a 3-pin metal hardness probe port; and a USB Human Interface Device (HID)-enabled port that connects with a wide range of non-proprietary tools including keyboards, micrometers, calipers and barcode scanners. No special software is required, and data from iBlue can be sent as a text email or placed into Microsoft Excel and Notepad. iBlue is compatible with the most common operating systems including Apple's iOS, Android, Blackberry, Windows and Linux.

Expanding Mobile Technology

iBlue isn't ITAMCO's first foray into mobile technology; the company has launched several free smartphone apps for industrial applications. Two of their apps, Hardness Tester and Convert Temperature, extend iBlue's capabilities. Hardness Tester calculates approximate hardness conversion numbers between

popular Rockwell, Vickers and Knoop hardness scales for non-austenitic steels. The Hardness Tester smartphone app converts data acquired with iBlue and a hardness probe. (iBlue accepts D/DC, D+15, E, C, DL and G hardness probes.) The Hardness Tester will graph results, and previous tests (Max, Min and Average) can be recalled with the touch of a button. The data can be sent to any compatible Air Print printer from the app. The app is in conformance with ASTM A956-06 and ASTM E140-07.

The Convert Temperature app converts different scales of temperature, such as Fahrenheit, Celsius and Kelvin. Temperature readings can be emailed, printed and graphed, the same as the Hardness Tester data. The app works seamlessly with iBlue and its K-type thermocouple probe (included). The apps are available for Apple, Android and Blackberry smartphones.

iBlue and the Technology-Driven Shop Floor

iBlue and smartphone apps are part of ITAMCO's overall initiative to bring technology to their own shop floor. Joel Neidig, an engineer at Indiana Gear (a division of ITAMCO) and one of iBlue's developers, said, "We're in the process of connecting our machine tools to a plant monitoring system, so it just made sense to have an electronic method of gathering and distributing the temperature, dimensions and hardness data of our gear products." iBlue is used by machine operators, engineers and quality control staff at Indiana Gear. "iBlue is saving me a lot of time on the shop floor because it's an all-in-one tool," said Michael

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Blum, one of Indiana Gear's quality control specialists. "It's easy to carry around and it's accurate. We're already using data gathered from iBlue to electronically track and analyze production processes." iBlue has worked so successfully at Indiana Gear that the ITAMCO staff decided to market it worldwide.

iBlue Is Bundled and Priced for Economy

iBlue comes with a USB charger cable, OtterBox belt clip and a K-type ther-

mocouple probe. The iBlue package is priced at \$499 and can be ordered online with Google wallet at <http://www.itamco.com/iBlue> or by calling ITAMCO at (574) 936-2112. The Hardness Tester and Convert Temperature smartphone apps can be downloaded from the Apple App Store, Google Play, Windows Marketplace and the BlackBerry App World. Search "ITAMCO" to locate the apps. iBlue is easy to pair with bluetooth devices and simple to use. ITAMCO has

provided how-to videos and a FAQ page at their website below.

For more information:

ITAMCO
6100 Michigan Road
Plymouth, Indiana 46563
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www.itamco.com

Polygon Solutions

DESIGNS ROTARY BROACHING BRAKE

Rotary broaching can be utilized for making small forms like hexagons and squares in soft materials like aluminum, brass and mild steel. However, when it comes to aligning multiple holes using a rotary broaching tool, the operation becomes extremely challenging. Most rotary broach holders have a free-turning spindle which does not allow for alignment of the holes. The rotary broaching brake is a new mechanical solution for aligning broached forms in machined products.

Polygon Solutions Inc. designed the



broaching brake to be used as an attachment to its innovative GT Series rotary broach holder. The brake mounts to the tool holder using set screws. Additional screws are included at the opening of the brake to gently tighten against the spindle. The broach is fastened into the spindle, and must make contact and be aligned at the first hole.

When the broach is engaged with the part, the brake is loose enough to allow the spindle to turn without interfering with the broaching operation. Unlike typical rotary broaching operations, turning must stop before removing the broach. When the broach is removed the brake screws are tight enough to hold

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From the Forest City Gear Family To You and Yours...Merry Christmas

During exceptionally busy years like this one we never truly stop thinking about our customers and their gear production challenges. Yet the holiday season reminds us of how blessed we are – for our family and team members, our industry and all our business associates.

From all of us at Forest City Gear: wishing you a very Merry Christmas and may your 2013 be a joyous and prosperous one.



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the broach's position until it makes contact with the part at the next hole.

The rotary broaching brake was used to hold orientation for single or multiple parts. Tightening the screw to be loose enough to allow broaching, but tight enough to hold orientation, requires patience and a level of experience. Some trial-and-error can be expected and the broach orientation will need to be checked at regular intervals. The hardware consists of standard

screws and nuts that can be replaced or reordered easily.

The rotary broaching brake was used recently at the 2012 IMTS show in the Hardinge booth. Hardinge's innovative Bridgeport GX 480 APC Vertical Machining Center held multiple broach holders by Polygon Solutions. However, the block was machined with square holes which were aligned to other features on the part. The squares were machined using a broach holder with Polygon's new rotary broaching brake.



The rotary broaching brake is a lightweight, low-profile tool and easily fits into the VMC's tool changer. It easily slides onto the head of the holder and does not require special tools for adjustment or assembly. The brake can also be easily removed for operations where it is not required.

For more information:

Polygon Solutions Inc.
16770 Link Court, Suite 106
Fort Myers, FL 33912
Phone: (239) 628-4800
www.polygonsolutions.com

Mitutoyo

RELEASES MACH-3A CMM

Mitutoyo America Corporation announces the availability of the new MACH-3A CNC Coordinate Measuring Machine - a CMM that attains levels of accuracy and performance expected from Mitutoyo to in-line applications. Instead of the basic GO/NO GO judgments common to in-line gaging, the MACH-3A CNC provides comprehensive measurements to enable statistical control utilizing numeric data. The MACH-3A is a clean slate design embodying



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numerous features dedicated to functionality and high performance for in-line applications.

The Mitutoyo MACH-3A CMM is a horizontal-arm-type machine with high speed and high acceleration (max. speed of 1,212 mm/s, max. acceleration of 11,882 mm/s² - both in vector direction) that contributes to high throughput for greater productivity and lower total owning and operating costs.

The MACH-3A is compact, requiring only a minimal envelope which minimizes its impact on line layouts. This, plus high environmental resistance, make the MACH-3A easy to integrate into both upstream and downstream processes - even under demanding production floor conditions.

Conventional CMMs typically require dust-controlled environments to maintain accuracy. But with a drive unit protected by covers, precision linear guide systems for each axis instead of air bearings, and with its controller and PC installed in a dust-proof housing, the Mitutoyo MACH-3A is highly-resistant to the effects of dust, mist and humidity. Additionally, the MACH-3A tolerates a wide range of operating temperatures - guaranteed to maintain accuracy between 5° and 40°C. Additional production-oriented features include a machine status indicator (signaling machine fault or abnormal measurement), an ergonomically

positioned touch-panel monitor with built-in compact keyboard, plus a built-in, industrial-grade controller and PC. It all means the MACH-3A CMM offers the functionality, durability and stability required for 24/7 in-line operation.

The MACH-3A CMM comes with standard with *MCOSMOS* (Mitutoyo Controlled Open System for Modular Operation Support) which supports virtually every CAD format while providing routines for in-line measurement, data feedback and process management.

MACH-3A architecture, together with available Mitutoyo software packages, make it easy to integrate this machine with high-level network environments for true enterprise-wide functionality.

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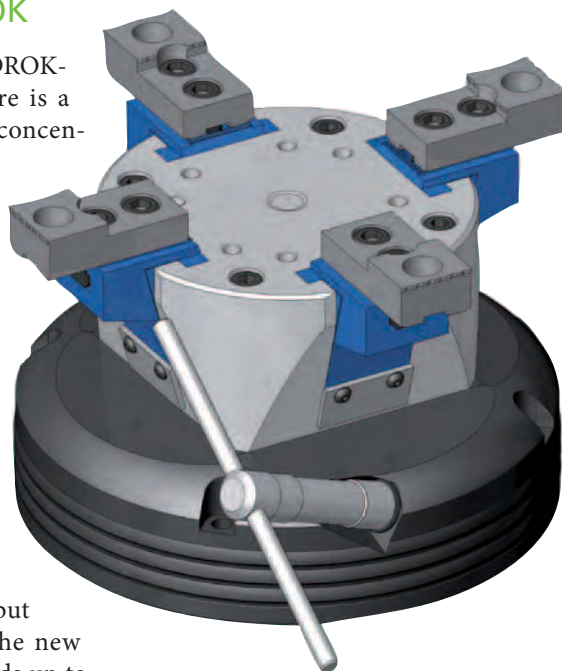


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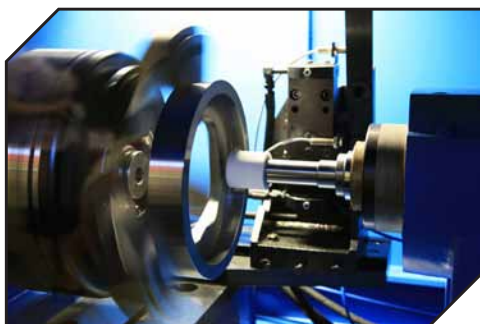
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Emuge Corp. has introduced the KSN5 and KSN6 Softsynchro Tap Holders. The holders are designed for tapping operations in components used in oil, power generation and wind turbine applications and in the production of large diesel, locomotive and ship engines.

"We are seeing an increased need for larger tapping applications such as in the energy sector," said Mark Hatch, product director of Taps and Threads Mills at Emuge Corp. "The new KSN5 and KSN6 Softsynchro Series are ideal for work in energy and other large component applications."

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The KSN5 series is for tap sizes M16 to M56 and ANSI sizes to 1 3/4". The KSN5 series uses the ER50GB collet and is available in both DIN and ANSI tap sizes. Tension and compression of 2 mm is used in machines with rigid tapping cycles. Coolant-through capability is available up to 50 bar and the KSN5 series is also available with an integral shank CAT50 or HSK100A.

The KSN6 series is for sizes M24 to M76 and uses Emuge HE2 large QC Tap Adapters used currently on Emuge HF20 tap holders. Emuge HE2-IKZZ adapters are available in both DIN and ANSI tap sizes 1" through 2 1/2". The KSN6 has 2 mm of tension and 2 mm of compression for rigid tapping cycles. The tool is coolant-through capable, to a maximum of 50 bar.

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Seco Tools

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At the JEC Americas 2012 Composites Show that took place Nov. 7-9 in Boston, Seco Tools spotlighted advanced solutions for efficiently machining composite parts including products from its Jabro and Feedmax lines. Developed to meet the rise in composite machining applications, the new Jabro JC800 family of solid carbide milling cutters – JC840, JC 850, JC860, JC870, JC 871 and JC 880 – eliminates fiber breakout and delamination as well as provides improved edge finish. Each cutter employs a high degree of specialization to meet the diverse requirements of composite materials and features a CVD Diamond coating with low surface roughness and high substrate adhesion characteristics.

- The JC840, a double-helix end mill for machining laminated materials, ensures cutting forces are directed inward and toward the component filler material.

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- The JC850, a four-flute ball nose cutter with low helix, is ideal for 3-D machining operations in carbon fiber and peek materials.
- The JC860 is a router for cutting non-ferrous honeycomb materials with carbon and/or glass top layers, such as those used to produce aircraft cabin walls and floor panels for the aerospace industry.
- The JC870 diamond cut router is a multi-flute design with two frontal teeth. It is capable of side milling, slotting and plunging in all types of composite materials.
- The JC871 diamond cut router is a multi-flute design with two different frontal tip configurations. It is capable of side milling, slot milling (open) and slotting in all types of composite materials.
- The JC880 low-helix end mill with a four-flute design effectively performs slotting and side milling operations in carbon fiber reinforced polymer and glass reinforced plastic materials

As the latest additions to Seco's series of Feedmax solid carbide drills, the Feedmax-C1 and Feedmax-C2 prevent delamination upon entry or exit when working in carbon fiber reinforced polymer materials. The -C1 geometry features sharp optimized double points, while the -C2 geometry is specifically designed to drill stacked CFRP materials with aluminum or titanium outer layers.

To combat the abrasive properties of carbon fiber reinforced polymer, the Feedmax -C1 and -C2 incorporate a polycrystalline diamond coating, which also provides good dimensional tolerance. The drills are 5xD with diameters ranging from 0.1260" - 0.5". All -C1 and -C2 drills also feature through-coolant holes.

Further advancements have also been made with the addition of solid PCD dome tip technology that makes it pos-

sible to grind geometries, such as the -C1 and -C2, into a solid PCD tip that is brazed onto a solid carbide drill. The edge sharpness that can be achieved with solid PCD further reduces delamination, uncut fibers, and improves performance.

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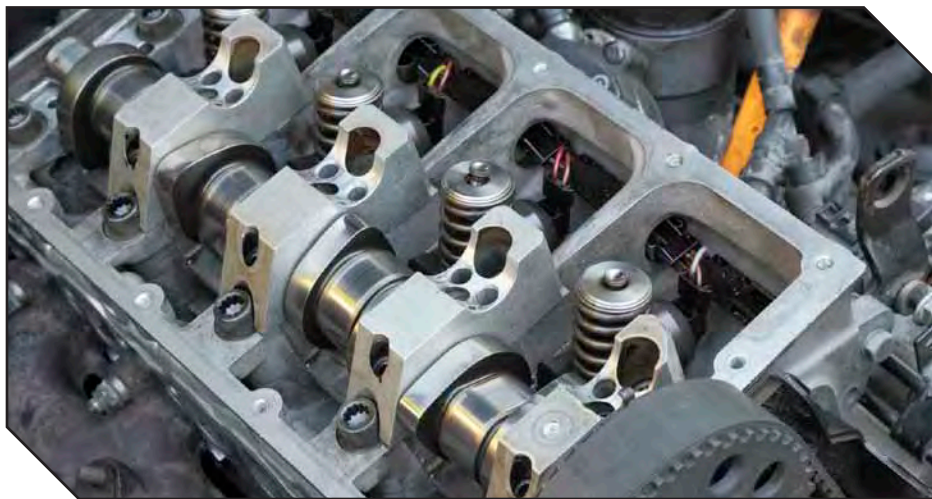
Cimcool Fluid Technology has announced the release of a new lubricant technology for machining and grinding of hard metals. These new Cimtech synthetic fluids feature synergistic lubricant blends that provide huge increases in productivity without the use of chlorine or other high levels of extreme pressure additives. Cimcool delivers significant cost reductions from the higher production rates these fluids can provide. More production and lower cost per part coupled with environmentally responsible fluids provide significant advantages to customers concerned with being competitive. With unique hybrid blends, including patented Milacron lubricants, only Cimcool can provide customers with these innovative fluids. Customers with heavy duty performance requirements looking to eliminate chlorine from their operations now have options never before available. "We

have developed something that is completely new and unique to the industry," said Tina Hunter, automotive product manager. "These fluids work best when really pushed to the limit. The tougher the operation, the better results we see. The performance of these fluids is significantly better. They have outperformed some popular heavy duty, sulfo-chlorinated oils by up to 300 percent. This is a huge jump in technology." Products include Cimtech 627 (a synthetic fluid used in heavy duty machin-

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Manufacturing and Pursuit of the American Dream: *Reality or Fool's Quest?*

By Jack McGuinn, Senior Editor

"The 'American Dream' is that dream of a land in which life should be better and richer and fuller for everyone, with opportunity for each, according to ability or achievement."

~ from American writer and historian

James Truslow Adams' *The Epic of America*

"They call it the 'American Dream' because you have to be asleep to believe it."

~ George Carlin

It wasn't so very long ago that a high school-educated, able-bodied person with a will to work typically had little trouble finding a decent job in manufacturing. Whether at an area job shop, an OEM plant or auto plant—work was to be had. Work that paid well enough to marry, buy a home, feed, raise and educate a family—with even enough left over for a modest retirement pension.

There was also a time when government-fueled jobs programs were not the "third-rail" political risk they have become today. Example: In 1956 President Eisenhower's Federal Aid

Highway Act was passed—with strong bipartisan support—that led to millions of jobs for Americans. (While the bill's collateral damage inflicted upon many of the country's urban centers—Chicago, Oakland, Atlanta, for example—is another story altogether.)

Things change—witness the battle over the president's stimulus program upon his 2008 election. It eventually passed, but in a partisan, much-weakened version. (Can any rational person envision any reality-based scenario in which a "big government" employment stimulus program such as that could ever pass in today's Congress? Say, perhaps, a nationwide infrastructure build-and-repair program (bridges, roads, schools, etc.)?)

Meanwhile, today's workplace—even, to a lesser degree, our military—is equally represented in numbers—if not pay, by women. They are commonly

referred to as "working women," "working moms" or "career women." Setting "nuclear" family issues aside, reasonable people would agree the struggle for equal rights by and for women was hard-fought and a long time coming. Indeed, Archie Bunker doesn't live here anymore.

Here's the question—define "middle class" as you will—but does it in fact still exist? Or has it been banished to the same dark corner as our nation's fading manufacturing spirit? What has become of what once was the symbiotic relationship enjoyed for decades between the majority of the country's working citizenry and its manufacturing entrepreneurs, i.e.—our greatest jobs producers?

According to a report issued in August by the Pew Research Center, middle class households—with incomes between \$39,000—\$118,000—experienced its "worst decade in modern history" due to income reversals not seen since the end of World War II.

And reported in an August 2012 *Associated Press* story by Hope Yen,



"These are the disaffected middle class who work hard and play by the rules of society, but increasingly see their situation declining by forces beyond their control," said Timothy Smeeding, a University of Wisconsin-Madison economics professor. "The climb back up for the middle class and the recovery will be slow and often painful."

Also from the AP story in reference to the Pew report: "The notion that the middle class always enjoys a rising standard of living is a big part of America's sense of itself. And in modern times, it's always been true—until now," said Paul Taylor, executive vice president of the Pew Research Center."

Henry R. Nothhaft, in an opinion piece in *Bloomberg News* last year, says "Given how desperately the U.S. needs jobs, it's amazing how little effort Congress and the president devote to revitalizing manufacturing—the most potent of all job creators. For more than 30 years now, economists and policy makers have instead worshipped the false God of 'comparative advantage,' believing that the U.S. could prosper by specializing in innovation while letting China and other nations do the manufacturing. Simply put, manufacturing is what created an American middle class that was the envy of the world. Its loss is now destroying that middle class."

"Recapturing the American dream starts with the manufacturing middle class," says Carlos M. Cardoso, head of Kennametal Inc., in a guest columnist piece in the *Cleveland Plain Dealer* in August. "For decades, good manufacturing jobs allowed workers to own homes and cars, take nice family vacations, satisfy their health care needs, send children to college and retire with financial security."

The above is a brief sampling of a growing crescendo of recent observations from people in a position to know something about the nation's withering middle. Fact is, you can't deal with a problem until acknowledging that one exists.

Some facts we ignore at our peril

- Eighty-three percent of all U.S. stocks are in the hands of one percent of the people.
- For the first time in U.S. history, banks own a greater share of residential housing net worth in the United States

than all individual Americans put together.

- In 1950, the ratio of the average executive's paycheck to the average worker's paycheck was about 30-to-1. Since 2000, that ratio has exploded to between 300- and 500-to-one.
- The bottom 50 percent of income earners in the U.S. now collectively own less than one percent of the nation's wealth. (*Source: Business Insider, 2010—"22 Statistics that Prove the Middle Class is Being Systematically Wiped out of Existence in America."*)

Forget about whether you are better off today than you were four years ago—think generationally. If you are a parent or grandparent—or you simply care about your country—isn't it all about tomorrow? And the tomorrows after that?

Too many of our youngest soldiers enlist in the military simply because no other job opportunities or pathways to training programs exist for them. Think of the GI Bill—the greatest boost to the middle class since the New Deal.

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We invited people from various perspectives to weigh in on the interconnected issues of U.S. manufacturing, a well-trained workforce and what was once known as the “manufacturing middle class.” They are teachers, longtime gear industry experts, AGMA members, businessmen and socio-economic policy influencers. As their comments reveal, they agree—and disagree—strongly on the issues raised here. But there is one hopeful constant: they care. What’s more, each—in his own way—is doing something about it.

Our Panel

Bart Aslin (baslin@sme.org), chief executive officer, SME Education Foundation; **William “Bill” Bradley** (billb111@att.net) former AGMA vice president—Technical Division, winner of AGMA Lifetime Achievement Award and *Gear Technology* technical editor; **Doug Bowman** (dbowman@vinu.edu), HTEC director, Vincennes University (Vincennes, IN); **Scott N. Paul** (spaul@aamfg.org), executive director, Alliance for American Manufacturing; **Jerry Ruble** (jruble@vinu.edu), director, ABB Robotics Lab and Industrial Maintenance Training Business & Industry/ South, Vincennes University; **Chuck Schultz** (gearmanx52@gmail.com), owner/operator, Beyta Gear Service, AGMA member and *Gear Technology* technical editor; and **Dwight Smith** (dsmith@colemfgsystems.com), owner/operator Cole Mfg. Systems, Inc., and current chairman of the AGMA Nomenclature Committee.

Gear Technology: What role would you like to see government and educational institutions do to promote careers in manufacturing?

Chuck Schultz (CS). We need a rational industrial and trade policy. Then we can talk about German-style apprenticeship programs.

Bill Bradley (BB). Provide the manufacturing industries with more incentives, like tax breaks that promote jobs.

Bart Aslin (BA). Besides the funding of a nationwide PR/marketing plan, government should stay out of the way. Lower the tax burden on industry and remove onerous regulations.

Jerry Ruble (JR). I’m not a big fan of government. My view is they are there to protect our county and uphold the constitution. I think it is the job of the manufacturing world to get people interested. (Vincennes University) just signed an agreement with Toyota Motor Manufacturing Indiana to recruit high school students into the high tech manufacturing jobs. It’s called the Toyota Advance Manufacturing Technician program. They will do this by showing the students what is available these days in manufacturing. Then they will agree to hire the students two days a week to work at TMMI while going to school three days a week for five semesters to earn an associate degree. After that, they can choose to continue on to a bachelor’s degree or enter the work force with a well-paying secure job.

Dwight Smith (DS). Promoting manufacturing with incentives for ‘on-shoring,’ for example, will boost manufacturing and therefore, boost careers in manufacturing.

Scott Paul (SP). At the federal level, the Administration has put some resources behind the Skills for the Future Initiative, which already has strong support from industry and academia. This initiative is designed to attract new talent into technical school and community college programs to gain skills certifications for manufacturing careers. There’s also a higher-level need, as well, to ensure that people know the government backs manufacturing and insourcing. Our polling showed that other than aspirations of achieving a four-year degree, the biggest obstacle to getting Americans to pursue manufacturing was a belief that the jobs would be outsourced. The (often cited) ‘dirty job’ and ‘mundane’ aspects of manufacturing were very far down the list of concerns.

Doug Bowman (DB). Just projecting a positive attitude about the importance of manufacturing to our nation would go a long way. I know SME and NTMA do a lot to promote careers in manufacturing. Maybe promoting careers in manufacturing would be a great role for all of the professional organizations to engage in.

Do you believe companies are spending enough to train their own workers?

CS. No, many spend more on landscaping.

BA. Smarter government tax policy should be enacted in order to incentivize ongoing education of our workforce.

JR. Absolutely not! Part of it is the economy; the other part is just competition. Companies are forced to quote their products with lower and lower prices. At some point they are just trying to survive and make 0.5 or 1 percent on their investment. They won’t allocate the money for training because they don’t see the return on their investment.

DS. Most companies do not invest enough in their employees in the way of training. Some company owners have told me that they don’t want to train workers for their competition. However, studies have shown that training employees actually improves employee retention.

SP. I think the mistake that too many companies make is expecting a perfectly suited, highly skilled worker to show up on their doorstep, willing to start for relatively meager wages and needing no additional training. That’s fantasy land. But too many businesses live in it. Investing in human capital is smart and pays dividends. Manufacturers succeed by being lean but also by being smart. There are also companies that have been smart about training, wages and recruitment.

DB. Some probably aren’t, but I think many companies are starting to invest more in training out of necessity.

If you accept the premise that unions once played a significantly positive role, why has that perception changed? Do we blame it all on Jimmy Hoffa?

CS. Cumulative PR by “Big Business” and some real stupidity on the unions’ part; and lots of jealousy from people misunderstanding how much they were really being paid. Who else talks about their salary with benefits and overhead rolled in?

DS. Labor unions certainly played a positive role in protecting workers during a less enlightened time. I believe the perception changed when the

unions became more powerful and failed to put the workers' needs in perspective. They may have become more interested in their own furtherance, and relationships with company management became adversarial.

SP. Unions and management have both made a lot of mistakes over the years, but they have also come together in times of crisis. Large industrial unions like the steelworkers' and UAW have accepted reduced wages, more cost-sharing for retiree health care, and work rule flexibility to help save entire industries. Scapegoating unions serves no real purpose today. Jack Welch helped to lead a wave of corporate outsourcing. President Bill Clinton opened up trade with China without demanding real accountability. Really smart engineers developed robots that replaced workers. Wall Street became the master of manufacturing rather than the provider of capital. Who's really to blame? You tell me.

Aside from the actual training, what more can companies do on their own to generate interest in manufacturing?

BA. They can establish a coalition that will develop a nationwide campaign to inform people about the dignity of all workers and the importance of manufacturing to our future economy.

JR. They need to show the benefits of manufacturing—good pay, good benefits, job security with technical knowledge, etc.

DS. Manufacturers can strive to be good places to work and be involved in their communities.

SP. Putting out the help-wanted sign is a start. For years, manufacturers shed workers without hiring many new folks at all. I'm not concerned about the ability of the large manufacturers to compete for and attract a skilled workforce—otherwise I'd call it a management failure. But there is certainly work to be done in connecting small manufacturers with qualified workers for positions that require specialization or a high degree of skill.

DB. I think that the companies that provide frequent, upbeat tours of their plants, educate people about the benefits of manufacturing to the local and national economy, sponsor students in training programs, and provide internships generally generate a lot more interest, and are more successful in filling their skilled positions with qualified people.

Is time to stop blaming China for everything?

CS. Why blame them for acting rationally? Blame the people in Washington and London who set this system up for their gain. Check out Billy Bragg's NPWA (No Power Without Accountability).

BA. Global competition spurs innovation and growth in the U.S. (Facing the challenges that global competition offers will lead to improved productivity and innovative processes.

BB. I don't blame China. They have taken every economic advantage that world governments have let them have, and will soon own the U.S. if we let them. (Our) government needs to change the things that have driven the majority of manufactured products sold in the U.S. to be manufactured (outside) the U.S.

DS. It never has been correct to blame China. If we became complacent and failed to compete, we have no one to blame but ourselves.

SP. No—I don't think China is blamed nearly enough. Yes, we must get our 'own house' in order, but China is a blatant rule-breaker: on currency, intellectual property, government subsidies, technology transfer, labor rights, environmental regulations, rule of law, piracy, etc. But so many multinational companies have a China-centric sourcing strategy that it would cause a lot of pain to stop China's cheating. The bottom line is that I blame our government for not holding China accountable. We're not acting in our own national interest when we let China get away with cheating on trade rules.

DB. I think that China is only taking advantage of our follies. They are using basically the same manufac-

A Better Way

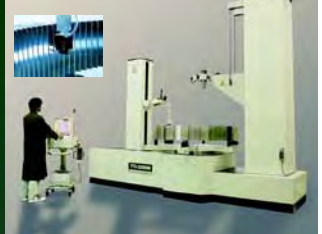
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turing model that we did to become a prosperous nation: capitalism. The interesting thing is that they are doing it in spite of the handicap of being a communist nation. Sure, it is well documented that some leaders in China promote suppressing their currency, stealing intellectual property and disregarding patents, but perhaps America has also helped to sponsor China's industrial growth. I think that the world is big enough for (both) China and the United States to be manufacturing giants. I have met many Chinese workers and they are good people, very hard working and friendly. They deserve a good quality of life also and manufacturing can provide that. I think some of the blame for our financial problems should fall rather to the greedy and powerful 'elite' financiers that work mostly behind the scenes to promote damaging agendas to their own financial gain.

Our middle class—some refer to it as “the manufacturing middle class”—is shrinking and in danger of eventually losing its majority status (nearly 6 million factory jobs lost since 2000—NY Times).

CS. (Due to) totally reciprocal trade agreements. If you have tariffs on my stuff you get the same tariffs on yours. Brazil charges an 80 percent tariff on goods that could be made in-country. Any surprise they are growing so fast?

JR. (We need to) control the amount of people entering the country; keep jobs in our country and not send them to other countries. Then, figure out how to compete with the other up-and-coming countries.

BB. First, I am not sure what defines middle class. Is it wages, net worth, type of job or what? If the average wage or net worth increases, is there more in the 'middle class,' more rich, or less poor, a combination, or what? There seems to be moving definitions of poor, middle and rich, depending on political need. We need to change our cultural perspective on class. Perhaps there are those that can live without assistance, contribute, and those that can't—some of which take from government. Job

loss or gain and unemployment are (other) areas where there seems to be a disconnect in definition.

DS. The emphasis on non-value-added activities, i.e.—financial services—has caused the best and brightest to seek their fortunes there rather than in science and engineering. When manufacturing is once again strong, young people will want to be part of it.

SP. When manufacturing is doing well, our economy does well. We are exporting more, creating jobs that pay relatively well. It means the 'ripple effect' produced by manufacturing and its value chain has a larger impact. Manufacturing is not likely to ever employ 30 or 40 percent of our nation again, but that doesn't mean its impact is unimportant. We need a smart (national) manufacturing policy (addressing) taxes, trade, innovation, infrastructure, skills and energy.

Do you envision any scenario in which Washington—or at the state level—would enact an education program based on the GI Bill model that would incentivize young people to pursue—or teach—STEM-type coursework—science, technology, engineering, and mathematics?

JR. I think a program like that is a real possibility. I think a program could be started to have the STEM educators that are off work in the summer work with local companies and manufacturers so they can keep up with this very quickly evolving technology in manufacturing. I think this would strengthen the relationships between education and manufacturing. The manufacturer would receive help in the form of not only another headcount (everyone is running extremely lean now days), but someone with a very good understanding of manufacturing that could pick up and be productive quickly. The educator would benefit by seeing the newest technology and how manufacturers really manage and react to the changing work environment. While the educators are (embedded) there, they could make suggestions of other types of training that would help improve the skills of current

workers. There are a lot of pluses on both sides when you start to think through the possibilities.

BA. One of the most promising (STEM programs) is in the area of providing funding to those who will begin their post-secondary education at community colleges. This gives a tremendous boost to young learners and also allows them the opportunity to figure out what educational path and eventual career path fits their passions. Too many young people are pushed into four-year institutions, only to leave during their first year with debt and frustration over their future. (Government) needs to understand that all people deserve the opportunity to pursue lifetime learning. (But we must first) fix the STEM problem at the elementary, middle school and high school level. The SME Education Foundation (and) Project Lead the Way are dedicated to (that).

BB. We can't cure a perceived problem with young people pursuing coursework in science, technology, engineering and mathematics by using taxes to reduce an individual's secondary education costs or increase pay to educators; manufacturing jobs still operate on a supply-and-demand basis. We need to have government make it desirable to return manufacturing jobs on-shore and promote them to stay in the U.S. Thus there would be a greater need for those who pursue science, technology, engineering and mathematics to support manufacturing.

DS. Unfortunately, it may take a further decline in America's status and position in the world to make education the priority it needs to be (and the priority it is overseas). For example, a recent study reported that the U.S. ranked 25th out of 50 countries in math literacy.

SP. I think there is general awareness among our lawmakers of the need for more Americans to pursue STEM education and careers. We're falling behind—there's no doubt about it. We may be at such a crisis stage that the time is right for a GI Bill-like effort.

Hypothetically, would you want your son or daughter to have a career in manufacturing?

CS. I discouraged it.

JR. Yes, it's a good job. Making stuff (manufacturing) is the building block for everything else in the economy.

DS. I hope for an America where my grandson can have a fulfilling career in manufacturing.

SP. Absolutely. I have twin five-year-olds (boys); they love to tinker and imagine. I hope they never lose that. I enjoy nurturing those innate abilities. There are lots of careers in manufacturing. I hope they will strongly consider whether or not such a career makes sense for them.

DB. Yes! I have four children in manufacturing careers already and more to come.

BB. Yes. 



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If Only We Had a Crystal Ball ...

Insiders Weigh In on the Present and Future of Gear Manufacturing

Matthew Jaster, Associate Editor

Before we get into projections and prognostications about the future, let's take a minute to review 2012. For many in the gear industry, the year was better than expected. Some manufacturers had a very successful year leading up to an even more successful manufacturing trade show (IMTS 2012). Others were searching for more business, hoping that the general state of the economy wouldn't make things worse. In some cases, it did.

Some companies invested a great deal in manufacturing education and training while small job shops tried to hang on to what's left of their skilled workforce. There was optimism, pessimism and perpetual talk of fiscal cliffs, economic uncertainty and political turmoil. 2012—for all intents and purposes—can be summed up in one word: polarizing. You'll see this in the quotes from gear manufacturers throughout this magazine as well as data collected for our 2012 State of the Gear Industry Survey (*Ed's note:*

See survey results starting on page 32).

But like other segments of manufacturing, the gear industry endures, simply because it has to. North America remains one of the largest manufacturing sectors in the world, producing more than 20 percent of the world's manufactured products. Whether business was slow and steady, fast and furious or underwhelming in 2012, there's work to do in 2013. Plan accordingly.

The Gear Market Today

In our 2011 State of the Gear Industry survey, respondents reported that the significant challenges to their business included lack of skilled labor, material costs, the overall economy and supply chain issues. These continue to be prevalent one year later.

"Growth of the world's major economies stalled in 2012 after beginning to recover from the recession," says Joe Franklin, AGMA president. "China and Europe are suffering more than North America, but orders from most end-markets turned down this summer. The United States had a good run from 2010 to the middle of 2012, but seems to have stalled. Additionally, coping with the volatile, uncertain political environments here in the United States (taxation, health care, fiscal issues, etc.) and the related uncertainty makes mid-to long-term planning difficult."

"We've been very pleased with overall sales in 2012, though we noticed customers

pulling back in the summer,” says Fred Young, owner and operator of Forest City Gear in Roscoe, Illinois. “I expect it to pick back up again at the end of the year.”

“There is a lot of uncertainty,” adds John Walter, president and CEO of Precipart Corporation, located in Farmingdale, New York. “We saw a lot of programs pushed out as our customers waited for the outcome of the election. Some programs may disappear entirely. Budget cuts and deficit reduction will come into play no matter who is in office. Meanwhile, we remain in touch with our customers in order to react to changing demands.”

“I think there will be a slight contraction in 2013, compared to 2012,” says Dylan Smith, president of Vancouver Gear Works, located in Richmond, British Columbia. “The economy has leveled off or slightly declined after the initial strong recovery.”

Joseph L. Arvin, president of Arrow Gear, located in Downers Grove, Illinois, believes things look OK today for Arrow’s gear business, but it could change overnight. “Not knowing what is going to happen with the sequestration and its \$109.3 billion cut per year could be devastating, because 35 percent of my work is in government defense.”

Arrow Gear’s challenges include the banks’ unwillingness to loan money, finding skilled help and the state of taxes and EPA regulations. “I wish the banks would give us more money for the latest equipment and the U.S. government would help manufacturing like other countries who realize it’s the backbone of economic growth and prosperity for the middle class,” Arvin says.

“The general economy is affecting us, particularly the work we do in business jets,” Walter at Precipart says. “The cost, quality and lead-time issues related to supply chain led us to bring in some secondary operation capability in-house, which will help us control processes and ultimately keep us highly competitive.”

“We had a lot of management turnover in 2012, which is both a challenge and an opportunity,” Vancouver’s Smith says. “It was difficult to find skilled workers in 2012, but the workforce we have now should carry us through 2013.”

But much like *Gear Technology’s* survey respondents, the skilled labor shortage remains the *greatest* challenge. “Machinists are a dying breed and this shortage of skilled labor



Fred Young,
Forest City Gear



Joseph L. Arvin,
Arrow Gear

will be a major drag on business performance unless companies employ strategies to overcome hiring difficulties,” Walter says.

“Some AGMA members are looking for a couple of people, but a number of companies are looking to hire 10 to 20 today. End markets are not being fully served,” Franklin says.

AGMA’s Education Advisory Council and the Board of Trustees are doing their part by developing a Skills Assessment document that will allow manufacturers to evaluate the current and needed skills for a variety of production and engineering positions, including machine operators, gear technicians, engineers, maintenance workers and managers.

“One of the most expedient ways to help younger engineers or those new to a technical topic is to get them involved with the industry’s technical community. AGMA’s 25 technical committees continue to develop standards on focused topics, including the analysis of micropitting and gear failure from sub-case crack initiation. There’s no better way for an engineer to learn a subject in great detail than working side-by-side with the industry’s top subject matter experts,” Franklin says.

“One of the top priorities for Citizens for American Manufacturing (CAM) is to high-profile the need for entry level employees to have some basic machining skills which can be provided by high schools, trade schools and colleges,” Arvin says. “It’s also to educate parents, teachers and our politicians about the need for an educated and trained technical staff.”

“I think the most serious skill deficiency is with the new machinists,” Smith says. “It is very hard to find someone who is capable of working with modern equipment but also understands theory and practical aspects that a manual machinist would understand.”

The Promise of IMTS

In September 2012, IMTS in Chicago attracted more than 100,000 registered attendees for the first time in more than a decade. “The energy level among visitors and exhibitors was at an all-time high,” said Peter Eelman, IMTS vice president – exhibitions and communications in a press release. “The most exciting take-away from IMTS 2012 is what it says about the prospects for manufacturing over the next year. The overall activity and buzz indicates that we are entering a period of sustained growth that will fuel economic prosperity and job creation.”

The most telling sign of the future of U.S. manufacturing may be the emphasis on process integration displayed during the show. Large machine tool companies like DMG/Mori



Joe Franklin,
AGMA

Seiki and Mazak continue to release multifunctional machines that include a variety of gear operations. Additionally, the collaboration/partnerships between Gleason/Heller, Star SU and MAG and the recent acquisition of Höfler by Klingelnberg, support the theory that flexibility, productivity and quality will be addressed in single machine operations in the future.

"We've watched the industry consolidate for decades. Most of the combinations were between smaller and larger companies," Franklin says. "Over the last few years, several mergers have been between larger companies. The demands of greater technological capability and a more global reach demand larger companies. Customers in developing markets want the same high quality as those in the most developed parts of the globe. Meeting these demands is complex and costly. Another factor supporting mergers gets back to the availability of management knowledge and skill. Some very fine manufacturers do not have a very deep management bench."

On the gear manufacturing side, companies like Forest City Gear work frequently with others in the industry. "You don't find many people who are as open with peers and competitors, but we regularly provide work for a number of our friends in the industry. Collaboration is becoming the norm," Young says.

"It has been interesting to see this happen," Smith adds. "It seems to be letting each company focus on their own expertise rather than trying to be everything to everyone. Mind you, the openness and cooperative spirit is something that has always uniquely characterized the gear industry in my mind."

Making Progress

AGMA's recent Fall Technical Meeting included topics on higher processing speeds, multitasking machine tools, advance heat treating capabilities, advanced gear design software and improved lubricants to enhance wear and efficiency. The technology is improving, here's hoping there's a stable market for it.

Regardless of economic forecasts, uncertainty has not stopped the gear community from investing in new equipment and their workforce. Downtime has always given organizations an opportunity to play "catch up" and prepare for the next business cycle.

"We've increased our workforce this year throughout the organization," Walter says. "This increase is to prepare for forecasted ramp-ups in key aerospace and medical technology programs. New machinery is allowing us to hold tighter tolerances while increasing throughput."

"It's not just the acquisition of more machines that operate faster and better than we need, but now more and different types of tooling



John Walter,
Precipart Corporation

and attachments are available to optimize productivity and the quality of parts produced."

"We've spent \$3.5 million in new equipment over the last 18 months," Arvin adds. "We have hired 60 people during the same period."

"I've never met a gear machine I didn't like," quipped Young when discussing machine investments. "We're constantly buying new equipment that enables us to provide rather unique capabilities in the size range and the types of gears we manufacture. There's no plan to change the way we approach our business in the future."

"I am investing in workforce training for our existing staff because I think it's always important to improve your skills," Smith says. "I will also be replacing/upgrading some of our aging equipment."


Manufacturing technology orders are up, according to the AMT, and Washington D.C. has promised a renewed focus on clean energy and science and engineering education. So what needs to be done to keep gear manufacturing on the right track, moving forward?

"We must continue to grow our custom-engineered, value-added assemblies for customers in our core industries," Walter says. "Additionally, we will utilize our continuous improvement team to find opportunities for us to operate leaner and more efficiently, while remaining focused on providing world-class customer service."

"It is a relief to see that the public is viewing manufacturing as an important part of our economy. There has been a lot of talk about on-shoring or re-shoring this year, and consumers are starting to pay more attention to where things are made, and seeing that as an important factor in their purchasing decisions," Smith says.

The image and realization that manufacturing is important *has* improved in the public eye, according to Arvin. Now it's time for the manufacturers to validate this by continuing to produce the very best products.

Though no one knows what's really in store for 2013, more substantial evidence should be collected by the time the industry regroups in Indianapolis for AGMA's Gear Expo (September 17-19, Indiana Convention Center).

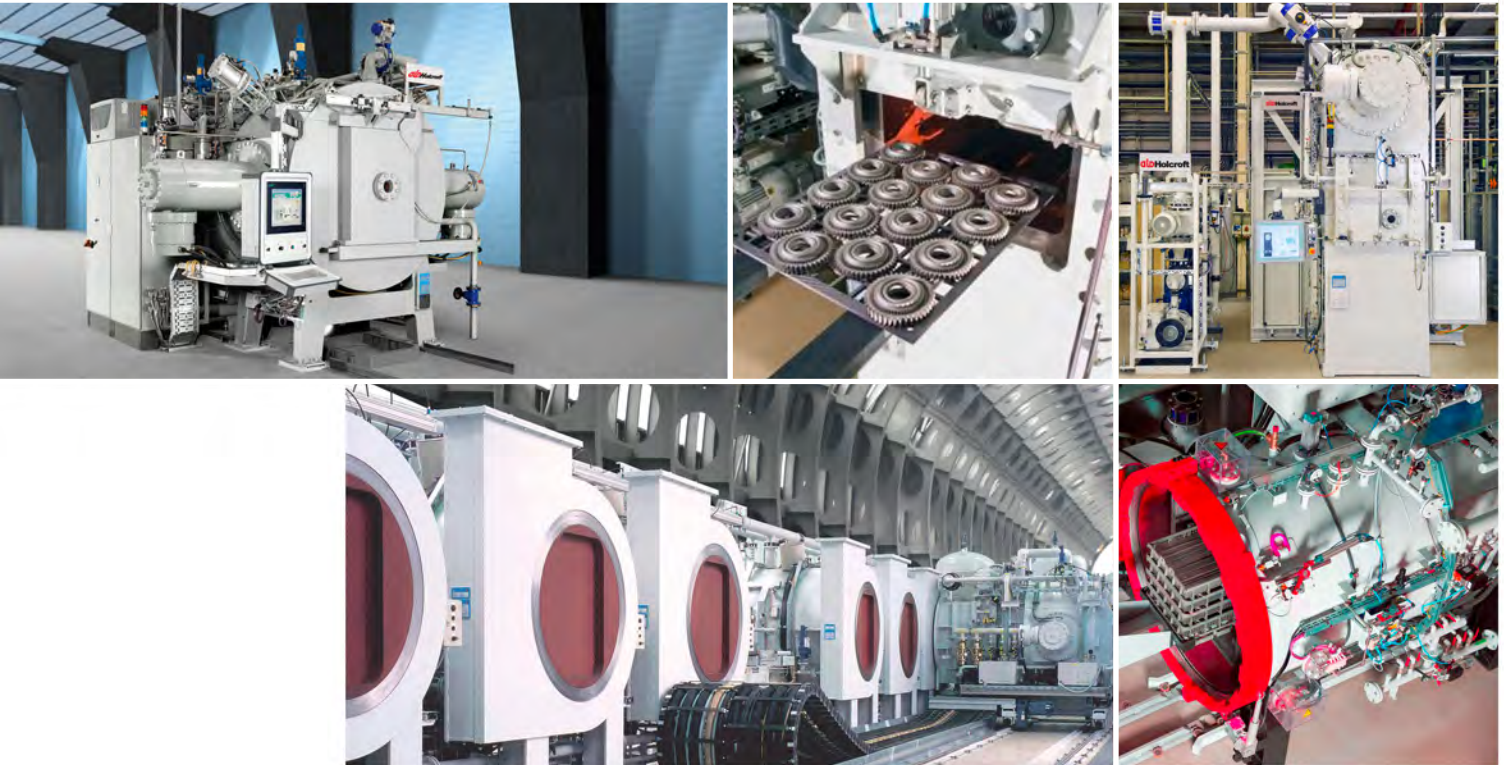
"Predicting the future is beyond my abilities, but I do believe that our industry has many very talented and clever individuals," Franklin says. "The manufacturers of machine tools, tooling and related products will continue to push the envelope. Customers will continue to be demanding—as they should—which will drive our industry to bigger and better solutions." 



Dylan Smith,
Vancouver Gear Works

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2012 State of the Gear Industry

Reader Survey Results

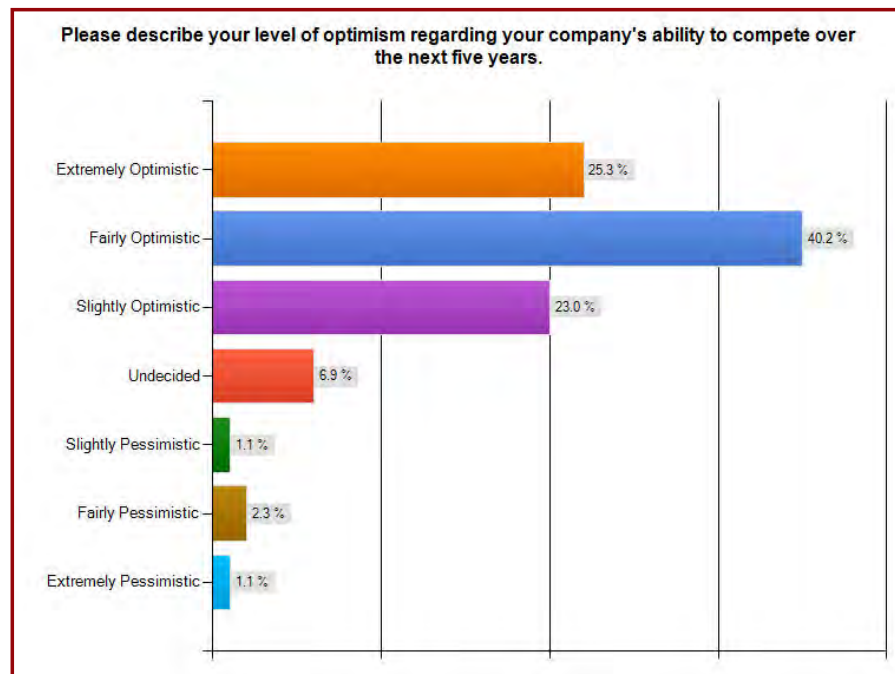
Gear Technology's annual state-of-the-gear-industry survey polls gear manufacturers about the latest trends and opinions relating to the overall health of the gear industry. As in years past, the survey was conducted anonymously, with invitations sent by e-mail to gear manufacturing companies around the world.

Hundreds of individuals responded to the online survey, answering questions about their manufacturing operations and current challenges facing their businesses.

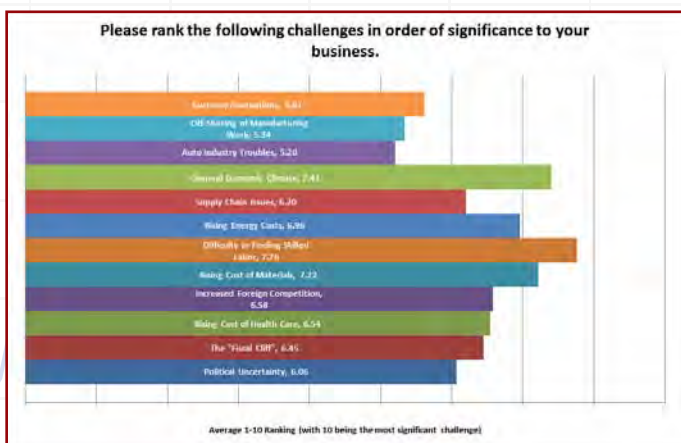
All of the responses included in these results come from individuals who work at locations where gears, splines, sprockets, worms and similar products are manufactured. They work for gear manufacturing job shops, captive shops at OEMs and end user locations.

A full breakdown of respondents can be found at the end of this article.

Gear Industry Optimism Remains High A Look at the Results



Significant Challenges



"European quality and Asian price is the concept of OEMs nowadays."

"Global economic climate."

"Uncertainty on a global scale."

"Health care costs."

"Retaining and nurturing skilled employees."

"Economic slowdown in Europe."

"Four more years of Obama."

"International shipping costs."

"Maintaining a high level of quality at all locations."

"Process optimization."

"Labor with low skill level."

"Maintaining the current level of business in light of perceived softening of the economy."

"Do more with less."

"Meeting rapidly changing customer requirements."

"Trained workers and money available for new equipment."

"Lean six-sigma implementation."

"Increasing capital spending to a level commensurate with long-term financial success."

"Find ways to reduce cost!"

"Getting and keeping qualified machinists and engineers."

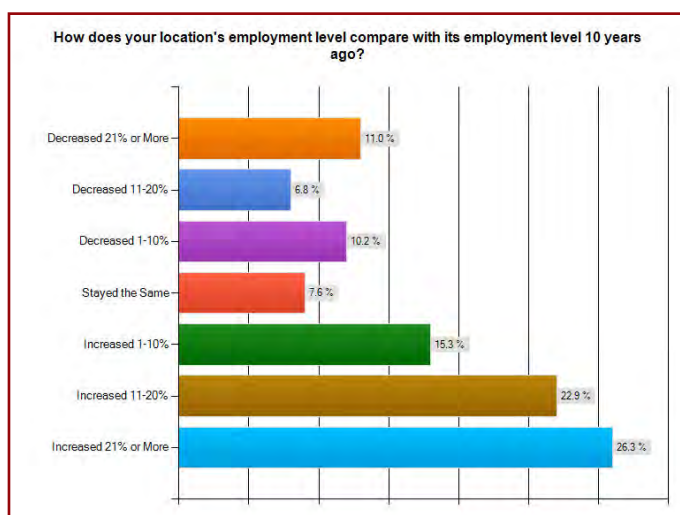
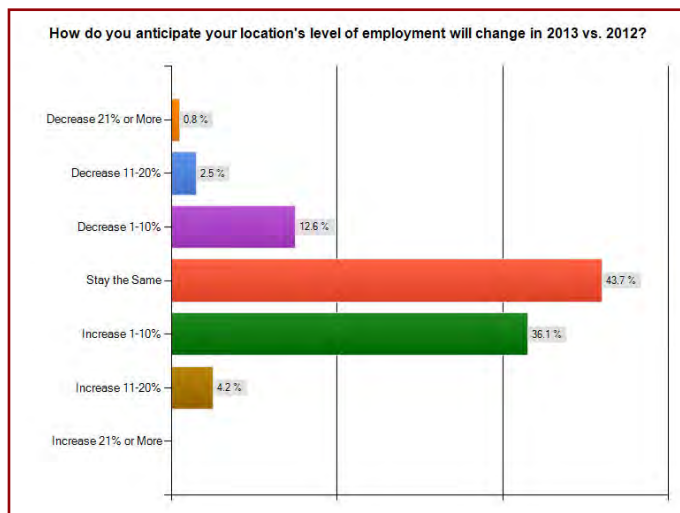
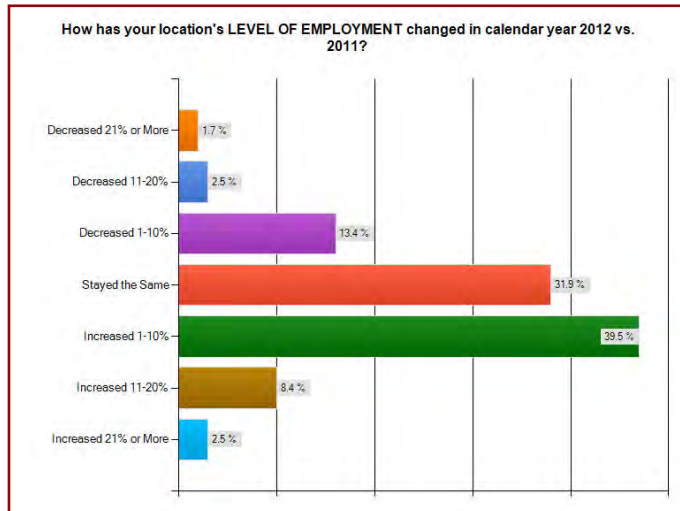
"Implementing Lean in more areas and reducing the cost to manufacture."

"Need for increased capacity and the capital cost of providing this when other companies have excess capacity."

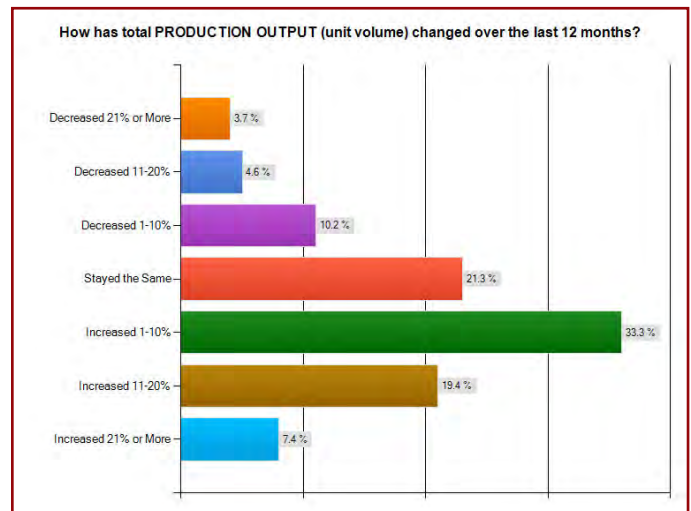
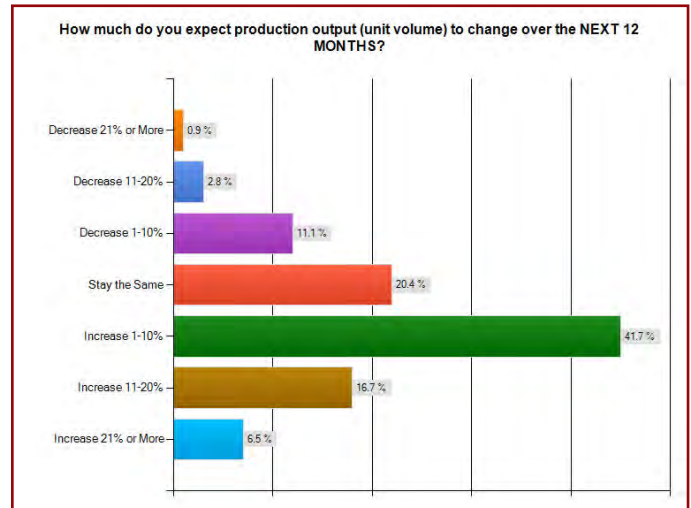
"Skilled production labor and skilled process engineers. OEMs are outsourcing more and losing their internal experience and expertise. They look more and more to the supply chain for gear expertise."

"The increasing problem of finding skilled labor."

Employment



Production Output



Why was production up this year?

"Sales were up."

"Gear units are getting larger; increase of production capacity."

"New orders."

"Increased demands from our customers."

"Business growth."

"Increased car sales."

"Boom in business."

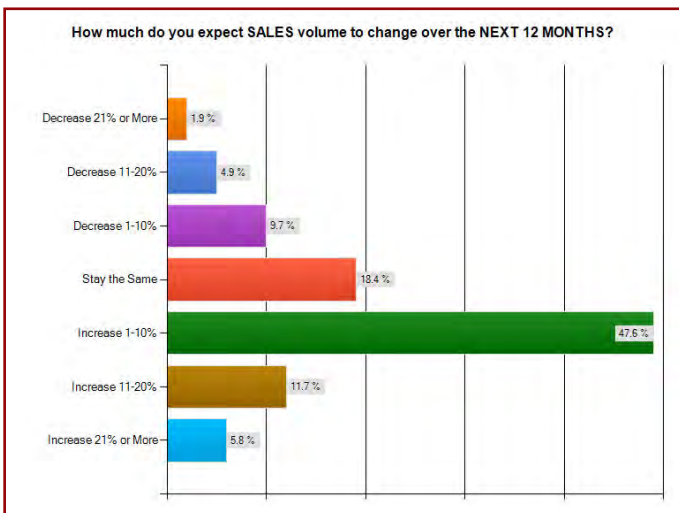
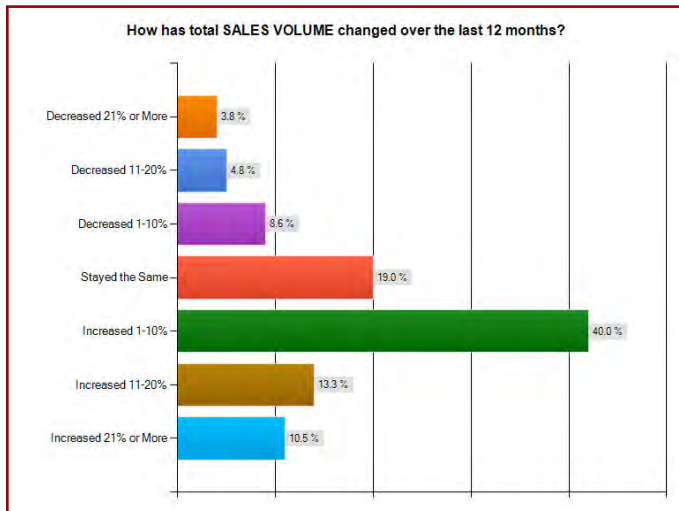
"Added solar energy customers."

"Industries like steel and automotive doing well."

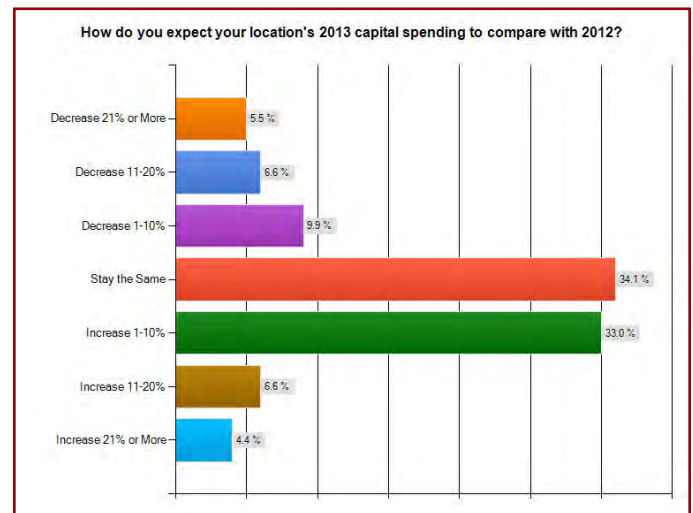
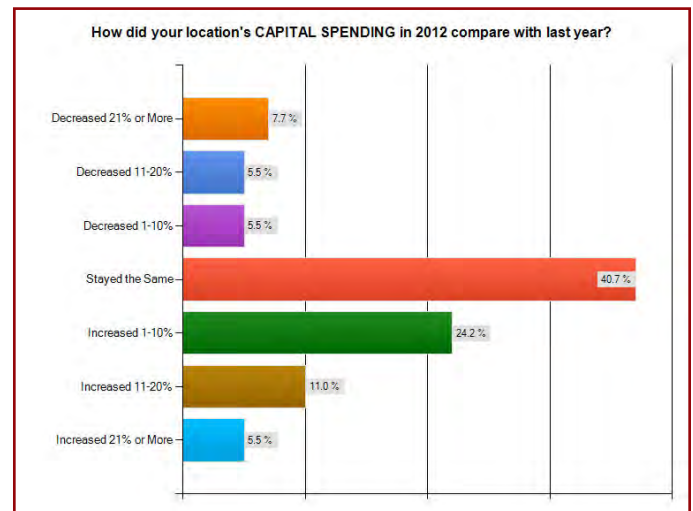
"Offshore supplemental product dramatically greater portion of product mix."

"Equipment acquisitions and increased staffing of 2nd shift."

Sales Volume



Capital Spending



Why were Sales up this year?

"New markets, new applications, utilization of group of companies sales network."

"Business growth."

"New programs."

"New orders/customers."

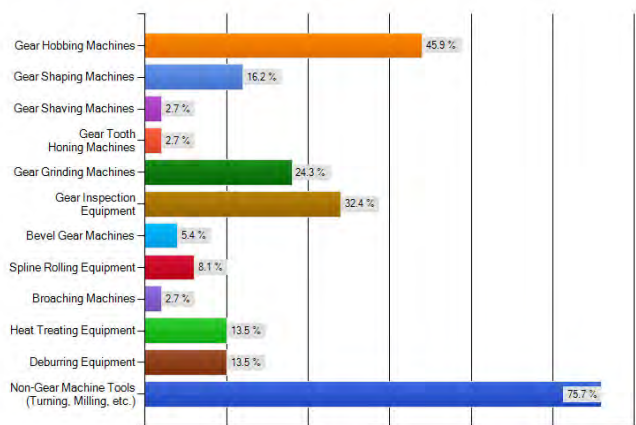
"Mining increase, primarily."

"Increased workload and increased pricing."

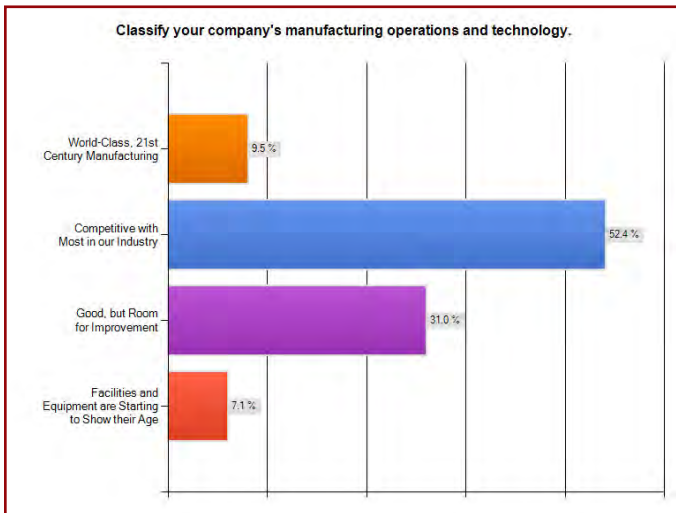
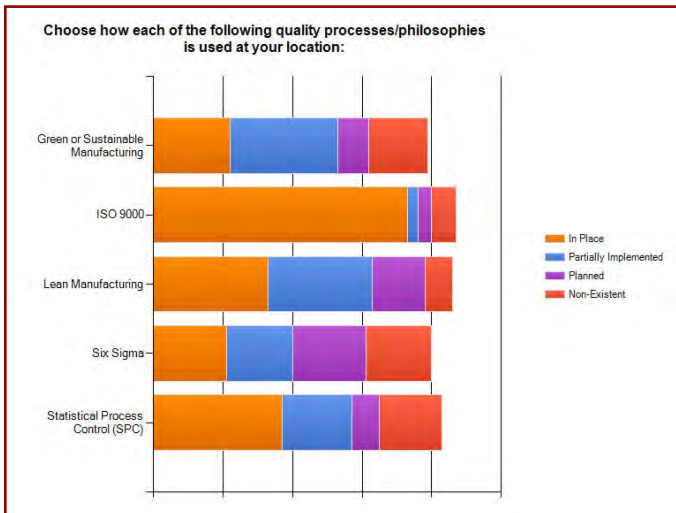
"New customers."

"A large sales increase occurred in the first half of the year, followed by a substantial reduction in volume."

For which production functions do you expect to purchase equipment in 2013? (check all that apply)



Quality



What other quality processes or philosophies are used at your location?

"Opex."

"5S."

"TPM, TBEM."

"TQM."

"Kaizen, productivity improvement."

"TQM, 5S."

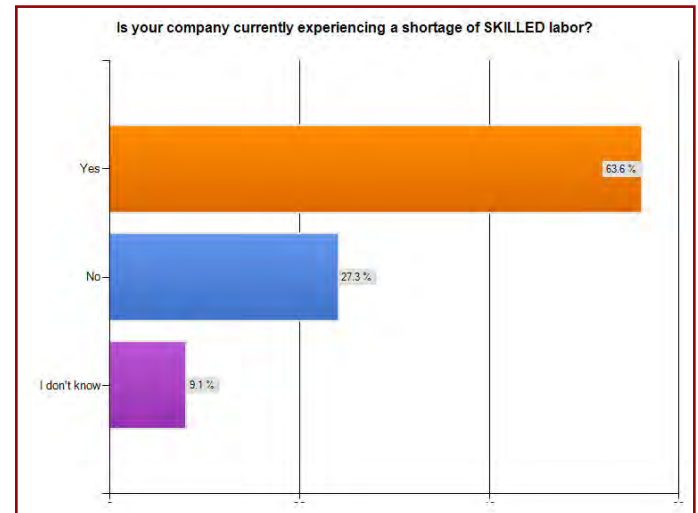
"ATEX."

"Automatic process validation and tracking."

"ISO/TS-16949, AS-9100, MIL-I-45208A, MIL-STD-45662."

"RoHS, REACH."

Skilled Labor



"Average age of skilled machinists rising rapidly."

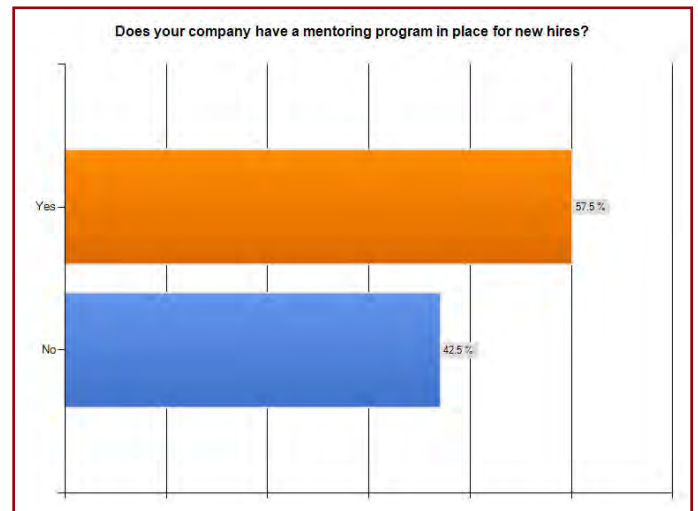
"Plenty of workers looking for jobs."

"Shortage of technical staff."

"Gear knowledge is going away fast."

"Cannot afford truly skilled labor."

"Good people are always hard to find and sometimes hard to keep."



How successful is your current mentoring program?

"It is important for new employees to identify with the entire 'Team' before commencing with their full-time job."

"It's far from perfect."

"It will create trust and support for new employees."

"Very successful. The older workers share their knowledge/skills with the new, inexperienced workers."

"Seems valuable but hard to measure."

"Not sure yet, it's relatively new."

"Just started this year, no measurable results yet."

"Only way to get people in this area."

"GOOD."

"It is new here - results pending."

"Still in the early stages."

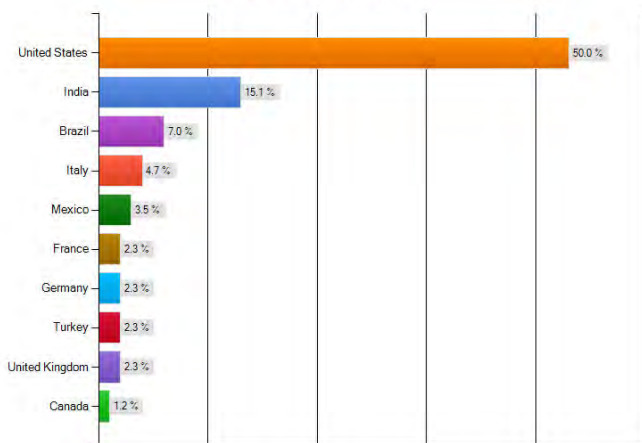
"Very successful; less resistance to lead people taking time off."

"New hires are put in a structured program to give them a taste of every aspect of the company."

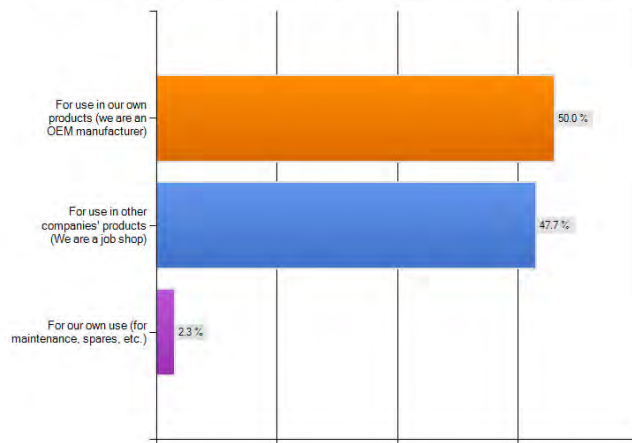
"For new engineers it has been very helpful in learning their job."

Demographics

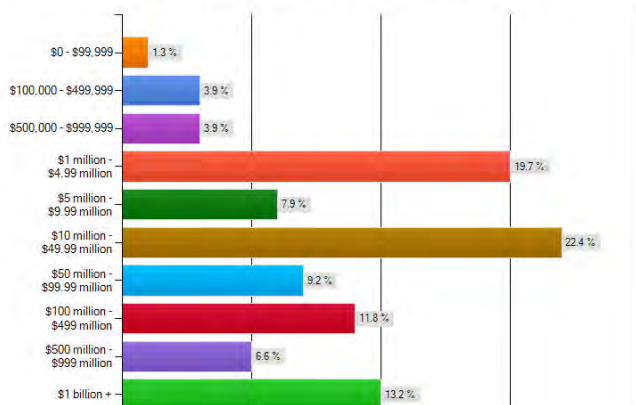
In what country are you located?



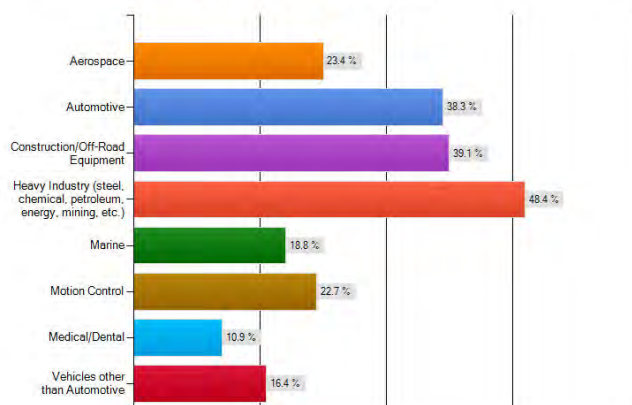
Gears (including splines, sprockets, worms and similar components) are manufactured:



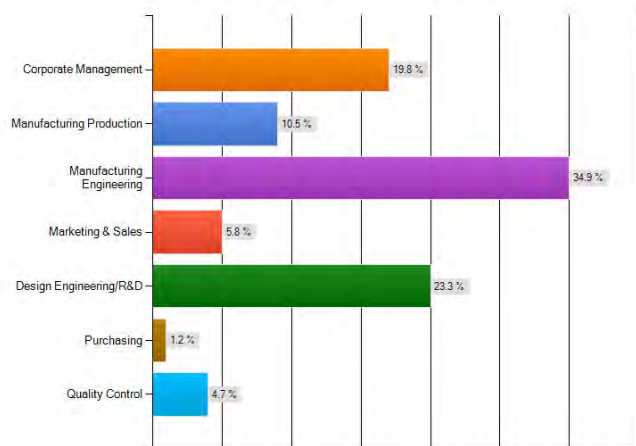
What is the approximate annual revenue for your company? (If this location is owned by another company, please use figures from the corporate parent)



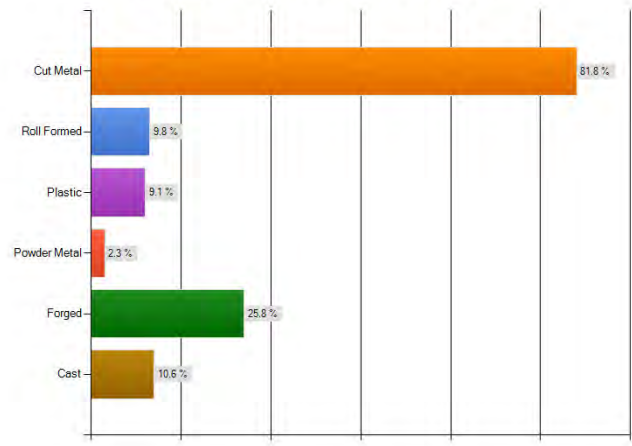
The gears (including sprockets, splines, worms and similar components) made at this facility are used primarily for (check all that apply):



Which category best describes your job title/function?



The gears manufactured at this location are primarily:





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Gear Industry Buyers Guide

About This Directory

The 2012 *Gear Technology* Buyers Guide was compiled to provide you with a handy resource containing the contact information for significant suppliers of machinery, tooling, supplies and services used in gear manufacturing.

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

But Wait! Where are the Gear Manufacturers Listed?

If you are looking for suppliers of gears, splines, sprockets, gear drives or other power transmission components, you will find our comprehensive directory in the December 2012 issue of *Power Transmission Engineering*. If you can't wait for that issue, you can also visit our online directory at www.powertransmission.com.

How to Get Listed in the Buyers Guide

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

Handy Online Resources



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

www.geartechology.com/dir/



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

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www.americanbroach.com

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www.IpsenUSA.com

For more information, please visit
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Fax: +(49) 7123-18384
geiger@geiger-germany.com
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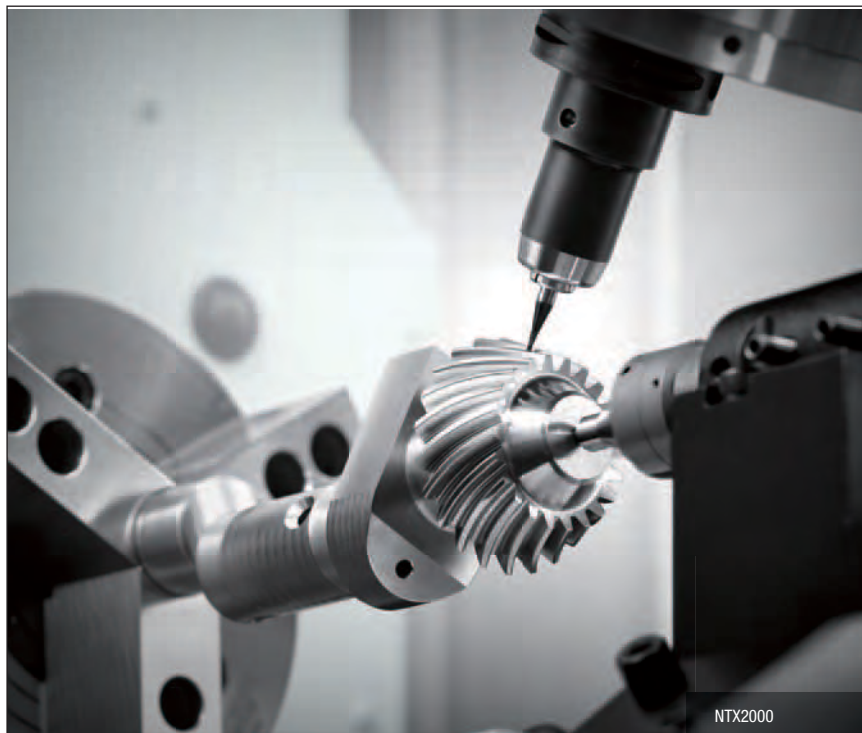
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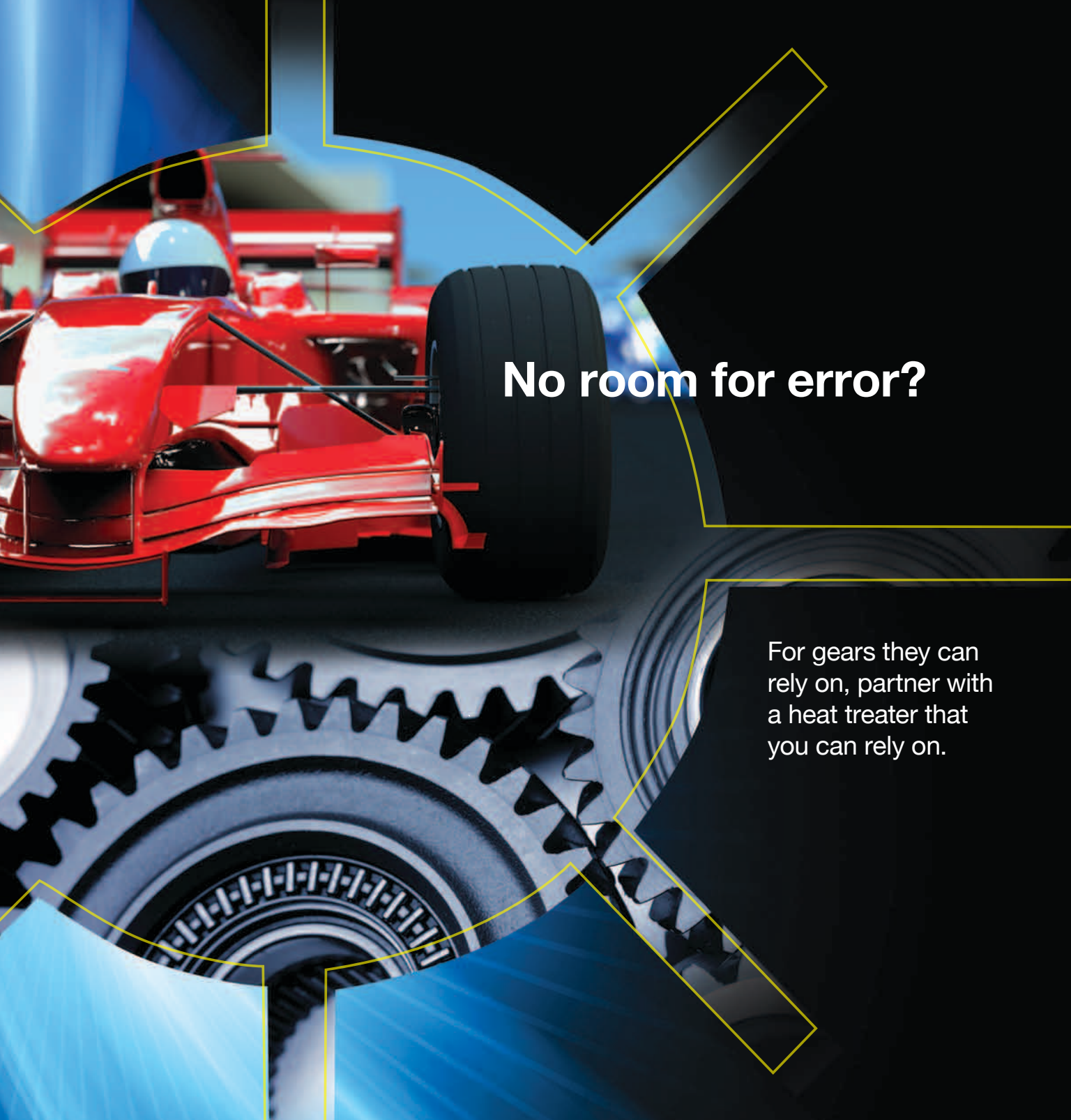
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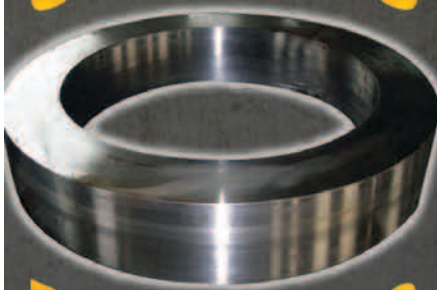
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1

ORIGINAL CONDITION

In-production 24/7; mechanically worn and controls outdated.



2

REMANUFACTURED

Mechanical gear trains replaced by servos, ballscrews installed, hydraulics redesigned, Turcite added to slides, reduced drive trains, geometry corrected, and fully CNC controlled setup.



3

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GOT A GEAR QUESTION?

Ask the Expert!

Welcome back to *Gear Technology's* Ask the Expert—our popular regular feature intended to help designers, specifiers, quality assurance and inspection personnel in addressing some of the more complex, troublesome gearing challenges that never cease to materialize—whether on the drafting table or the shop floor. Simply email your question—along with your name, job title and company name (if you wish to remain anonymous, no problem)—to: jmcguinn@geartechnology.com; or submit your question by visiting geartechnology.com.

QUESTION

Gleason Machine Set-Up

We have a Gleason 116 and we want to cut a 4/49 ring and pinion set. We have cut the ring with a 6" cutter diameter on a Gleason 22. No formate type, but we are not able to develop the pinion with a 6" cutter.

The 116 Bevel and Hypoid Gear Generator (Fig. 1) is a mechanical machine that was designed for cutting gears and pinions from five teeth to 99 teeth with a limiting ratio of 10:1. In some cases—where the number of teeth is small, the ratio high and face width long—the total amount of cradle roll and work roll becomes very large. The large work roll can't be handled by the mechanical drivetrain of the No. 116 machine. For these conditions there was a special version of the No. 116 machine with special features that was renamed the No. 121 High-Reduction Hypoid Gear Generator (Fig. 2). The No. 121 machine was capable of cutting one-tooth pinions and virtually any desired ratio. The No. 121 machine modifications consisted of one additional source of motion in



Figure 1 Gleason No. 116 bevel and hypoid gear generator.



Figure 2 Gleason No. 121 high-reduction hypoid gear generator. the drivetrain. This was a separate motor which drives the cradle and work spindle, while the standard main motor drives the cutter and the feed cam. The added motor drive is a variable speed unit which permits fast return after the relatively long generating roll required for pinion teeth under five teeth with a high ratio. The No. 116 and No. 121 are no longer offered by Gleason, but a Gleason Phoenix machine (Fig. 3) is ideally suited for cutting these types of gear sets.

The gear set in question—4 × 49 with a ratio of 12.25:1—would require approximately 31° of cradle roll and 368° of work roll to generate the pinion tooth form. Therefore, this gear set would be considered beyond the capacity of a standard No. 116 machine.



Figure 3 Gleason Phoenix 280C universal bevel gear cutting machine.

The pinion development procedure for low teeth numbers and high ratios is somewhat different than a normal hypoid or spiral bevel gear set. The following cutting changes were developed by experienced operators and can be used to develop a left-hand pinion.

Topping or flanking changes:

- **Machine offset:** Down, flanks—both sides
- **Machine offset:** Up, tops—both sides

Toe or heel changes:

- **Eccentric angle:** Plus, towards heel—both sides
- **Eccentric angle:** Minus, towards toe—both sides

From the basic data mentioned in the question, there is no reason why a 6.00" diameter cutter could not be used for this design. However, this could be better determined by a bevel gear application engineer after knowing all the required gear design data, such as pressure angle, spiral angle, face width, etc.

Anthony J. Norselli
Gleason Corp.

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Morphology of Micropitting

R. L. Errichello

Understanding the morphology of micropitting is critical in determining the root cause of failure. Examples of micropitting in gears and rolling-element bearings are presented to illustrate morphological variations that can occur in practice.

General Morphology

To the unaided eye, micropitting appears dull, etched or stained, with patches of gray. Micropitting is difficult to see under diffuse fluorescent lighting and is best observed with intense directional lighting. A flashlight with a concentrated beam held in the proper direction effectively illuminates micropitting. With intense lighting, micropitting might sparkle or appear speckled. Figure 1 is a scanning electron microscopy (SEM) image that shows the floor of a micropit crater sloping gently downward from its origin at the tooth surface. The floor has a rough surface typical of that caused by ductile-fatigue-crack propagation. A feather-edge forms at the back of the crater due to plastic flow of material over the crater rim. The feather-edge appears white in SEM when it becomes charged with electrons. Material surrounding a micropit generally appears smooth and featureless, unless abraded.

Gear Tooth Sliding

Figure 2 shows the directions of the rolling (R) and sliding (S) velocities on the driving and driven gear teeth. Contact on the driver tooth starts near the root of the tooth, rolls up the tooth, and ends at the tooth tip. Sliding is away from the driving gear pitch line. Contact on the driven tooth starts at the tooth tip, rolls down the tooth, and ends near the tooth root. Sliding is towards the driven gear pitch line. Like macropitting, micropitting cracks grow opposite the direction of sliding at the gear tooth surface. Consequently, the cracks converge near the pitch line of the driver and diverge near the pitch line of the driven gear.

Figure 3 shows metallurgical sections cut transversely through micropits that show cracks start at or near the gear tooth surface and grow at a shallow angle (typically 10–30°, but sometimes as steep as 45°) to the surface.

Hydraulic Pressure Propagation

Gear teeth dedenda have negative sliding; i.e., direction of rolling velocity is opposite sliding velocity. Negative sliding is significant because it promotes Hertzian fatigue by allowing oil to enter surface cracks where it accelerates crack growth by the hydraulic-pressure-propagation mechanism first proposed by Stewart Way (Ref. 1) and verified many times by experiments such as Littmann's (Ref. 2).

Figure 4 shows profile inspection charts that demonstrate typical profile damage due to micropitting on the drive flanks of a wind turbine high-speed (HS) pinion.

The charts for the coast flanks show the original accuracy of the pinion was high, but the micropitting caused severe deterio-

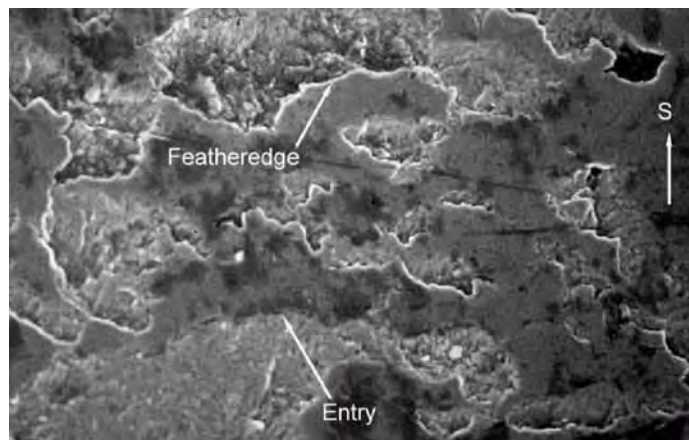


Figure 1 SEM image of micropitting.

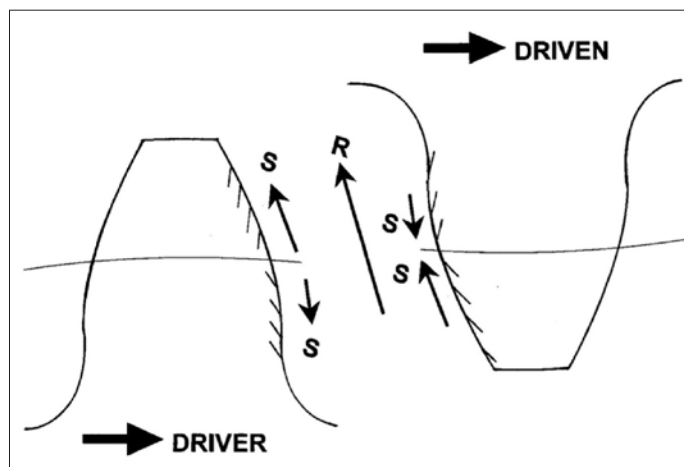


Figure 2 Rolling (R) and sliding (S) directions.

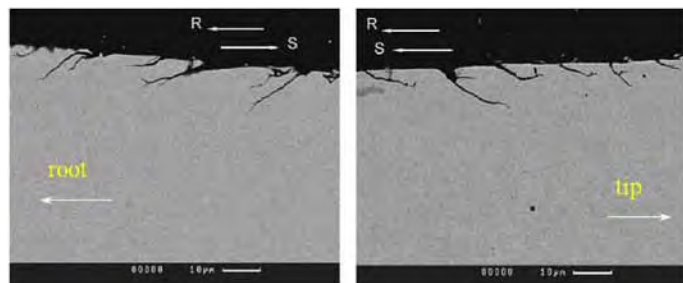


Figure 3 Micropitting cracks on a driven gear (courtesy of Newcastle University).

ration of the drive flanks. Note that the entire active drive flanks were damaged, but the damage was most severe in the dedenda in the area of negative sliding.

Figure 5 shows a form-ground wind turbine intermediate (INT) pinion with micropitting that crosses the pitch line.

Because slide directions reverse as the pitch line is crossed, micropitting cracks grow in opposite directions above and below the pitch line. Figure 5 shows that when micropitting grows across the pitch line, it makes the pitch line readily discernible because opposite inclinations of the floors of micropit craters scatter light in opposite directions above and below the pitch line.

Surface Topography

Figure 6 is an SEM image of micropitting on a high asperity of a ground tooth surface.

Micropitting begins by attacking high points on gear tooth surfaces such as crests of undulations, peaks of cutter scallops, ridges of grinding lay, and edges of grinding scratches. Figure 6 shows the surface of the asperity has been severely plastically deformed. Tractional stress from sliding has caused material to flow over the micropit craters and form a featheredge at the exit side of the craters. Growth of the micropits is opposite to the slide direction and begins at the entry (first point reached by the roll direction) and ends at the exit (last point reached by the roll direction).

Figure 7 shows a skive-hobbed wind turbine low speed (LS) wheel with micropitting on peaks of the hob scallops. Figure 8 shows a form-ground wind turbine INT wheel with micropitting on peaks of longitudinal grind scratches. Multiple cracks originate at these sites and coalesce to form micropits along lines that follow high points of surface topography. If ridges are periodic, micropitting might form in regularly spaced rows. Micropitting generally progresses until surface peaks are removed, and might continue until large areas of tooth surface become porous and continuously cracked.

Figure 8 shows a form-ground wind turbine INT wheel with micropitting on peaks of longitudinal grind scratches.

Gear teeth dedenda are vulnerable to micropitting, especially along the start of active profile (SAP) and the lowest point of single tooth pair contact (LPSTC). However, micropitting might occur anywhere on active flanks. Micropitting might occur at edges of teeth, at boundaries of surface defects such as scratches and debris dents, adjacent to damage from other failure modes such as macropitting or scuffing, and wherever the elastohydrodynamic lubrication (EHL) film is disrupted.

Micropitting Patterns

If the pinion and wheel were initially accurate and had little run-out, micropitting damage might be similar from tooth-to-tooth. In these cases micropitting patterns can be interpreted in much the same way contact patterns are used to assess gear tooth alignment and load distribution. For example, Figure 9 shows a helical wheel that had some misalignment.

When micropitting damage varies from tooth-to-tooth, it usually means there are tooth-to-tooth variations in tooth geometry or surface roughness. Gear sets with non-hunting gear ratios might develop micropitting patterns that repeat at

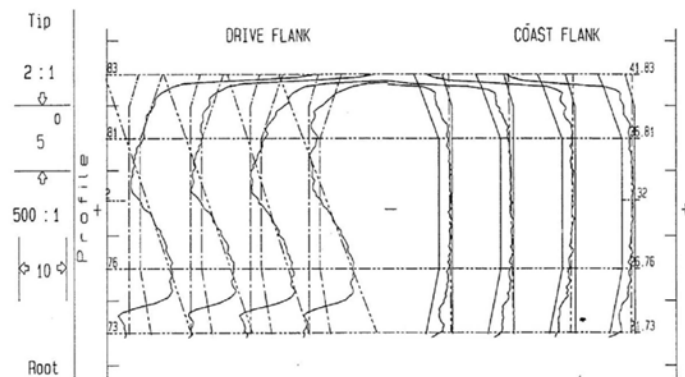


Figure 4 Typical profile damage due to micropitting on wind turbine HS pinion.

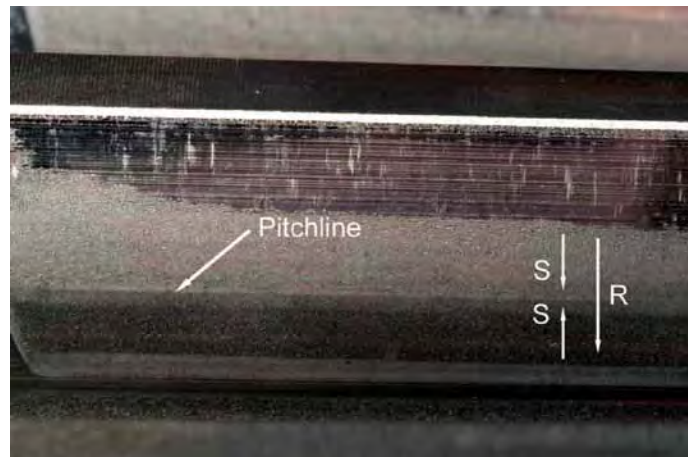


Figure 5 Pitch line is readily discernible on a driven wind turbine INT pinion.

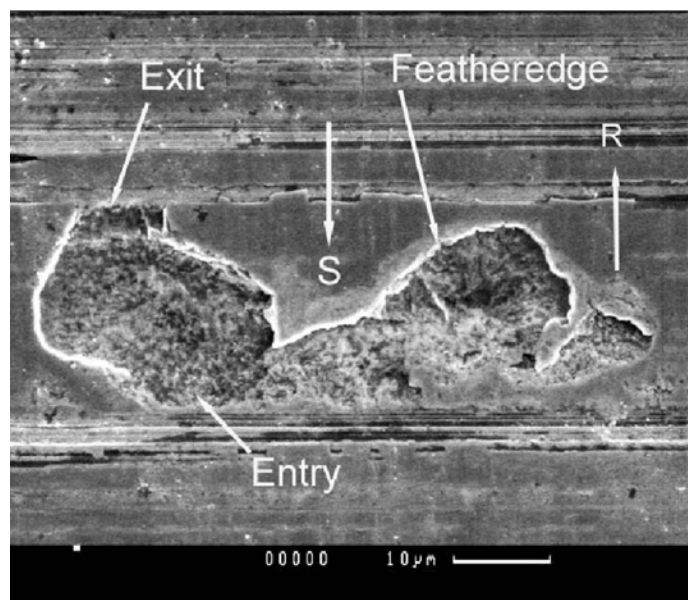


Figure 6 SEM image of micropitting on asperity peak of ground tooth surface (courtesy of Newcastle University).

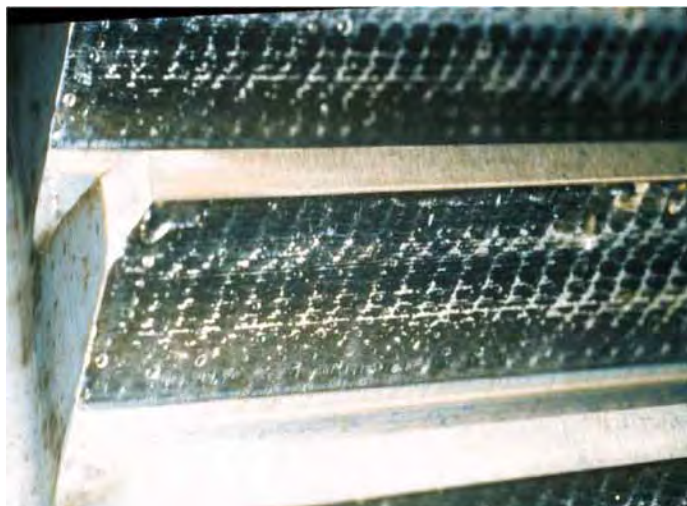


Figure 7 Wind turbine LS wheel with micropitting on peaks of hob scallops.

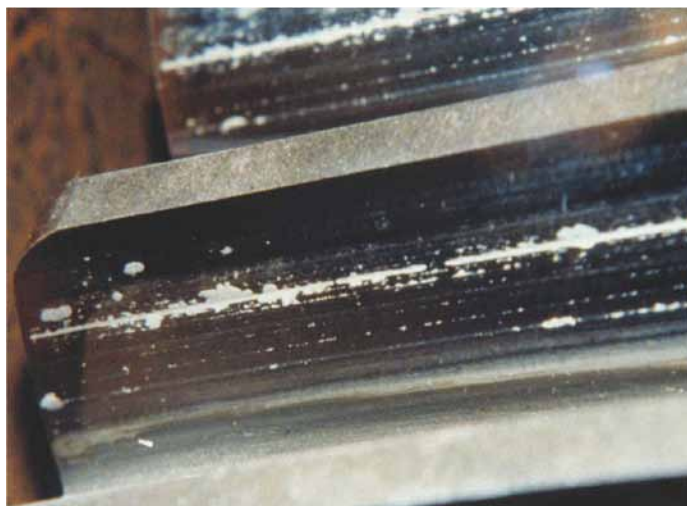


Figure 8 Wind turbine INT wheel with micropitting on peaks of grind scratches.



Figure 9 Micropitting pattern on a helical wheel that had some misalignment (courtesy of Caterpillar).

the frequency of a common factor of the tooth combination. For example, a gear set with a 25/55-tooth combination, and a common factor of five, might have similar micropitting on every fifth tooth.

There might be micropitting only on the pinion, only on the wheel, or on both. Generally, the gear with the roughest surface causes micropitting on the mating gear, especially if it is harder than the mating gear. Micropitting is most damaging when the opposing surface is rough, harder and faster. Micropitting resistance improves when the harder surface is made smooth. A worst case example would be a sun pinion that mates with multiple planet wheels that are rougher and harder than the sun pinion.

Geometric Stress Concentration (GSC)

Micropitting might occur at GSC such as:

- Edges of gear teeth
- Ends of bearing rollers
- Boundaries of surface defects such as macropitting, scuffing, fretting corrosion, or debris dents
- Tip-to-root interference at the SAP
- Corners of tip relief
- Wherever the EHL film is disrupted

Figure 10 shows a form-ground wind turbine HS pinion with micropitting at the edge of contact at the drive end of the active face width.

Figure 11 shows a form-ground wind turbine sun pinion with micropitting on shoulders of debris dents. Debris dents are local depressions that cause loss of EHL film thickness and lead to GSC at shoulders of dents. Cyclic contacts at these sites generate pressure spikes, plastic deformation, and tensile residual stresses that eventually initiate micropits.

Debris dents on rolling-element bearing raceways usually cause micropitting that frequently initiates point-surface-origin (PSO) macropitting. Therefore, debris dents are a common root cause of bearing failure.

Figure 12 shows a shaved automotive planet wheel. In addition, Figure 12 shows micropitting at edges of a PSO macropit. It is a secondary failure mode that occurred because the PSO macropit disrupted the EHL lubricant film. Other teeth show there is also micropitting on peaks of the shaving marks.

Figure 13 shows a FZG PT-C pinion with a PSO macropit that initiated at the cusp above tip-to-root damage at the SAP.

The root cause of the PSO macropit shown in Figure 13 is GSC caused by tip-to-root interference (Ref. 3). The FVA micropitting test (Ref. 4) requires the test to be terminated when a macropit occurs.

Figure 14 shows a FZG GF-C pinion with a PSO macropit that initiated at the upper edge of a 2 mm-high band of micropitting.

The root cause of the PSO macropit shown in Figure 14 is GSC caused by micropitting (Ref. 5).

FZG GF-C gears (Ref. 4) are the same as FZG PT-C gears in all respects except PT-C gears have a tooth surface roughness of $R_a=0.3\mu\text{m}$, whereas GF-C gears have tooth surface roughness of $R_a=0.5\mu\text{m}$. The rougher surfaces of GF-C gears cause more severe micropitting that removes the cusp at the SAP due to tip-to-root interference and prevents initiation of PSO mac-

ropitting at the SAP. Therefore, the micropitting prolongs the micropitting life until the micropitting spreads to the pitch-line, where PSO macropits initiate at the top of the micropitting band because of GSC caused by the step in the tooth profile at the upper edge of the micropitting crater (Ref. 6). Consequently, in the FZG GF-C test, a lubricant with superior micropitting resistance might give a shorter macropitting life than a lubricant with inferior micropitting resistance.

Figure 15 shows a contact line with fretting corrosion on a wind turbine INT wheel, as well as micropitting at edges of the fretting line. The fretting corrosion occurred when the wind turbine was parked; the micropitting occurred later during operation due to GSC at the edges of the fretting line. Therefore, fretting corrosion was the primary failure mode and micropitting was a secondary failure mode.

Micropitting in Rolling-Element Bearings

Figure 16 shows micropitting on the inner ring (IR) of a cylindrical roller bearing (CRB) from a wind turbine HS pinion. The micropitting reduced the diameter of the IR, increased the bearing internal clearance, increased the roller loads, and increased stresses. Furthermore, the micropitting caused the IR to conform to the rollers and negate the crown of the rollers. This caused GSC at the ends of the rollers and resulted in macropitting at each end of the raceway. Therefore, micropitting was the primary failure mode and GSC macropitting was a secondary failure mode.

Figure 17 is an SEM image of the central part of Figure 16, showing an enlarged view of the micropitting.

Figure 17 shows that micropitting in rolling-element bearing components has a directional randomness that differs from the more directionally oriented micropitting that is typical in gear teeth. This is probably caused by differences in sliding directions, which are more random in rolling-element bearings than in gears.

Figure 18 shows a roller from a CRB from a wind turbine INT pinion. The roller has scuffing in two circumferential bands that were caused by skidding between the roller and the outer ring (OR) raceways.

The bearing has a disc-shaped cage that is guided by a groove in the two-piece OR. No contact occurs between the roller and OR raceway in the central portion of the roller because the OR raceway is interrupted by the cage groove. Consequently, no scuffing occurred in the central portion of the roller. Furthermore, the roller has end-reliefs that prevented scuffing at the roller ends.

Figure 19 shows a CRB IR from a wind turbine INT pinion that mated with the roller shown in Figure 18.

Figure 19 shows micropitting that occurred in two circumferential bands—separated by a central band without micropitting. The two bands of micropitting were caused by the scuffing-induced roughness on the rollers. There is also a band without micropitting at each end of the active raceway; GSC macropitting occurred on the left and central bands.

Figure 20 is a plot of the axial profile of the IR shown in Figure 19.

Figure 20 shows the micropitting caused two ruts in the raceway that are up to 64 μm deep. Consequently, a major portion

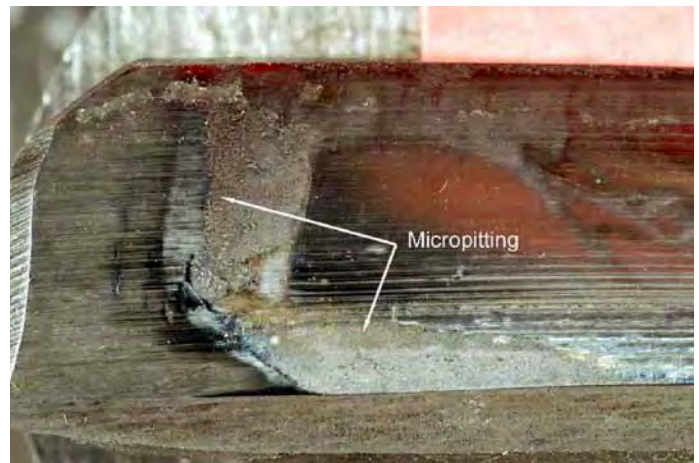


Figure 10 Wind turbine HS pinion with micropitting at edge of contact.



Figure 11 Wind turbine sun pinion with micropitting on shoulders of debris dents.

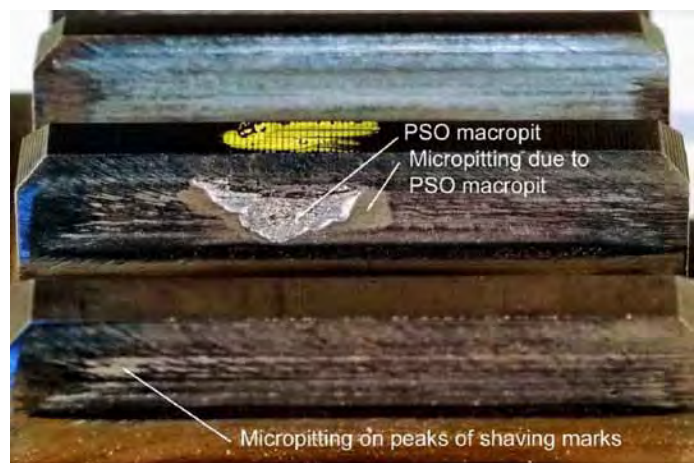


Figure 12 Micropitting at edges of PSO macropit on shaved automotive planet.

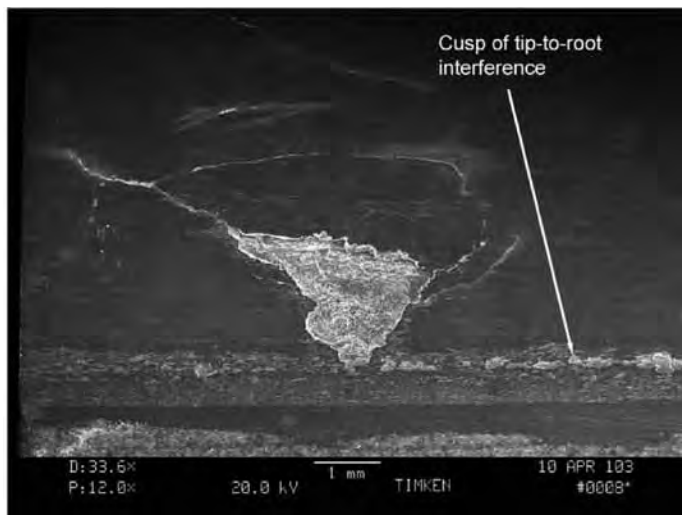


Figure 13 FZG PT-C pinion with PSO macropit starting from GSC at SAP (courtesy of Afton Chemical).

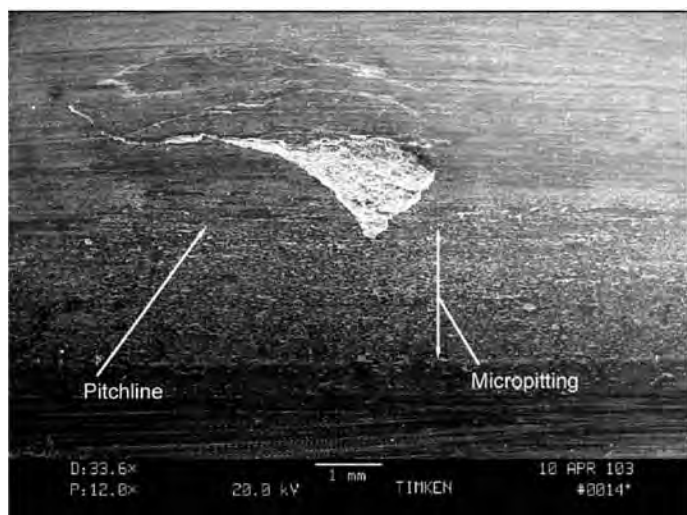


Figure 14 FZG GF-C pinion with PSO macropit starting from GSC near pitch line (courtesy of Afton Chemical).

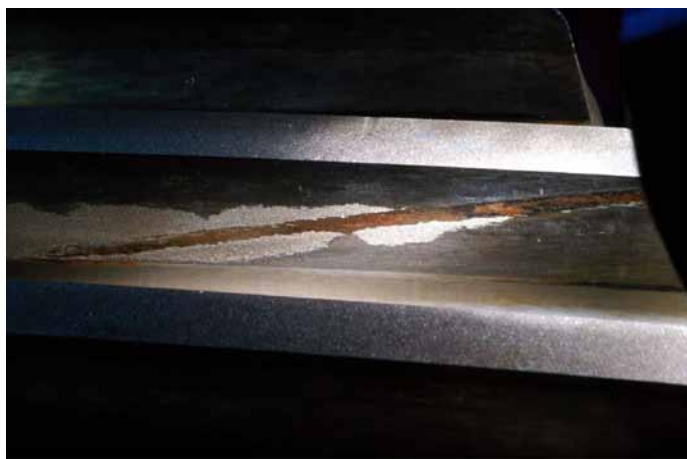


Figure 15 Wind turbine INT wheel with micropitting at edges of fretting line.

of the load-bearing area of the IR raceway was lost, leaving only the central part of the raceway and two ends to support load; this in turn led to the GSC macropitting (Fig. 19).

This example demonstrates a complex series of failure modes that started with scuffing between the rollers and OR raceway; this was followed by micropitting on the IR raceway caused by the rough surfaces of the scuffed rollers, and, finally, GSC macropitting on the IR caused by GSC due to micropitting. Therefore, scuffing was the primary failure mode and micropitting and GSC macropitting were secondary failure modes.

Figure 21 shows the influence of oil type on micropitting. The test results were obtained with AGMA test gears (Ref. 7). The pinion and wheel have tip relief, and the pinion has a crown that limits the size of the contact pattern.

Influence of Lubricant Properties

Figure 21 shows Oil-A had the lowest micropitting resistance and Oil-E had the highest micropitting resistance. Oil-A and Oil-B initiated macropitting due to GSC at the top of the micropitting band. Oil-F had the second-best micropitting resistance, but a PSO macropit initiated due to GSC caused by tip-to-root interference.

Micropitting resistance is strongly affected by lubricant properties—especially the base oil type, viscosity at the operating temperature, viscosity-pressure coefficient (Ref. 8) and the lubricant chemistry. Anti-wear additives are generally detrimental to micropitting resistance, primarily because they inhibit run-in and preserve damaging roughness. However, some friction-reducing additives are beneficial (Ref. 9).

Oil cleanliness must be maintained to avoid micropitting caused by debris dents (Ref. 10). Furthermore, gearbox inspections have shown that water contamination promotes micropitting in gears and bearings, and experiments (Ref. 11) have shown that water contamination can significantly reduce the anti-corrosion, film formation, and friction-reducing properties of oil.

Influence of Metallurgy

Gears have maximum micropitting resistance when made from steel with sufficient hardenability to obtain microstructures consisting primarily of tempered martensite. Retained austenite of about 20% is thought to be beneficial. Retained austenite greater than 30% generally reduces hardness, strength and compressive residual stress in carburized gears, and is therefore detrimental to micropitting resistance.

Carburized gears are usually hobbed, carburized, hardened and ground, so their tribological properties depend on characteristics of ground surfaces. But some carburized, nitrided and induction-hardened gears are not ground after hardening, and their surfaces may be hard and rough. These surfaces are likely to produce micropitting on mating gears. However, if heat treat distortion is adequately controlled—and tooth surfaces are smooth—heat-treated surfaces can be resistant to micropitting. Oxidation at the surface and along grain boundaries might actually be beneficial. The oxide layer formed during heat treatment might provide boundary-film protection similar to a solid lubricant and provide protection during run-in.

Conclusions

- Understanding the morphology of micropitting is the key to determining the primary failure mode and root cause of failure.
- Like macropitting, micropitting cracks grow opposite the direction of sliding at the gear tooth surface. Consequently, the cracks converge near the pitch line of the driver and diverge near the pitch line of the driven gear.
- Metallurgical sections cut transversely through micropits show that cracks start at or near the gear tooth surface and grow at a shallow angle—typically 10–30°, but sometimes as steep as 45° to the surface.
- Gear teeth dedenda have negative sliding; i.e., the direction of rolling velocity is opposite sliding velocity. Negative sliding is significant because it promotes Hertzian fatigue by allowing oil to enter surface cracks where it accelerates crack growth by the hydraulic-pressure-propagation mechanism.
- Because slide directions reverse as the pitch line is crossed, micropitting cracks grow in opposite directions above and below the pitch line. When micropitting grows across the pitch line it makes the pitch line readily discernible because opposite inclinations of the floors of micropit craters scatter light in opposite directions above and below the pitch line.
- Micropitting begins by attacking high points on gear tooth surfaces such as crests of undulations, peaks of cutter scallops, ridges of grinding lay, and edges of grinding scratches. Tractional stress from sliding causes material to flow over the micropit craters and form a feather-edge at the exit-side of the craters.
- If the pinion and wheel were initially accurate and had little run-out, micropitting damage might be similar from tooth to tooth. In these cases micropitting patterns can be interpreted in much the same way contact patterns are used to assess gear tooth alignment and load distribution.
- When micropitting damage varies from tooth to tooth, it usually means there are tooth-to-tooth variations in tooth geometry or surface roughness. Gear sets with non-hunting gear ratios might develop micropitting patterns that repeat at the frequency of a common factor of the tooth combination. For example, a gear set with a 25/55-tooth combination, and a common factor of five, might have similar micropitting on every fifth tooth.
- There might be micropitting only on the pinion, only on the wheel—or both. Generally, the gear with the roughest surface causes micropitting on the mating gear—especially if it is harder than the mating gear.

Micropitting is most damaging when the opposing surface is rough, harder and faster; micropitting resistance improves when the harder surface is made smooth.

Micropitting might occur at GSC such as:

- Edges of gear teeth
- Ends of bearing rollers
- Boundaries of surface defects, such as macropitting, scuffing, fretting corrosion, or debris dents
- Tip-to-root interference at the SAP
- Corners of tip relief
- Wherever the EHL film is disrupted
- Micropitting in rolling-element bearing components has a directional randomness that is different from the more directionally oriented micropitting typical in gear teeth. This is probably caused by differences in sliding directions, which are more random in rolling-element bearings than in gears.



Figure 16 Micropitting on CRB IR of wind turbine HS pinion.

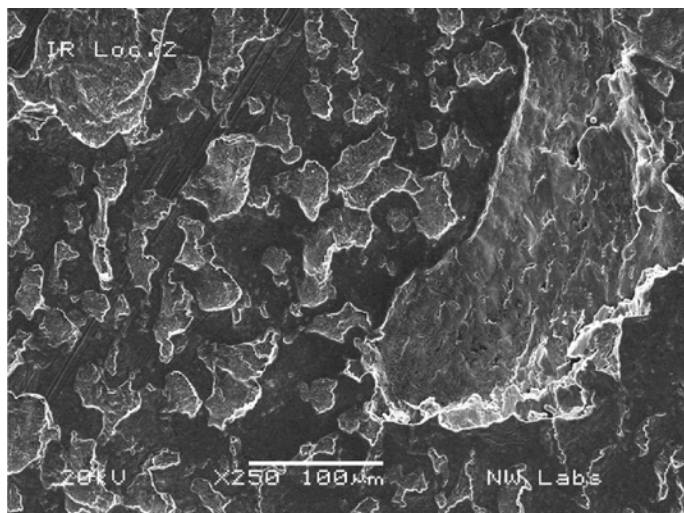


Figure 17 SEM image of micropitting on pinion (courtesy of Northwest Labs).



Figure 18 Scuffing on CRB roller from wind turbine INT pinion bearing.

- Micropitting resistance is strongly affected by lubricant properties, especially the base oil type, viscosity at the operating temperature, and the lubricant chemistry. Anti-wear additives are generally detrimental to micropitting resistance primarily because they inhibit run-in and preserve damaging roughness. However, some friction-reducing additives are beneficial.
- Oil cleanliness must be maintained to avoid micropitting caused by debris dents. Furthermore, water contamination promotes micropitting in gears and bearings, and significantly reduces the anticorrosion, film formation and friction-reducing properties of oil.
- With FZG PT-C gears, PSO macropits initiate at the cusp formed by tip-to-root interference, whereas With FZG GF-C gears, their rougher surfaces cause more severe micropitting that removes the cusp at the SAP and thereby prolongs the macropitting life until PSO macropitting occurs near the pitchline because of GSC caused by the step in the tooth profile at the upper edge of the micropitting crater. Consequently, in the FZG GF-C test, a lubricant with superior micropitting resistance might give a shorter macropitting life than a lubricant with inferior micropitting resistance.

Table 1—Metallurgy and finished method

Figure No.	Steel alloy	Heat treatment	Surface hardness	Finishing method
5	17CrNiMo6	Carburize	59 HRC	Form ground
6	17CrNiMo6	Carburize	58 HRC	Form ground
7	AISI 4320H	Carburize	59 HRC	Skive hobbled
8	17CrNiMo6	Carburize	58 HRC	Form ground
9	AISI 8620H	Carburize	58 HRC	Shaved
10	AISI 9310H	Carburize	60 HRC	Form ground
11	17CrNiMo6	Carburize	59 HRC	Form ground
12	AISI 8620H	Carburize	58 HRC	Shaved
13	16MnCr5	Carburize	60 HRC	MAAG 0° ground
14	16MnCr5	Carburize	60 HRC	MAAG 0° ground
15	17CrNiMo6	Carburize	60 HRC	Form ground
16	AISI 52100	Through hard	60 HRC	Ground
17	AISI 52100	Through hard	60 HRC	Ground
18	AISI 52100	Through hard	60 HRC	Ground
19	AISI 52100	Through hard	60 HRC	Ground
21	AISI 8620H	Carburize	58 HRC	Form ground

- Gears have maximum micropitting resistance when made from steel with sufficient hardenability to obtain microstructures consisting primarily of tempered martensite. Retained austenite of about 20% is thought to be beneficial. ⚙️

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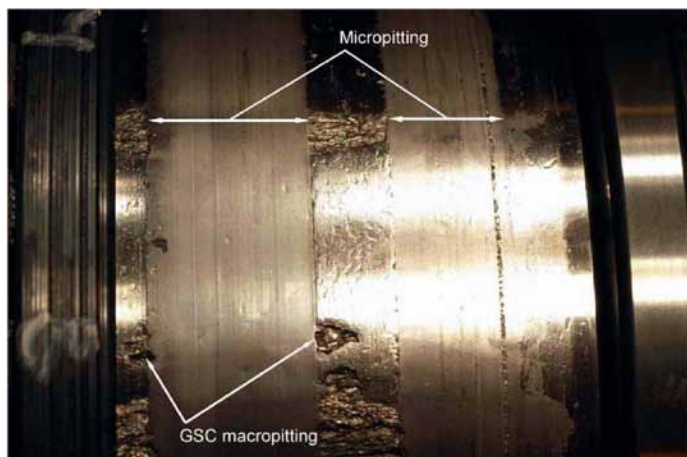


Figure 19 Micropitting on CRB IR from a wind turbine INT pinion bearing.

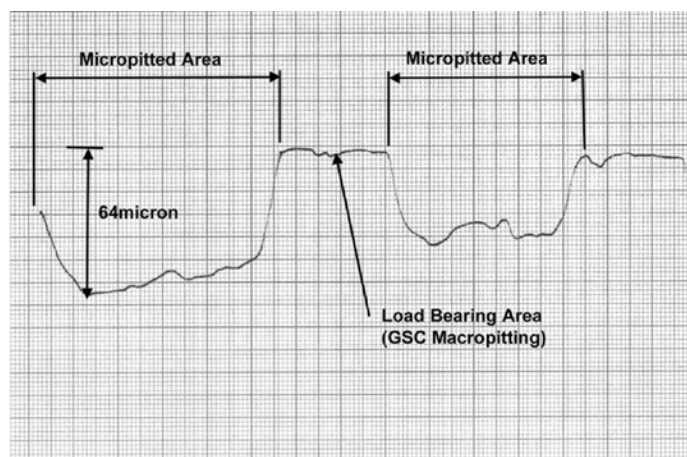
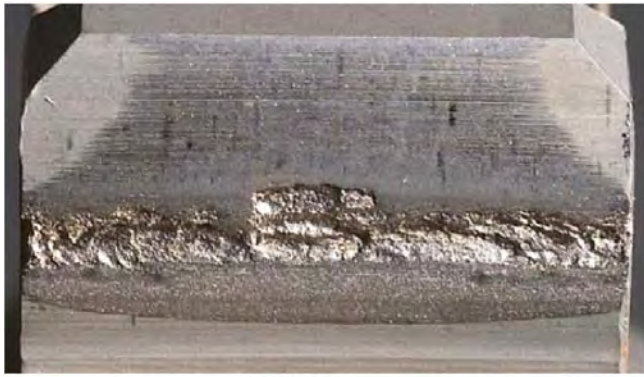


Figure 20 Axial profile of CRB IR from wind turbine INT bearing.



Oil A



Oil B



Oil C



Oil D



Oil E



Oil F



Oil G

Figure 21 Influence of oil type on micropitting (courtesy of ExxonMobil).

Robert Errichello, PE, heads his own gear consulting firm—GEARTECH—and is a founder of GEARTECH Software, Inc. A graduate of the University of California at Berkeley, he holds B.S. and M.S. degrees in mechanical engineering and a master of engineering degree in structural dynamics. In his more than 30 years of industrial experience, Errichello worked for several gear companies; he has also been a consultant to the gear industry for more than 20 years and has taught courses in material science, fracture mechanics, vibration and machine design at San Francisco State University and the University of California at Berkeley. He is also a member of ASM International, STLE, ASME Power Transmission and Gearing Committee, AGMA Gear Rating Committee and the AGMA/AWEA Wind Turbine Committee. Errichello has published dozens of articles on design, analysis and the application of gears, and is the author of three widely used computer programs for the design and analysis of gears. He is also a longtime technical editor for *Gear Technology* magazine and STLE Tribology Transactions, and has presented numerous seminars on design, analysis, lubrication and failure analysis of gears. Errichello is a past recipient of the AGMA TDEC award and the STLE Wilbur Deutch Memorial award.

Predicted Scuffing Risk to Spur and Helical Gears in Commercial Vehicle Transmissions

Carlo H. Wink

AGMA925-A03 scuffing risk predictions for a series of spur and helical gear sets of transmissions used in commercial vehicles ranging from SAE Class 3 through Class 8.

Introduction

The risk of gear tooth scuffing in commercial vehicle transmissions has gained more attention because of increasing demand for fuel-efficient powertrain systems in which diesel engines run at lower speeds, power density is higher, and lubricants are modified to improve efficiency and compatibility with components of new technologies, such as dual-clutch transmissions.

Accordingly, predicting scuffing risk during the design phase is vital for the successful development of commercial vehicle transmissions. AGMA 925-A03 (Ref. 1) is a comprehensive method for predicting the probability of gear scuffing. This paper presents the AGMA 925-A03 (Ref. 1) scuffing risk predictions for 50 spur and helical gear sets in transmissions used in commercial vehicles ranging from SAE Class 3 through Class 8. Limiting scuffing temperatures using two mineral and three synthetic gear lubricants was determined from FZG scuffing tests. The risk of scuffing was determined for each gear set according to AGMA 925-03 (Ref. 1). The predictions were compared with field and warranty data, and dynamometer test results. The predictor was correct in all cases. High scuffing risk was predicted for gears known to scuff, and low scuffing risk was predicted for all other cases with no history of scuffing. The document correlation between prediction, test results and actual usage instills confidence in the predictor of scuffing risk for gears in commercial vehicle transmissions.

Background

Scuffing failure causes localized damage to gear teeth, resulting in matte and rough finishes of the contacting surfaces, and tooth form changes as well. This type of damage generally occurs in the tooth contact zone where contact pressure and sliding velocity are high, far from the pitch line. The tooth damage can increase vibration and noise, compromise gear load capacity, ultimately leading to catastrophic failures (Ref. 2). As a severe adhesive wear phenomenon, scuffing occurs when the oil film thickness between the tooth contacting surfaces is insufficient to prevent metal-to-metal contact, which in turn causes local welding and subsequent tearing. Metal particles are transferred between the two surfaces or lost from them; they scratch tooth flanks in the sliding direction. Scuffing is not a fatigue phenomenon, as it may occur at the beginning of the operation (Refs. 3-4).

There are several analytical methods for predicting scuffing risk; however, the threshold for determining whether a gear set will scuff remains mostly dependent on empirical results.

The method of evaluating scuffing risk in AGMA 925-A03 (Ref. 1) is a function of oil viscosity and additives; operating bulk temperature of the gear; sliding velocity; surface roughness of gear teeth; gear materials and heat treatments; and surface pressure. The risk of scuffing is defined by comparing the calculated tooth contact temperature with the limiting scuffing temperature; this is done via gear scuffing tests for each gear lubricant.

Contact Temperature Calculation

Flash temperature across the tooth contact path is calculated by Blok's Equation 1.

$$\theta_{fl(i)} = 3162 K \mu_{m(i)} \frac{X_{r(i)} w_n}{(b_{H(i)})^{0.5}} \frac{v_{r1(i)} - v_{r2(i)}}{B_{M1}(v_{r1(i)})^{0.5} B_{M2}(v_{r2(i)})^{0.5}} \quad (1)$$

where

$\theta_{fl(i)}$ is flash temperature, °C;

K is 0.80, a numerical factor for the Hertzian distribution of frictional heat over the instantaneous contact band width;

$\mu_{m(i)}$ is mean coefficient of friction;

$X_{r(i)}$ is load sharing factor;

w_n is normal unit load, N/mm;

$v_{r1(i)}, v_{r2(i)}$ are rolling tangential velocities in m/s of the pinion and gear respectively, m/s

B_{M1}, B_{M2} are 13.6 N/(mm²K), thermal contact coefficient of steel;

$b_{H(i)}$ is the semi-width of the Hertzian contact band, mm;

i is a subscript of line-of-action points

Contact temperature at each line-of-action point is given by Equation 2.

$$\theta_{B(i)} = \theta_M + \theta_{fl(i)} \quad (2)$$

where

$\theta_{B(i)}$ is contact temperature, °C;

θ_M is the tooth temperature, in °C, which is the temperature of the tooth surface before it enters the contact zone. The tooth temperature can be estimated by calculation, testing or experience.

In terms of calculation of the tooth temperature, it can be estimated by Equation 3.

$$\theta_M = k_{\text{sump}} \theta_{\text{oil}} + 0.56 \theta_{\text{fl max}} \quad (3)$$

where

k_{sump} is 1 for splash lube and 1.2 for spray lube;

θ_{oil} is oil supply or sump temperature in °C;

$\theta_{\text{fl max}}$ is the maximum flash temperature found over all line-of-contact points i (Eq. 1).

The maximum contact temperature is obtained by Equation 4.

$$\theta_{B \text{ max}} = \theta_M + \theta_{\text{fl max}} \quad (4)$$

where

$\theta_{B \text{ max}}$ is maximum contact temperature, °C.

When the maximum contact temperature is closer to or higher than the limiting scuffing temperature, scuffing may occur.

Limiting Scuffing Temperature

The limiting scuffing temperature is the tooth contact temperature at which scuffing is likely to occur, given a combination of lubricant and gear material (Ref. 1). It can be obtained from gear scuffing tests, such as FZG tests—an industry standard test used worldwide to rate different lubricants for scuffing resistance. The FZG test method per CEC L-84-02 (Ref. 6) was developed by the Coordinating European Council (CEC) and is extensively used by the automotive and petroleum industries in Europe and throughout the world.

The FZG gear test rig is operated at constant speed for a fixed period of time at successively increasing loads until the failure criteria is reached. The test gears are then examined for scuffing damage to the gear tooth flanks both before and after the prescribed duration at each load stage. The test gear fails when the sum of the scuffed area widths on all teeth exceeds the gear face width (Ref. 3).

In 2004 the Eaton Corporation Vehicle Group developed an extensive project to investigate industry-standard scuffing test methods to and correlate their results with different gear lubricants in transmission tests in dynamometers. The investigation was motivated by longer oil drain intervals and new lubricants being used in Eaton transmissions. Under these conditions the former ASTM D5182-9 (Ref. 3) method did not correlate with known scuffing occurrences.

The FZG method defined by CEC L-84-02 (Ref. 6) and designated as A10/16.6R/120 yielded consistent results and true agreement with dynamometer tests. Eaton Corp. has since adopted this test method as part of its internal procedure for gear lubricant qualification and approval.

The A10/16.6R120 stands for A-type gear geometry, 16.6m/s pitch line velocity, and a sump temperature of 120°C. The A-type gear is designed with longer addendum geometry to generate high sliding velocity, and is manufactured with only a 10 mm face width to increase the contact stress so that the scuffing could be more easily produced than with the 20 mm face width. The 10 mm face width gear test is commonly referred to as the “half-tooth, double-speed test.” Figure 1 shows a FZG A-type gear after a test.

Scuffing Risk Prediction

When the maximum contact temperature is close to or above the limiting scuffing temperature for the combination of lubricant and gear material, scuffing is likely to occur. The probability of scuffing can be predicted by comparing the contact temperature with the limiting scuffing temperature. The AGMA 925-A03 probability of scuffing is obtained from a Gaussian distribution of scuffing temperature assuming a 0.15 coefficient of variation. The contact temperature is a random variable, the limiting scuffing temperature is the mean value of the random variable, and the standard deviation of the random variable is assumed to be 0.15 of the scuffing temperature. AGMA 925-A03 (Ref. 1) then proposes a criterion to assess the risk of scuffing based on its calculated probability (Table 1).

Application Examples

In this study, 50 gear sets were evaluated using the AGMA 925-A03 scuffing risk method (Ref. 1). Twenty-four spur gear sets and 26 helical gear sets, whose helix angles were between 12–33°, were evaluated. The gear sets are used in nine different models of commercial vehicle transmissions, with up to 18 forward speeds and transmission torque capacity between 420 Nm–2500 Nm. Their applications include light-duty pick-up trucks, delivery trucks, buses and vocational and heavy-haul

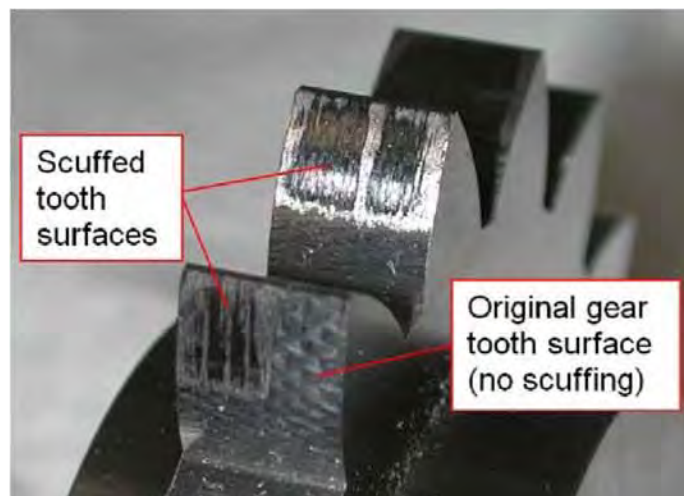


Figure 1 FZG A-type gear after test.

Table 1 Scuffing risk per AGMA 925-A03

Probability of scuffing	Scuffing risk
< 10%	Low
10% to 30%	Moderate
> 30%	High

trucks.

Figures 2 and 3 show basic geometric and operating parameters of the gear sets, such as module, pressure angle, contact ratio, pitch line velocity and sliding velocity.

All gears were of case-hardened steel with a surface hardness of 58–63HRC. Among the gear sets, three tooth flank finish processes were used—1) shaving: surface roughness $R_a = 1.25$ mm; 2) honing: $R_a = 0.40$ mm; and 3) CBN grinding: $R_a = 0.63$ mm.

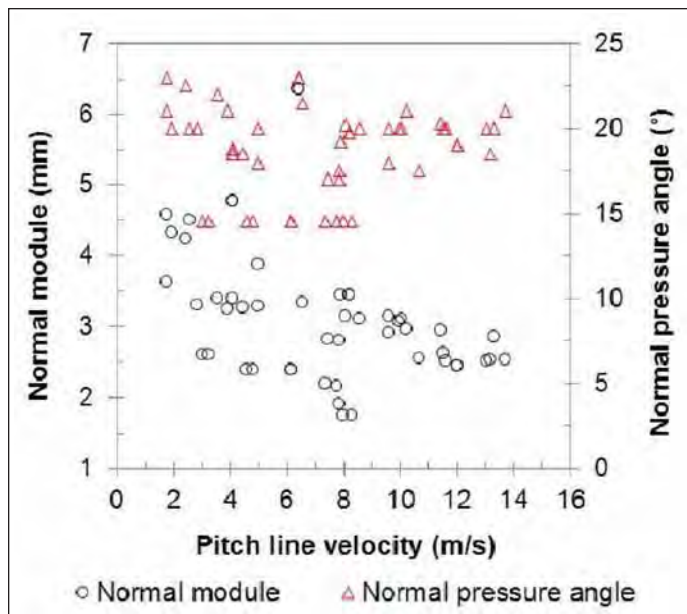


Figure 2 Characteristics of studied gear sets.

The flash temperature was calculated for each gear set using Equation 1 for 25 line-of-action points, as recommended by AGMA 925-A03 (Ref. 1).

The coefficient-of-friction (COF) was calculated with the formulae in AGMA 925-A03 (Ref. 1) for an approximation of the COF by a constant. The COF was calculated with the average surface roughness of the pinion and gear teeth, and was assumed constant along the line-of-action. The maximum COF value was limited to 0.11. The effect of the COF on the maximum contact temperature predicted by the analytical model was investigated for one of the gear sets. The COF was arbitrarily changed from 0.03 to 0.11, and the contact temperature calculated.

The results showed that small variations on the COF may not significantly affect contact temperature results. For example, a

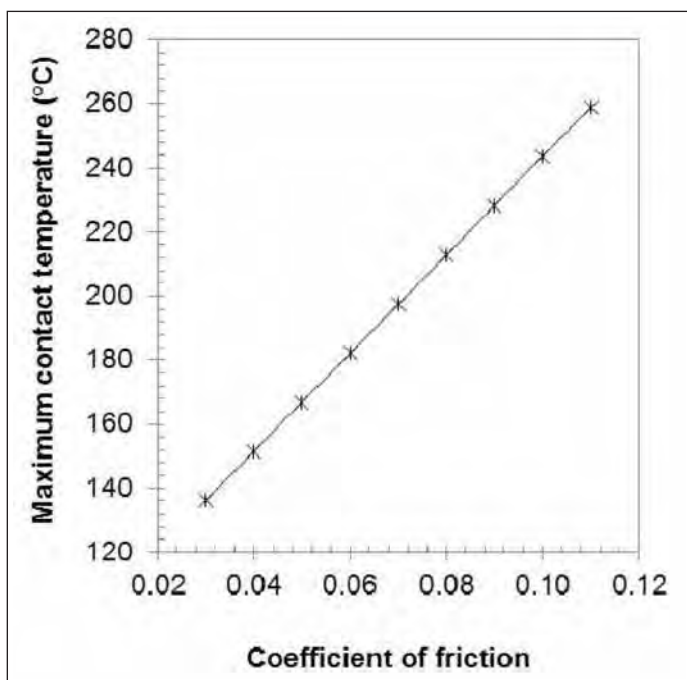


Figure 4 Effect of coefficient of friction on contact temperature results.

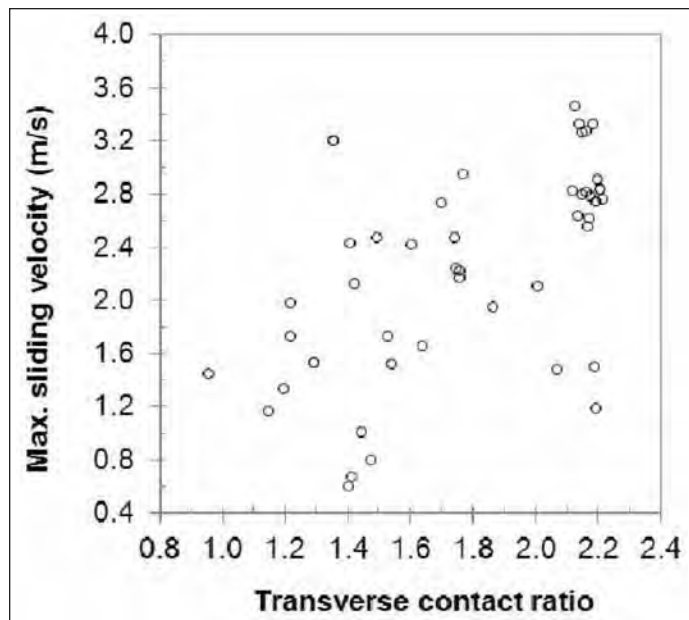


Figure 3 Sliding velocity and transverse contact ratio of gear sets.

10% variation of a 0.10 COF caused the maximum contact temperature to vary only about 6% (Fig. 4). However, more pronounced COF changes—e.g., changing finish processes and obtaining much smoother surfaces—can significantly affect maximum contact temperature.

Another uncertainty when calculating the contact temperature of gear sets used in commercial vehicle transmissions was the load condition for the calculation; i.e.—torque and speed, or power. Vehicles powered with combustion engines run under a certain power regime, which is a function of the characteristic engine power curve. In typical engine power curves the point of maximum power does not match the point of maximum torque. Typically, the maximum torque is at a lower engine speed than the maximum power point. In order to find the critical load

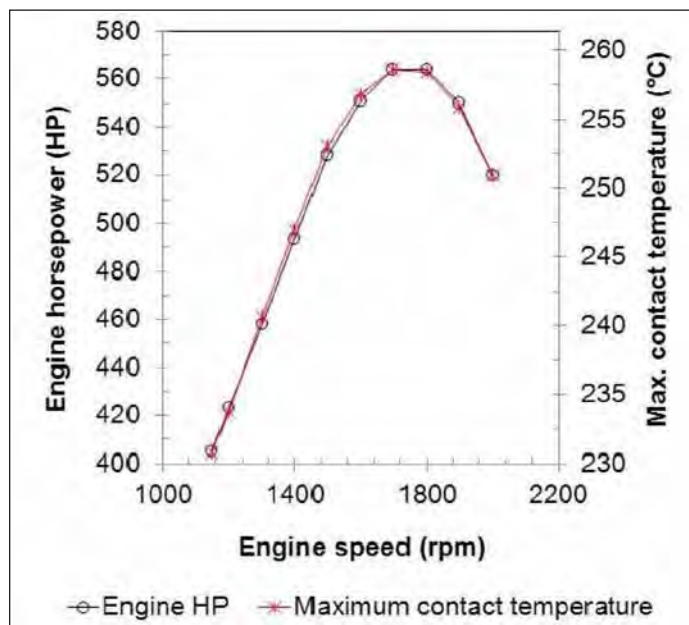


Figure 5 Effect of engine power on contact temperature results.

Table 2 Gear lubricants					
Gear lubricants	1	2	3	4	5
Oil base	Synthetic	Mineral	Synthetic	Mineral	Synthetic
Viscosity index (ASTM D227)	151	194	146	164	150
Kinematic viscosity @ 40°C (mm ² /s)	135.0	33.8	132.0	51.0	40.5
Kinematic viscosity @ 100°C (mm ² /s)	18.2	7.6	17.5	9.1	7.4
Scuffing failure load stage of FZG test*	3	6	9	7	6

* FZG A10-16.6R120

condition for scuffing, the maximum contact temperature was calculated to 10 points along the engine power curve (Fig. 5).

The maximum contact temperature followed the engine power curve; i.e., as power increases, so, too, the contact temperature. The maximum value of contact temperature was obtained at maximum engine power. Based on the results, all calculations were made at maximum engine power rather than at peak torque.

Five different gear lubricants were used in this study—two mineral and three synthetic lubricants. Table 2 shows the basic characteristic of the gear lubricants and their load stage (the torque at that stage of the test) at which scuffing occurred.

The limiting scuffing temperature was then calculated for the FZGA-type gear (A10/16.6R120) at the scuffing failure load using the AGMA 925-A03 method, which was implemented into a spreadsheet.

With the scuffing temperature defined for each one of the five gear lubricants in Table 2, and the maximum contact temperature calculated for each of the 50 gear sets, the scuffing risk was determined by comparing contact temperature and scuffing temperature. Two approaches were taken for this: 1) the ratio of contact temperature and scuffing temperature was calculated and named “scuffing ratio”; ratios close or above one usually indicate that scuffing is likely to occur; and 2) the risk of scuffing was assessed as low, moderate or high, based on the probability of scuffing defined in AGMA 925-A03 (Ref. 1).

Among the 50 gear sets studied, four showed scuffing failures in both dynamometer tests and in the field (Fig. 6).

Figures 7 and 8 show the scuffing ratio and probability of scuffing, respectively, for all 50 gear sets. The four scuffed gear sets are identified in red and with an asterisk in front of the results in Figures 7 and 8.

Scuffing ratios closer to, and above, one, were predicted for all four gear sets in which scuffing failures were known (Fig. 7). However, looking at the scuffing ratio only can lead one to think that scuffing could occur on gear set Number 5, which has a scuffing ratio of around 0.9.

This pointed out the advantage of using AGMA 925-A03 probability of scuffing (Fig. 8). The results clearly show a high risk of scuffing—greater than 30%—to all four gear sets at which scuffing was observed.

Looking at gear set Number 5, its probability of scuffing is around 20%, which is classified as moderate risk in AGMA 925-A03 (Ref. 1). Thus, a clearer assessment can be done using the probability of scuffing recommended in the AGMA standard.

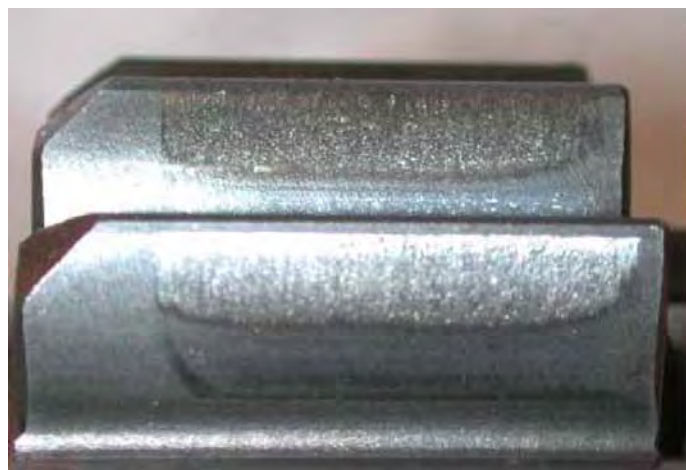


Figure 6 Scuffed gear set from dynamometer test.

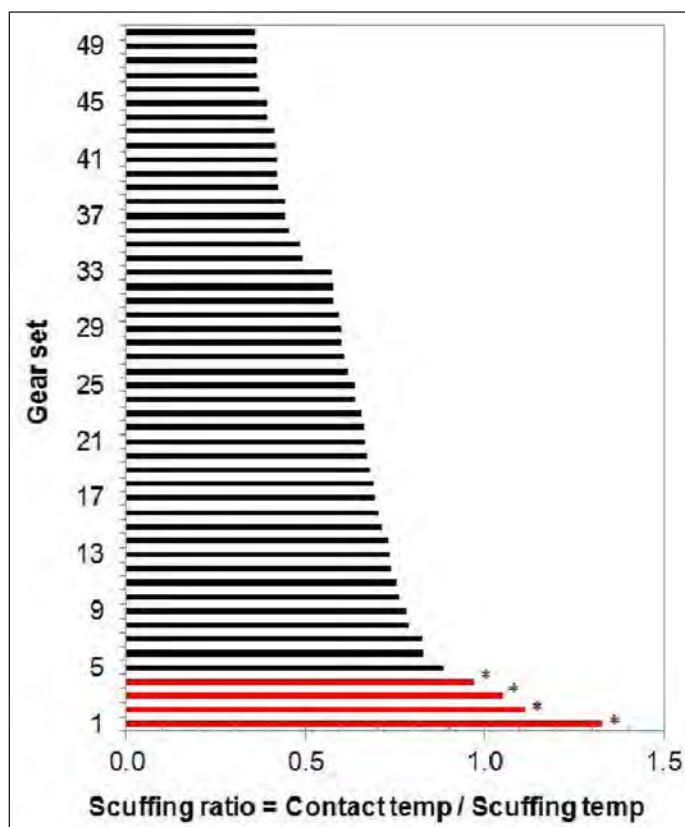


Figure 7 Scuffing ratio results (scuffed gear set).

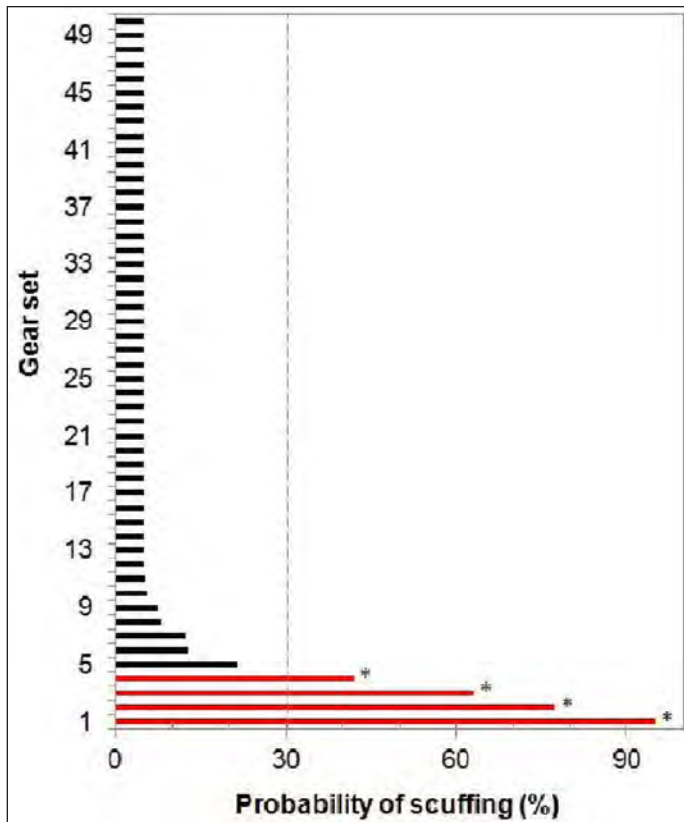



Figure 8 Probability of scuffing: > 30% = high risk (*scuffed gear set).

Discussions

The AGMA 920-A03 standard was used to predict the scuffing risk of 50 spur and helical gear sets in nine transmission models, which are applied to commercial vehicles ranging from SAE Class 3 through Class 8. Scuffing temperatures of two mineral and three synthetic gear lubricants were defined, based on FZG test results. Scuffing risks were assessed based on the probability of scuffing according to AGMA 925-A03. The results indicated that the AGMA 925-A03 is indeed effective and consistent in predicting scuffing risk, as evidenced by the good match to dynamometer and field results for the known scuffed gears, and also for the gears with no history of scuffing failures. The agreement between prediction, test results and actual usage provides confidence in the predictor of scuffing risk of gears in commercial vehicle transmissions. 

Acknowledgments. The author thanks the Eaton Corporation Vehicle Group for support on the development of this paper.

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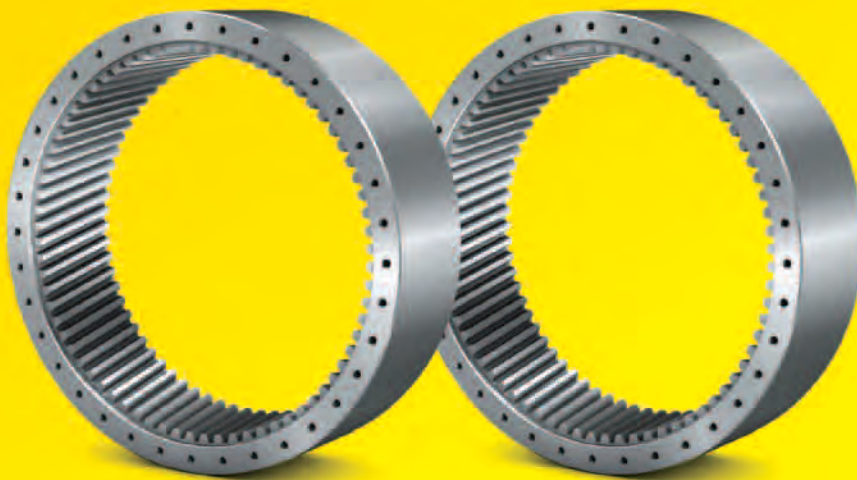
Carlos H. Wink is gear engineering manager at Eaton Corporation's Global Center of Excellence (Automotive) near Kalamazoo, Michigan, where he previously worked as a senior gear specialist. Wink has been with Eaton's Vehicle Group since 1985. He is also an AGMA member and the author of numerous technical papers.

CORRECTION

A Technical Paper in the October *Gear Technology*—"Pitting Resistance of Worm Gears: An Advanced Model for Contact Pattern of Any Size, Position or Flank Type," by Dr. Karsten Stahl, Dr. Bernd-Robert Höhn, Dr. Joerg Hermes and Alexander Monz, was incorrectly attributed. Attribution should have read:

This article appeared previously—and exclusively—in (in German) in the April 2012 issue of Antriebstechnik.

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Heller Machine Tools

MARKS 30 YEARS IN THE UNITED STATES

In 2012, Heller Machine Tools marked its 30th year of operations in the United States as a subsidiary of Gebr. Heller Maschinenfabrik, Nürtingen, Baden-Württemberg, Germany. Heller worldwide is a 600-million-euro company with approximately 3,000 employees. The company specializes in designing and building high-precision flexible production systems for the powertrain operations of automotive and heavy-diesel industries, primarily. In 2012 the U.S. company expects to double sales over 2011, which was a record for the operation, and is about a third of the global total for Heller.

Heller has increased the U.S. content of the systems it produces, partly due to the cost advantages of producing the systems in the United States as compared to Europe. The company has helped to increase the amount of manufacturing technology produced and exported from Michigan, some systems shipping to China for major automotive companies and suppliers. More than 60 percent of the content of the systems produced at Heller Troy is sourced in Michigan.

The company is a full-line manufacturer in Michigan, designing, building, and servicing its machines from its 100,000-sq-ft facility in Troy. There are 130 employees at Troy working alongside 60 contractors. The company estimates it supports several thousand additional employees in 50 or more supplier companies in Michigan.

A specialty of Heller is the machining of compact graphite



iron, a very hard material cast into large diesel engine blocks. Machining CGI requires a very stable, heavy-duty machine tool, and Heller CGI machining centers have been placed in nearly all heavy-duty diesel engine and others.

Heller began its operations in the United States in 1982 in Elk Grove Village, Illinois, primarily as an importer and servicer of its crankshaft milling machines it was then selling to Ford, Deere, Caterpillar and Chevy Bay City plants. Its first generation of horizontal machining center, the BEA, was developed and first sold in 1986. Since then, the company has become the largest European manufacturer of horizontal machining cen-



ters. Originally, the company designed and produced its own CNC control for the machining centers. Now, most controls are Siemens or Fanuc, depending on customer preference.

In 1995, Heller management in Germany decided to move to the Detroit area as it was increasing its role as a supplier to the automotive industry. The thinking then was that "the auto industry will always need machine tools." So it built a plant in Troy, expanding it three times since 1996 to create more assembly space, engineering offices and service capability for repairs, machine rebuilds, and spare parts. The company has, in the last 30 years, shipped over 1,500 machining centers from its U.S. operations.

In 2000, Heller introduced the MC and MCH lines of machining centers, designed for production of heavy precision components. Heller also began producing flexible transfer lines at Troy, the first systems going to American Axle in Buffalo and Three Rivers, Michigan. In 2006, the company earned its first large flexible machining system order, comprised of 64 machining centers and ancillary equipment including automation. The system, for Detroit Diesel in Redford, Michigan, is producing that company's new generation family of three heavy diesel engines.

Since 2006, Heller has taken on multiple turnkey flexible system projects, which has accounted for its rapid sales growth in the United States to \$200 million. The company is staffed today for all sales, proposal engineering, mechanical and electrical engineering, service and assembly functions—full service from Heller in Troy to the transportation industry.

Important to Heller in Germany as well as in Troy, apprenticeships in manufacturing are the source of future skilled employees. Currently, eight persons are engaged in manufacturing apprenticeships, from tooling to project management. The company in Troy also sponsors engineering internships with three candidates in various engineering disciplines. The company finds it is best to train and develop skilled workers from within rather than hiring from a competitor. For more information, visit www.heller-us.com.

Micro Precision

FOCUSES ON NADCAP ACCREDITATION

When it comes to industrial quality procedures, aerospace is one of the most demanding. Every component must be checked, tested and logged to an incredible level of detail and, just as importantly, all processes, procedures and standards documented to ensure traceability to a depth many engineers would find baffling. As a result of these quality demands, the vast majority of precision aerospace components are made in-house. Those that aren't, and there aren't many, are manufactured by companies prepared to have their products, processes and procedures regularly run through with a fine-tooth comb.

One of the key quality standards for the aerospace industry is Nadcap, managed by PRI, a non-profit organization set up to address the development of performance standards and the administration of quality assurance, accreditation and certification programs. Nadcap is described by PRI as "an international, independent manufacturing process and product assessment and certification service for the purpose of adding value, reducing total cost and facilitating relationships between subscribers and suppliers."

In short, it manages a set of common standards set by various bodies in the aerospace industry and then ensures that those certified comply fully with their requirements. Going far and beyond most company's in-house quality procedures, Nadcap adds another level of detail to what is already an exacting science. Nadcap accreditation is not impossible; it just takes a certain mindset and work ethic that can see the positives in terms of reputation, self-improvement, orders and, of course, the bottom line.

Hemel-Hempstead-based Micro Precision is one company that has taken the plunge and has successfully operated two Nadcap-approved processes for the last few years at its 20,000-square-foot production and testing facility. The company has held Nadcap accreditation for chemical processing (nital etch inspection) since 2004 and NDT (Non Destructive Testing?) (magnetic particle and liquid penetrant testing) since 2006.

Micro Precision supplies a number of leading aerospace OEMs and Tier One suppliers with a selection of components, including motor cores for aerospace pumps and generators and geared components for multiple applications throughout the airframe. Using its Nadcap-accredited facilities, it is able deliver its customers with a level of confidence that they would normally only see by manufacturing these components in-house.

So, why did Micro Precision seek Nadcap accreditation? Peter Skelton, general manager explains: "We actually handle a fairly significant amount of aerospace work and the post-manufac-



turing testing of these components is vital. We used to have to (subcontract) the testing out, which lead to inevitable lead time issues and a heavy reliance on third parties. Therefore the decision was made to get our own accreditation as we realized that there would not only be time benefits, but it would also allow us to manage costs more effectively.

"It is an onerous task," he continues, "but if I am honest, it is not that far removed from the quality procedures we already had in place. We have never been a 'get it out of the door quick' company; we believe in doing a job right the first time and to a quality level that wins us repeat orders. Nadcap simply put an official stamp on what we were already doing."

The Nadcap qualification process involves multiple steps, the first of which is an eAudit, where companies complete a preliminary questionnaire. Once this has been completed and approved, the supplier then has to send a hard copy of its quality control manual and procedures to the auditor 30 days prior to the audit visit. The audit then takes place and any subsequent remedial action is performed. Once this is satisfactory and any identified non-conformance reports (NCRs) have been closed the accreditation status is determined by the Nadcap management council and a certificate is issued.

It may sound straightforward, but the level of detail being assessed by the auditor is daunting. "To us it is also an ongoing process," Skelton elaborates. "The initial audit is just the start of it. We are then subject to regular re-approval audits, the frequency of which is determined by our test scores. If you get a good score, the frequency of audits gets longer. We are currently in the second 18-month cycle and if our scores are satisfactory, we will move on to a 24 month cycle, which is a long as it gets. So, not only are we Nadcap-accredited, we are performing to such a level that they are confident enough to audit us every two years, rather than annually."

Is it worth it? "I think that the Nadcap certificate certainly makes us more attractive to other aerospace customers," Skelton explains, "but its benefits are not restricted to this industry

alone. Nadcap accreditation speaks volumes, it means that you are doing something to an exacting standard for one of the most demanding industries in the world, and this is certainly an appealing facet for other industries. We also do NDT and chemical processing for Formula One teams; they don't have their own industry standards, primarily due to their highly competitive business model, but Nadcap certainly paints a positive message for them.

"We are certainly proud of how far we have got in the timescale that we have been doing the processing and to get to the 24-month audit window is no mean feat. A new set of checklists for conventional machining is also being prepared by Nadcap, but has yet to be mandated by the major stakeholders as yet, but you can be sure that Micro Precision is geared up to address this as and when it arrives."

Terry Grubb, managing director, says: "Micro Precision has been in business for over 30 years, quietly supplying sub-contract and make-complete engineering work to some of the highest profile commercial engineering operations in the world - from the latest generation of aircraft to Formula 1 cars. We have grown organically by providing an absolutely top-class service, and this has now allowed us to make this latest investment in new machinery and factory expansion in order to satisfy demand.

"As engineering production becomes ever more streamlined and tolerances and materials become ever more exacting, our value to our customers is on the increase, mainly because of our quality and our flexibility. If a customer requires just one part, manufactured to the same tolerances and put through the same test regime as a larger batch would, then we can do it. Low-to-medium volume production is our current forte, and having continually invested in the very latest high-accuracy machines, the best people and the most exacting approvals such as Nadcap, we believe we are in the right position to provide the type of precision engineering today's growth sectors demand."

For more information"

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Perly L. Hahn

(1948-2012)

Perly L. Hahn passed away on October 16, 2012. He is survived by his wife Gail and children Nathan and Melanie (Hahn) Dawkins. Also surviving are his mother, Doris Henderson, and three siblings (names unavailable). Hahn worked many years in the gear industry as a service engineer, dating back to the 1970s with Barber-Colman Company and later with the Pfauter Corporation. He subsequently moved on to Liebherr Gear Technology, Inc. (1986–2011), where he worked for 25 years until his retirement. However, Hahn continued working in the gear industry—with ITC—until his death. As a result of his long-term employment at Liebherr, along with his days at Barber-Colman and Pfauter, Hahn befriended many fellow workers who now mourn his passing. Everyone who knew Hahn testify to his wit and sense of humor. He will be sadly missed.

Klingelberg

AWARDED DOCUMENTATION PRIZE

The Klingelberg Group has received awards for the second year in succession for the quality of its operating instructions – this year with no fewer than four commendations. The company received prizes for all four of its submitted operating instructions.

"Due to the technical complexity of our machines, we naturally provide the users with very complex operating instructions, and precisely for this reason it is important to us that these are comprehensibly structured, formulated and illustrated in accordance with needs of our target groups," explains Pascal Kesselmark, head of technical documentation of the Klingelberg Group.



Tekom (Gesellschaft für Technische Kommunikation e.V.) had previously awarded the company two prizes in 2011. The operating instructions for four machines were singled out for prizes this year: the Oerlikon spiral bevel gear cutting machine C 50, the Oerlikon tool grinding cell for bar blades B 27, the Oerlikon spiral bevel gear lapping machine L 60 and the Klingelberg measuring center P 65.

Dr. Hartmuth Müller, CTO of the Klingelberg Group, is absolutely delighted with the awards: "We regard them as a validation of our meticulous work in this area. For us it is not only a matter of simple compliance with the Machinery Directive, but far more a question of our responsibility towards the users: we supply instructions that enable safe utilization of the technology. Only then do they guarantee an intuitive and smooth

machine operation in conjunction with innovative control concepts.”

Since 2005, Tekom has been awarding its renowned documentation prize, an independent prize recognizing user and operating instructions for consumer and investment goods as well as online help for software products. The reviewers take into account an extensive list of criteria that, with an eye on user-friendliness and operating safety, places special emphasis on: structure and text, illustrations, design/layout, safety instructions, navigation, scope, and a comparison between the documentation and the actual product.

Gleason and SMT

FORM STRATEGIC PARTNERSHIP

Gleason Corporation and Smart Manufacturing Technology (SMT) have formed a global strategic partnership to provide gear manufacturers worldwide a complete design to manufacturing system. Gleason and SMT will offer a system that seamlessly integrates SMT's premier System Design and Analysis Software (MASTA) with Gleason's software for Bevel Gear Design and Manufacturing (CAGE). Gear manufacturers will benefit from a fully integrated workflow when designing powertrains, gearboxes, transmissions and more. The first products from the cooperation will be available in the first half of 2013.

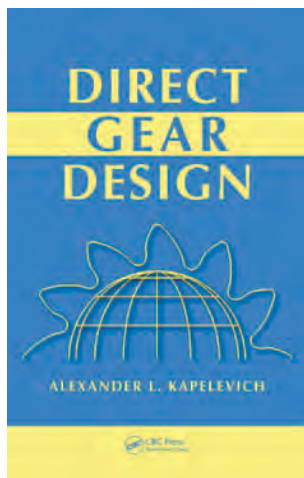
John J. Perrotti, president and chief executive officer of Gleason Corporation said, “We have great respect for SMT's capabilities and are excited about the integration of MASTA and CAGE, and providing designers and manufacturers of gears and power transmission drives with exciting new opportunities to enhance their processes and products. This is the first step in our partnership with SMT and we look forward to exploring other areas of mutual cooperation.”

David Beedan, operations director of Smart Manufacturing Technology, adds, “Gleason Corporation has a distinguished history as the world leader in gear technology and we are delighted to be entering into this partnership to enhance the capabilities of both CAGE and MASTA to provide the user with a fully integrated design-to-manufacturing solution.”

Kapelevich

TO RELEASE DIRECT GEAR DESIGN BOOK IN 2013

Direct Gear Design (Hardcover; 328 pp.; CRC Press) by Dr. Alex Kapelevich, will be available for online purchase—at both CRC Press (\$129.95) and Amazon (\$117.58) March 12, 2013. *Direct Gear Design* presents Kapelevich's copyrighted, alternative “direct gear design” approach and compares it to



traditional methods. It covers all theoretical and practical matters of advanced gear geometry and outlines various optimization techniques for custom gear drive performance maximization. It explains asymmetric gear design and its benefits for various applications and provides real-world examples of direct gear design implementation. Direct Gear Design includes information on macrogeometry of gear, tolerancing and tolerance analysis, gear measurement, gear fabrication technologies and tooling and much more. Kapelevich is a consultant at AKGears, LLC and a regular contributor to *Gear Technology*. To order, visit www.crcpress.com/product/isbn/9781439876183; or www.amazon.com/s/ref=nb_sb_noss?url=search-alias%3Daps&field-keywords=kapelevich.

ANCA

WINS EXPORT AWARD

ANCA has won the Large Advanced Manufacturer category in Australia's Governor of Victoria Export Awards for the seventh time. According to the company, 2011 was an exceptional year of growth for ANCA, an Australian owned and based market leader in CNC tool and cutter grinder design and manufacturing. Pat Boland, co-founder and director of ANCA, made the announcement.

ANCA makes a significant investment to the Australian economy with 98 percent of its products exported globally with major markets in Germany, Japan, China and the United States. ANCA has defied the odds to achieve success on a global scale in a sector traditionally dominated by German and Swiss companies.

The award is one of the most prestigious business awards in Victoria rewarding the most successful and innovative exporters with the stamp of international success.

ANCA reported almost 20 percent export sales increase FY2011/2012, with significant success developing the Chinese, South American and Indian markets. As the EU continues to struggle, ANCA had its most successful trade show at the EMO exhibition with the highest sales ever achieved in its 38 years and has launched new machines and software into the market to remain at the forefront of machine tool technology.

Boland said “This award is an endorsement of the hard work and innovative thinking of the team at ANCA. We continue to push the boundaries, developing even more flexible and sophisticated products and identifying new untapped global markets to sell to. I am proud of the success of our business and our amazing talent that enable us to be the market-leading business we are today.

“Given that we are based in Australia but sell to the world, we have to be the best of the best. Our investment in research and development from the beginning has instilled a culture of excellence where we continue to seek out new and better innovations for our customers.”

The business continues to invest heavily in research and development, create industry firsts and has built a specialist team of around 350 at its head office in Bayswater, Melbourne. Founded in 1974 the business is a market leading manufacturer of CNC tool and cutter grinders.

AGMA FTM: Where Great Minds and Manufacturing Mesh

By Jack McGuinn

Another year, another AGMA Fall Technical Conference.

But this is no ho-hum event. Not when every year, the conference attracts some of the greatest mechanical engineering minds on the planet, along with representatives of the world's greatest manufacturing entities. And who knows—perhaps one day there will be an extraterrestrial contingent—the science is that good. And all of it readily applicable to real-world manufacturing.

“The presentations on wind turbine design and testing, manufacturing considerations for large-girth gear systems, gear lubricants and bevel gear load capacity studies were all noted as practical topics for which the attendees can find direct use in their company's product lines,” says Charlie Fischer, AGMA vice president, Technical Division. (Twenty-four peer-reviewed papers were presented this year.)

Convened this year in Dearborn, Michigan, attendance was “definitely encouraging,” according to Fischer, with about 155 participants. Expect even greater numbers next year in Indianapolis as 2013 is a Gear Expo year—always an incentive for higher attendance.

Citing the attendee survey results, Fischer says “There were many positive remarks as to the value of the FTM this year. One such comment: ‘This is one of the most important meetings I attend each year—would not miss it.’”

Concurring with Fischer was Matt Mondek, current AGMA chairman and just the second to serve a two-year term since the length of service was extended.


“The coupling of the FTM with Gear Expo next year should result in even greater attendance, as we saw in 2011.”

Asked how he is enjoying his chairmanship, Mondek responds: “My selection and service as AGMA chairman has been a very rewarding, enlightening and enjoyable opportunity. I have been honored to represent a great association dedicated to supporting and providing valuable added services to its membership.”

As for the two-year term, “The change was made to allow the chairman a better opportunity to more thoroughly learn the association, to meet and get to know more members and have more opportunities to represent the association internationally. My tenure as chair will end next April at our annual event being held in Carlsbad, California (April 25-27, 2013). After that I will serve as Chairman Emeritus for two more years.”

Also worthy of note is the fact that the demographic seemed to skew a bit younger this year—indeed a welcome development, certainly by AGMA.

“The FTM has been a landmark event for literally generations of gear engineers, presenting practical and useful information on research and experience with power transmission systems,” says Fischer, adding, “But these days it can be considered an extension of the powerful educational programs AGMA offers. Companies realize this opportunity and many are sending their younger engineers to take advantage of the knowledge transfer and networking available.”

So now it is on to 2013—a Gear Expo year and another FTM. The Call for Papers has already gone out, and another strong showing is expected. 

Submitting 2013 Technical Papers

Prospective authors should be prepared to meet the following schedule:

Prepare a brief abstract—one page or less—of your paper and submit to AGMA headquarters by **December 20, 2012**.

January 11, 2013: Authors of selected abstracts notified and requested to prepare first draft.

April 12, 2013: First draft of selected papers due at AGMA headquarters for peer review.

June 4, 2013: Review comments returned to authors for preparation of final draft.

July 31, 2013: Final paper (with illustrations and figures) due at AGMA Headquarters.

For more information: Contact ftm@agma.org.

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January 15–16—AWEA Wind Project Operations, Maintenance and Reliability Seminar.

La Jolla, CA. Join the wind industry's leading owners, operators, turbine manufacturers, material suppliers and specialists from national laboratories to discuss strategies on how best to manage wind projects' assets to maximize the bottom line. Attendees will investigate and analyze condition-based monitoring systems to learn how optimizing them can ensure future success, evaluate case studies and best practices in the evolving wind marketplace and receive the *AWEA Operations and Maintenance Recommended Practices* that will be released at the seminar. For more information, visit www.awea.org.

February 5–7—Expo Manufactura 2013. Cintermex, Monterrey, Mexico. The largest event in Mexico for the processing and manufacturing industries boasts 350 companies representing more than 600 national and international brands. Expo Manufactura brings professionals together with technological solutions in aerospace, medical devices, automotive, metallurgical, aeronautics and electrical appliances. More than 9,000 industry professionals will visit the show looking for industry insights, new technologies and networking opportunities. Exhibitors will include representatives from the United States, Japan, China, Germany, Spain, Italy, England, Canada, France, Taiwan, Korea, Brazil and Mexico. For more information, visit www.expomanufactura.com.mx.

February 26–28—Houstex 2013. George R. Brown Convention Center, Houston, TX. The Society of Manufacturing Engineers (SME) presents this unique trade show that offers presentations and demonstrations on the latest manufacturing technologies. Manufacturing solutions have evolved from simple, off-the-shelf machines to highly specialized technologies of the future. Machines that were once mundane and common are now literal works of art — original, creative, and designed to work with a sophistication that's efficient and compelling. At HOUSTEX, the Art of Manufacturing is on full display. Whatever your industry, you'll discover unique and original solutions for your most urgent and perplexing manufacturing challenges. The event includes keynote speakers, panel discussions, new product presentations, learning lounge presentations, student activities and much more. For more information, visit www.houstesonline.com.

March 5–8—The MFG Meeting (Manufacturing for Growth). Hilton Waikoloa Village, Waikoloa, Hawaii. The MFG Meeting (Manufacturing For Growth) brings together a broad spectrum of manufacturing business owners and top industry executives for a 4-day forum on how we can work together to restore manufacturing to its rightful place as an engine that drives the U.S. economy. Jointly produced by three major industry trade groups, this ground-breaking event tackles the issues that affect the entire realm of manufacturing and provides a forum for a conversation that can't be found at any event presented from a single sector's perspective. For more information, visit www.themfgmeeting.com.

March 5–10—TIMTOS 2013. Taipei, Taiwan. This biennial event will be held at the Taipei World Trade Center. It currently boasts about 38,000 local and 5,500 foreign attendees. Four halls will feature the latest technologies in areas like Measuring Equipment, Software, Surface Treatment Equipment, Metal Forming Machinery, Casting and Forging, Metal Cutting

Machine Tools, Industrial Robots and much more. Conference and seminar topics include innovative hydraulic solutions, machinery safety, rotary tables, intelligence service platforms and R&D machinery components. Taiwan is the 4th largest machine tool producing country in the world with 1/3 of its total production value contributed by machining centers. For more information, visit www.timtos.com.

March 12–14—Gearbox CSI – Forensic Analysis of Gear and Braking Failures.

Hyatt Regency Baltimore on the Inner Harbor, Baltimore, MD. Determining the cause of a failure in a gearbox is like a "whodunnit" mystery. What caused the failure: The bearings, a gear, the lubrication or a shaft problem? Where do you start, and how can you tell? Instructors Raymond Drago and Joseph Lenski, Jr. from Drive Systems Technology, Inc. will help gear designers gain a better understanding of various types of gears and bearings. Learn about the limitation and capabilities of rolling element bearings and the gears that they support so you can properly apply the best gear-bearing combination to any gearbox, whether simple or complex. A certificate will be awarded upon completion of the seminar. For more information, visit www.agma.org.

April 8–12—Hannover Messe 2013. Hannover Fairgrounds, Hannover, Germany. The world's leading trade show for industrial technology returns in 2013 with a full lineup of trade shows under the banner "Integrated Industry." The eleven co-located shows include Industrial Automation; Motion, Drive and Automation; Energy; Wind; MobiliTec; Digital Factory; ComVac; Industrial Supply; Surface Technology; IndustrialGreen Tec and Research and Technology. Russia is the official partner country in 2013. Discover new perspectives on energy, automation and industrial supply and engineering topics as well as a broad range of events and displays affecting the global industrial market today. Other Hannover highlights include Metropolitan Solutions, TectoYou, Job and Career Market and Energy Efficiency in Industrial Processes. For more information, visit www.hannovermesse.de.

May 22–23—AGMA Marketing and Forecasting Conference 2013. Crowne Plaza, Chicago O'Hare Hotel and Conference Center, Rosemont, IL. What's going on in the gear market? What is happening in the end user market that will affect next year? How can you better prepare your company for the ups and downs of the current economic climate? The Marketing and Forecasting Conference will present a comprehensive report on the U.S. Economic Conditions, Industry Conditions for Gears, Gear Market Bookings and Gear Market Shipments. This will be broken down into a series of end user markets including total gears, industrial machinery gears, construction machinery gears, farm machinery gears, power transmission equipment, mining, ship and offshore, railroad and aerospace gears. For more information, visit www.agma.org.

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If you enjoy working with your hands—without doubt a large segment of *Gear Technology's* audience—you *must* go to *robives.com*. There you will find one of the most clean-but-serious fun websites on the Internet. It is where you will learn—or re-learn, in some cases—how to create things from paper. Origami, you're thinking? Nah—mere *child's play*.

We're cuttin' gears, baby!

And not just dainty little paper things to admire—these are fully functioning, *meshing* gears! Bevel gears! Worm gears! Rack-and pinion gears! Yes!

Rob Ives is the mad genius—the man behind the mechanisms—Willy Wonka without the drippy drama—who has elevated child's play to an exquisitely whimsical art form—form that follows function with geometric precision.

His creations exist in many shapes and movements—not just gears. But this *is* a gear magazine, after all, so...

We recently caught up with Rob in his workshop in England, and he was kind enough to do some Q&A with us.

At what age did you begin making paper mechanisms?

I remember making a series of paper models by Peter Markey and having them on my desk in my student (dormitory). So that must have been when I was about 19.

What was the inspiration for the site?

It has been an evolution. I started the *Flying Pig* (*flying-pig.co.uk*) site in 1997, not long after the Internet began. I've always enjoyed computer programming, so when the Internet came along that seemed like the logical thing to do.

What would you call or how do you categorize what you do?

I generally call it paper engineering.

Is this your day job?

It is! It is a weird way to make a living, and from time to time I miss having a regular income and paid holidays. But I love it and wouldn't want to do anything else. I used to be a primary school teacher. I stopped teaching in 2000 to work on the paper projects full-time.

Is there a staff or are you a one-man band?

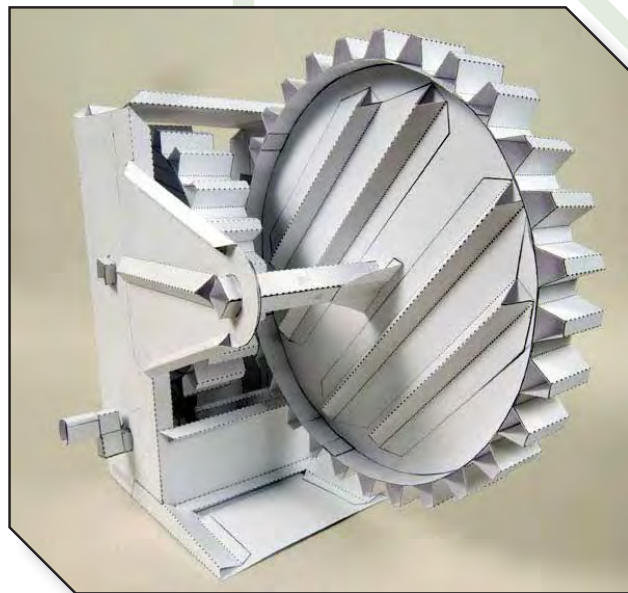
Just me.

Do you have a design and/or engineering background relative to gears?

Only in the sense that I am interested. I have no formal training, but I read a lot about science and engineering.

Do you see yourself as an educator?

Yes. I used to be a teacher, as mentioned. I think education is in my blood. I've had arguments with people I've worked with—publishers usually—where they complain that I reveal too many 'secrets' on my website. For me, it is all about sharing the knowledge and the enthusiasm.



What is the price range for the kits?

On the *robives.com* membership, the main thing I'm trying to sell is a membership. Members can download the projects from the site for free. One year's membership starts from on £9.95.

How's business?

Pretty good, actually. I had a real crisis at around the time of the banking crisis, when three big customers went bankrupt, owing me a five-figure sum. It was pretty scary at the time and it has taken ages to pick myself up. But I think I'm there now.

Any famous customers/fans?

Noel Edmonds (*British broadcaster, writer—Deal or No Deal—and executive*)! That's the only one that I know of. I have customers from all round the world.

What is the point or benefit of membership?

Members can download models for free. My aim in having memberships is that I get a loyal group of followers.

I assume this is a for-profit endeavor?

It is, though profit is not the main motive. I enjoy making things and sharing ideas. The membership lets me do that and put food on the table as well.

Do you have a favorite kit/mechanism?

Usually my favorite is the model that I'm working on currently. I'm really pleased with the Nessie project that I'm working on at the moment. That said, I have a Surly Jack on my desk which I'm rather fond of.

There almost seems to be something of a Zen vibe going on here.

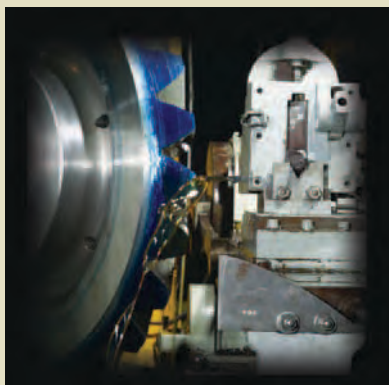
Sure. Did you see the Zen in the Art of Cardboard Engineering model? Turn the handle to hear the sound of one hand clapping!

Who is your typical customer (age, etc.)?

I'm guessing, but I think there is quite a mix. I get parents and children writing in quite a lot. Several teachers, young people, retired people. Exciting, isn't it!? ⚙️

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