January/February 2011

GEAR TECHNOLOGY

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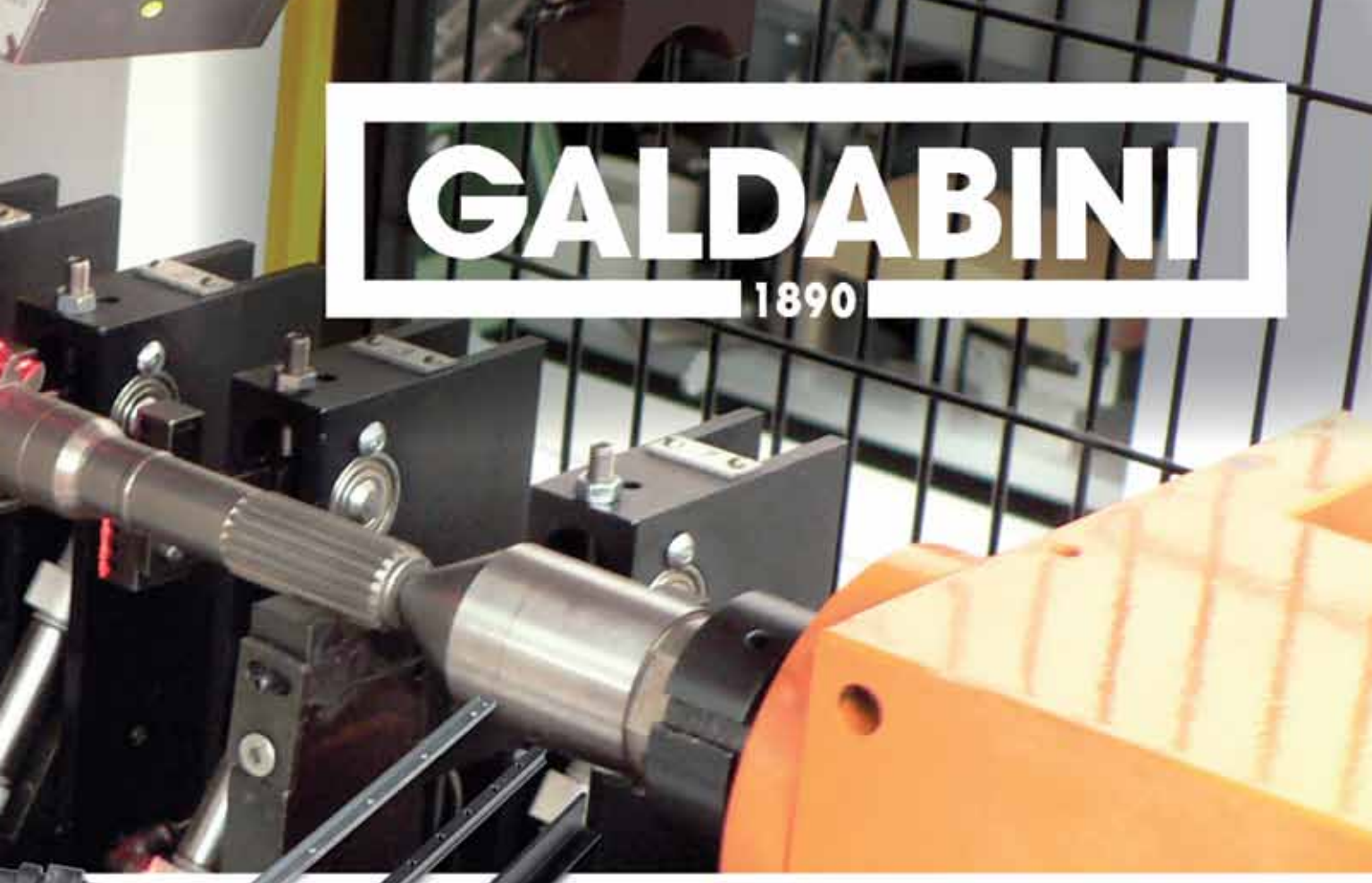

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GEAR TECHNOLOGY

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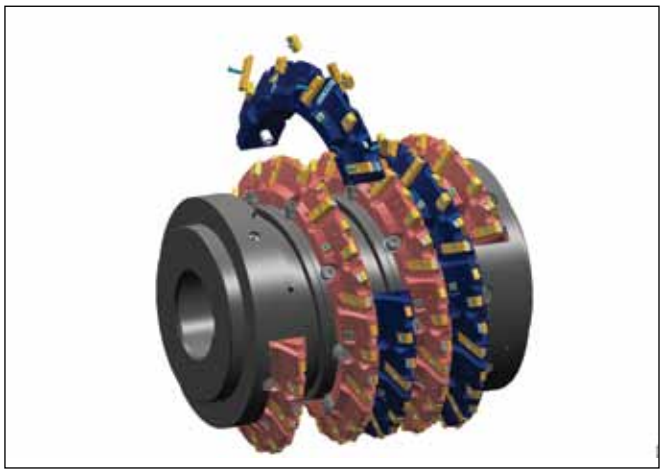

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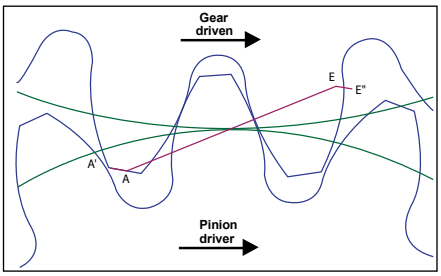

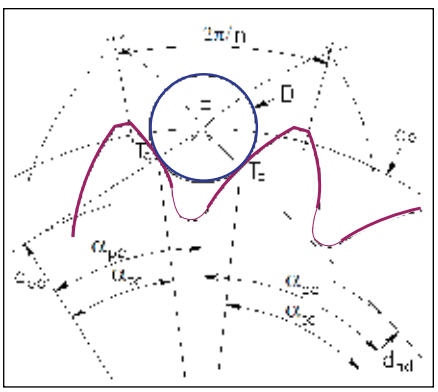

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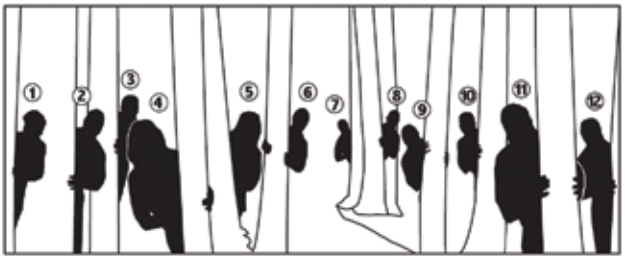

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FOREST CITY GEAR

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Eminently suitable for the wind, industrial, construction and mining industries, the Mitsubishi large machine series sets targets and trends others can only envy and admire. To experience the perfect balance of function and form for yourself visit **mitsubishigearcenter.com** or contact sales **248-669-6136**.

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PROTECTING OUR OWN

I recently spoke with a gear manufacturer whose primary business is supplying gears to U.S. Department of Defense contractors. Things aren't going so well for his company these days.

Despite the fact that business is booming at the factories of most of the gear manufacturers I talk to, this particular gear manufacturer is struggling. In 2010, his shop just laid off 40 people.

The reason for the layoffs, he said, is that he'd lost a big chunk of his business to overseas competitors. His customer, a major U.S. government contractor, was able to save $10 per part by outsourcing to an Asian supplier.

So our government is saving $10 a part, but at the same time, indirectly, it's allowing 40 U.S. citizens to go unemployed. That's 40 people who would otherwise be paying Social Security, federal taxes, state taxes, and so forth, not to mention that they would be earning money and spending it in the U.S. economy instead of the government paying them unemployment.

Is it just me, or is there something wrong with this picture? Does saving $10 on a part that may be vital to our nation's defense seem rather shortsighted? As a nation, we need to be more cognizant of what provides those jobs and keeps our factories and people working.

I know what you're thinking. Protectionism is the dirty word of economics. Tariffs and quotas inevitably do more harm than good—to both trading partners. But something should be done. We need to be more vigilant in looking out for our own economic well being.

The fact is, many countries employ protectionist measures. The United States is no exception. The "Buy American" clause in the recent American Recovery and Reinvestment Act is just one example. Brazil's restrictions on the import of machinery and China's currency exchange rate manipulation are two well-publicized examples.

When I visited China several years ago, I learned quite a bit about the Three Gorges Project, a massive undertaking to build the world's largest hydroelectric power station on the Yangtze River. As part of the project, the Chinese required their foreign joint-venture partners—including ABB, Alstom, General Electric, Kvaerner, Siemens and Voith—to sign technology transfer agreements with their Chinese joint-venture partners. By the end of the second phase of the project, eight of 26 generators had been built almost entirely by the Chinese.

Other nations seem to have a far better understanding than we do of the value of a healthy manufacturing economy, and they take steps to protect their own.

In their book, *A Nation on Borrowed Time*, Joe Arvin of Arrow Gear and Scott Newton describe what they call "the brighter side of protectionism." In the book, they suggest that the way to help U.S. manufacturing is to remove barriers to investment. The primary tool they recommend is tax incentives. Unlike tariffs and quotas, which restrict trade, these measures—if used properly—can encourage growth and investment, particularly in key industries like manufacturing.

Arvin and Newton give an extreme example of possible tax incentives that would help U.S. manufacturers: "For all U.S. based manufacturing companies that produce products, and do so without relying on foreign labor or suppliers, the profits of all shareholders will be 100 percent tax free. In addition, all employees of these companies will be exempt from paying Federal income taxes."

Although the authors themselves admit that this idea is "rather outlandish," they do a good job of arguing for its merits. Instead of restricting trade, like many protectionist measures, their tax incentives would encourage growth and investment in vital industries. If such a law were enacted, they argue, investors—both American and foreign—would rush to find ways to build manufacturing plants in America, and workers would line up to find employment at these facilities.

Undoubtedly, there are other options besides Arvin and Newton's radical approach. In their book, they admit that tax incentives have to be carefully constructed and well targeted, or they may do more harm than good.

But whatever the solution, I'm certain that something must be done. There are only three ways for a nation to create wealth. You can dig it out of the ground in the form of raw materials. You can grow it in the form of agriculture. Or you can manufacture it. It's foolish of us as a nation to continue to be the world's only champion of free trade while our ability to create wealth is being slowly bled away.

If we can find solutions like Arvin and Newton's, which encourage growth and investment, as opposed to restricting imports or artificially adjusting the prices of our competitors, I'm confident that our nation's defense contractors won't have to search overseas to save $10 a part.

Michael Goldstein,
Publisher & Editor-in-Chief

P.S. If you're concerned about America's future, you should read *A Nation on Borrowed Time*. You can order your copy by visiting the authors' website at *www.anationonborrowedtime.com*.

Writing the Standards

Gary A. Bish, Director-Product Design Technology
The Horsburgh and Scott Company

The AGMA committee experience is second to none in developing technical awareness among its members and technical influence among the standards user community. Having personally worked through the local chair positions of a national manufacturing engineering organization, and having belonged briefly to a national engineering organization serving the steel industry, I can say without hesitation that my years on the AGMA Mill Gearing Committee have been without equal in terms of my learning experience.

When the Mill Gearing Committee convened about eleven years ago under the leadership of Craig Danecki, it was blessed with gear engineers representing original equipment manufacturers in the grinding mill industry, as well as representatives of gear manufacturing companies for both grinding mill and rolling mill products, and consulting engineers for both sets of products; and the membership represented three countries on two continents. The group attempted for the first few meetings to divide time between grinding mill and rolling mill applications. It became evident early on, however, that the majority of the membership was involved solely in the grinding mill and related product application. The committee elected to address the development of that standard first. After withdrawing 6004-F88, the work began in great earnest on creating what would become 6014-A06.

The standard 6014-A06 is now being reconsidered for revision or reaffirmation, which will be required in 2011. I have seen a considerable number of mill builders already calling for gearing to be rated to this standard. That is actually an accomplishment, as engineering companies are traditionally slow to change the standards by which they qualify and quantify the capacities and design life of their products. The ring gear manufacturers still see more gear inquiries which refer to AGMA 321, (replaced by 6004-F88 22 years ago), than any other standard. By all accounts 6004-F88 was a failure, as most of those directly involved with the ball mill gearing industry couldn't accept the more liberal ratings and range of solutions it provided versus 321. In fact, a real surprise to me was the "goal" expressed at the onset of the committee work for the 6014 standard, which was to develop a standard that produced ratings more in line with those of 321.

This, of course, was no easy task, as this standard would have 2001 as the parent standard, which includes a different geometry factor standard than 321, as well having all the complexities of multiple material "grades" and the related metallurgical factors which dictate the choice of allowable design stress numbers. Also, time marches on. Since 321 had been replaced, materials like ductile iron, or sheroidal graphitic iron (SGI) and austempered ductile iron (ADI) had made significant inroads to this application. The committee would need to deal technically with these and other issues for the 21st century.

The committee developed its own specific approach to the dynamic factor for the grinding mill application, because the large diameter, flange mounted and spring mounted, split gear blanks experience considerably different transmission accuracy levels than do smaller shaft mounted non-split gears. Member companies shared with the committee results of their research on how pitch varies as the gear split rolls past the pinion, as well as differences in gear deflections between "T"-style and "Y"-style blanks, and mesh stiffness changes with mesh point varying relative to the position of cross stiffeners (ribs) on the gear blank. A standard of this magnitude takes a long time to digest and produce.

AGMA has always carefully kept commercial influence out of committee produced product, which is not easy to do when committee members are convinced that there ought to be factors that acknowledge what they believe is overwhelming technical evidence to support their product design culture. The perfect example is what went on for years in this committee between parties that believed cast steel structure was superior to forged, as in rolled rings or rectangular forgings, and vice-versa. At the end of the day, untold hours of technical research done by companies in the United States, Canada and France were presented, argued and massaged to yield allowable stress numbers for all three materials involved, and a series of metallurgical factor constraints that equate a well made steel weldment with a good forged rim to a well made, sound cast steel gear. Manufacturing guidelines were provided that encourage the standard user to assure that the "T" or "Y" section gear blank was mechanically sufficient, as were maintenance guidelines to assure proper alignment and lubrication. In this way the "application" standard has gone further than any of its predecessors.

The committe members who contributed to ANSI/AGMA 6014-AO6, *Gear Power Rating for Cylindrical Shell and Trunion Supported Equipment*, were chairman Craig

Danecki and myself, vice-chairman, along with: J.C. Berney-Ficklin of Bechtel Corp., J. Carr of FLSmidth & Co., J.L. Daubert of FLSmidth & Co., M. Dreher of Ferry-Capitain, T.C. Glasener of Xtek Inc., R.W. Hankes of A-C Equipment Services Corp., E.O. Hurtado of FFE Minerals, M.J. Raab of Anderol Inc., V. Svalbonas of Metso Minerals Ltd., Y. Theberge of Metso Minerals Ltd. and F.C. Uherek of Rexnord Industries LLC.

The rolling mill standard 6005.B89 was intended to be reaffirmed with a cautionary note, but it was also withdrawn at the same time as 6004-F88. When 6014-A06 work was concluded, many committee members were compelled to withdraw from active duty as rolling mill gear products were not associated with the product offerings of their company. Chairman Danecki also passed the gavel to me at this time. The remaining members were quite few. Fortunately, additional technical experts whose companies were not involved with grinding mills and ring gear manufacturing joined the activities. The committee continues to grow, and in non-conventional ways. We have had involvement by members representing the lubrication industry, and most recently a member involved in the vibration analysis of rolling mill gear drives. The Mill Gearing Committee has survived a few institutional changes at AGMA as well. We were successful in attaining a grandfathered status when AGMA membership became a requirement for committee membership, and a challenge by the AGMA Technical Division Executive Committee over the need for a rolling mill rating standard separate from the enclosed drive rating standard, 6013-A06 in its present version. The reasons why a rolling mill standard is required are exhaustive and beyond the scope of this column. However, the exercise of fighting for the life of a standard document that essentially defines the nuts and bolts of a good portion of your professional life is a real motivation to do the job correctly. This opinion was shared by the committee and was evident in the passion displayed when responding to the committee's request.

The committee membership undertook the rolling mill standard with a considerably different goal than it did the grinding mill standard. The goal was to make the standard reflect the product requirements in the industry today. Unlike 6004-F88, the rolling mill gearing standard 6005.B89 was readily accepted and applied in the metals rolling industry. However, over the last 20 years the rolling mill gear industry has been dominated by an evolving specification for high quality gearing products, with fatigue capacity calculations requiring AGMA 2001 ratings. Only a few customers today require AGMA 6005.B89 ratings, and that is basically because of the lower allowable root bending stress levels in 6005.B89 in comparison to the basic 2001 rating. However, in the rolling mill gear product industry today, the use of the 2001 gear rating standard also requires the application of stress cycle factors equal to 20 years of continuous cycles, longitudinal flank modifications and exhaustive manufacturing control to meet strict metallurgical factors.

Writing a new standard to replace 6005.B89 would guarantee AGMA 2001.D04 as the parent standard. The operational characteristics of rolling mill gearing required that the committee establish metallurgical controls linked to the allowable Grade 1 and Grade 2 stress numbersthat are sufficiently conservative for coarse pitch, shock loaded gearing. While shock loads are a given, much of the gearing today must be highly accurate so as not to negatively affect the surface of the strip being rolled. In the superseded AGMA accuracy standard 390.03, mill gear set accuracy requirements were listed as Q5. Today, requirements run from Q8 to Q12 in the AGMA 2000-A88 system. It is precisely that range of accuracy requirements, in conjunction with requirements for flank and profile modifications, fine surface finish, shot peening enhancements, etc., that requires the new standard allow for quantitative differences in the calculated capacities to agree with the significant manufacturing differences.

Quantifying enhancements are currently provided for by the presence of certain rating factors in the AGMA 2001.D04 power formulas. Many of these factors are, however, undefined or undefined in the 2001 base standard. Linking the enhancement to the benefit of such enhancements requires the benefit of the theoretical research done by many scholars, and the significant applied experience of the committee members. Nevertheless, the introduction of new values to rating factors requires the committee be not only directionally correct, but also significantly conservative.

One of the most enjoyable and educational facets of committee membership is the review of an application standard with engineers from the target industry, who are not gear engineers by background. The rolling mill gearing committee met with two senior maintenance engineers from an Alabama plant of a major international steel firm to discuss the spectrum of loads in the rolling process. We learned how the steel makers interpret the telemetry charts for their mill stands, and from that the committee determined an approach to dealing with the mean rolling loads, the cyclical peak loads, and the non-cyclical peak loads. While this standard is still under construction, we promise a product worthy of the time taken to produce it.

The current committee members and the hard-working AGMA Staff member who are contributing to AGMA 6015-AXX, *Power Rating of Single and Double Helical Gearing for Rolling Mill Service*, are myself, chairman, and Chris Dale of Xtek Inc., vice-chairman, along with: Dick Calvert of Chalmers & Kubeck, Bob Fern of CHL Systems, Hal Johnson of Lufkin Industries, Tom Shumka of Global Inspections, Frank Uherek of Rexnord Gear Group and Amir Aboutaleb of AGMA.

Sincerely,
Gary A. Bish
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Gear Chamfering Robot

SUITABLE FOR SLEW BEARING RING GEARS

The Gear Chamfering Robot from Banyan Technologies is suitable to deburr, chamfer or radius the edges of slew bearing ring gears (courtesy of Banyan).

Banyan Global Technologies Gear Chamfering Robot (GCR) is the newest generation of machines developed to deburr, chamfer or radius the edges of large wind energy slew bearing ring gears. Conventional chamfering occupies significant floor space and requires that large, heavy ring gears be moved onto the machine bed for deburring, a dangerous and time consuming task that requires a skilled operator to "dial-in" the gear position on the rotary table. The Banyan GCR (less than 250 lbs. can be moved into place on the ring gear using a small overhead crane, chainfall or forklift. With a self-locating drive pinion and locking cylinders, there's no need to indicate anything.

"Our gear crawler operates by moving a lighter weight machine tool to the heavier parts instead of moving heavier parts to an even heavier machine," says Darryl Witte, vice president, Midwest Region. "Through self developed onboard intelligence, our crawler will monitor and position a cutting tool to the part form and will debur any form within the range of the tool. It can operate with parts set on the floor and does not require a large ring to be indicated and adjusted central to a rotary table."

The machine finds its own location on the gear and drives around the ring with no user intervention. Banyan's internally developed machine motion controller maintains a constant cutting pressure regardless of tooth geometry, functions with either internal or external gearing, spur or helical forms and ensures a smooth surface finish and consistent cut. Special coated carbide chamfering tools are available in both solid and indexable configurations.

"Operation cannot be easier," Witte says. "We have an onboard touch screen that requires four pieces of gear data and three inputs for cutting parameters that can be either input directly to the control or uploaded from a wireless data point. The machine can even operate via web connection through smart phone technology."

Features on the GCR include program-less operation requiring a minimum number of users, a three hp spindle with vector drive control for precise machine motion and a complete machine cycle that does not require user intervention. The six-inch graphic display touch screen for programming and diagnostic display is user-friendly and includes onboard memory to recall hundreds of chamfering configurations, a multi-axis servo control for machine movement and function, a high precision/low backlash drive transmission and an optional automated Z-axis (spindle height) for multiple pass chamfer depth requirements. Wired and wireless communication is available for remote status, service and diagnostics. A two-color stack light (red/green) is also available for quick status check of operation.

"We have had nothing but positive reaction to this technology," Witte notes. "The most common comments point to the benefit of the flexibility and ease of programming, in addition

continued

to the cost savings over fixed machinery that consumes floor space."

The GCR includes one set of spindle tool holding collets, collet wrenches and tools, removable safety covers for easy service, an operators manual, electric wiring diagrams and a spare parts list. Lift bars for easy movement and positioning of machine for use, storage or service are also included. "The crawler comes complete, less tooling and drive gears as they are specific to the parts to be cut. We provide a one-year warranty of functionality based on single shift usage," Witte says.

Additionally, the GCR can add features such as zoned composite gear inspection, automatic z height adjustment and tooling choices that change the chamfer into a filleted roundover if desired. "The current base model is built for spur form ring gears and we are entertaining quotes for helical applications that require a tilting axis for the cutting tool spindle."

Banyan Global Technologies is a sales and engineering company specializing in the manufacture and implementation of custom designed tooling and machining solutions for major market industries worldwide, including but not limited to the aerospace, agricultural, automotive, compressor, medical, military, marine, mining, offroad, and wind energy markets.

In addition to the GCR, Banyan offers a variety of tools for gear gashing, spline milling, rack milling, skiving, shaping, indexable inserts, slitting saws, bevel gearing, indexable hobbing and reconditioning.

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Gleason's 350GMS

OFFERS FASTER CYCLE TIMES AND MENU-DRIVEN INTERFACE

Complete inspection of gears as large as 350 mm in diameter now can be performed up to 40 percent faster (gear design dependant) with the introduction of the Gleason 350GMS Analytical Gear Inspection System, one of a new generation of analytical inspection systems from Gleason Metrology Systems Corporation. Among the new design features now available on the 350GMS is the *GAMA 2.0 Windows* "object oriented" applications software suite, which offers users faster cycle times and a menu-driven human/machine interface that simplifies day-to-day operation.

GAMA operating software offers a simple, highly intuitive graphical user interface (GUI). The time it takes to create new part inspection programs and conduct a complete analytical inspection of even the most complex bevel and cylindrical gears is reduced, according to the company. In addition, *GAMA* is a true Windows based application, making it fully compatible with the latest LAN and WAN networks, so users can easily interface inspection results with their gear design and production resources for corrective actions downstream.

The 350GMS is also equipped with the Renishaw SP80H 3-D scanning probe, available with various stylus sizes, configurations and extension lengths. The Renishaw probe provides a high speed, high accuracy measurement capability to 2-D probe systems used by other gear inspection machines. With a solid granite base, Meehanite cast-iron slide assemblies, linear drive motors and large-diameter heavy duty rotary table, the 350GMS is also designed and built to deliver accuracy and reliability. The 350GMS has a new operator control panel and remote control with new features and enhanced functionality to improve day-to-day operation.

The 350GMS joins the recently-introduced 1000GMS with these new features and capabilities. Gleason Metrology Systems also offers customers throughout the world's gear production industries a host of other products including functional gages, composite gage systems, software, automation, calibration and other services, and the western hemisphere's only A2LA gear lab.

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CoroMill 325

ENSURES FASTER/ ACCURATE THREAD WHIRLING

Sandvik Coromant recently announced the introduction of its CoroMill 325 thread whirling inserts and holders. These tools address the growing demand for techniques that produce threads fast and at high tolerances, arising from the special thread forms used for medical bone screws, implants and other microcomponents. Thread whirling is a fast and accurate way to thread long, slender components in difficult-to-machine materials. By combining the speed of thread whirling with the rigidity of a sliding head machine, complete threads are produced accurately in a single pass, without the need for special supports. CoroMill 325 thread whirling inserts and holders can produce a wide range of high precision screws and implants from rough stock at high speeds and fit a large number of sliding head machine types. For many manufacturers, this can eliminate the need for a dedicated thread whirling machine. Thread whirling provides a number of advantages over traditional single-point threading, including increased productivity, faster set up times, no extra costs for finishing treatment, suitable chip control and increased tool life over conventional tools.

For more information:
Sandvik Coromant
1702 Nevins Road
Fair Lawn, NJ 07410
Phone: (201) 794-5000
www.coromant.sandvik.com

Luren

OFFERS GEAR CUTTING TECHNOLOGY AND CNC MACHINE TOOLS

Luren Precision Co., Ltd., founded in Hsinchu, Taiwan in 1994, has been dedicated in gear technology including the design and manufacture of hobs and shaving cutters. Owing to its own capabilities in software design and machine tool building, Luren manu-

continued

factures 800 hobs and 500 shaving cutters monthly with its key customers in Taiwan, Japan, Korea, China, Germany and the United States.

During the past decade, Luren also developed other gear-related business sectors like CNC grinding machine tools. A CNC hob sharpening machine was developed first, followed by a CNC worm and thread grinding machine and a CNC gear profile grinding machine (horizontal). The latest development from Luren is a vertical CNC gear profile grinding machine capable of grinding gears of 800 mm in diameter with features of automatic

stock dividing, onboard inspection and rotary dressing. In total, more than 100 CNC grinding machines were ordered and shipped to date.

Additionally, the company manufactures spinning pumps and oil finish pumps used in man-made fiber production, especially for polyester and nylon filament yarns or staple fibers. Luren also manufactures driven tool holders for a CNC turning center. Both VDI and BMT types are currently under development. Strict tests in noise level, temperature increase and vibration are performed for quality assurance.

After the establishment of two sales offices in Osaka, Japan in 2004, and Shanghai, China in 2008, the third overseas sales office was opened in Chicago in July, 2010. Gerald Kuo was appointed as general manager. The function of this sales office is mainly in supporting and reinforcing Luren's existing distributors of gear cutters, CNC grinding machines and spinning pumps in North America.

For more information:
Luren Precision Co., Ltd.
1320 Tower Road
Schaumburg, IL 60173
Phone: (847) 598-3555
www.luren.com.tw

Milling Cutter

DESIGNED SPECIFICALLY FOR MACHINING TITANIUM

ATI Stellram recently introduced a new chevron-style milling cutter, the Stellram 5230VS12, designed specifically for machining titanium and other difficult to machine materials, such as nickel-based alloys and cobalt-based alloys. In comparison studies, the Stellram 5230VS12 cutter achieved metal removal rates up to two times greater than comparable cutters on the market, according to the company's press release. This is vital in aerospace applications where part design often calls for up to 80 percent metal removal. The 5230VS12 chevron cutter positions multiple inserts along the cutting edge of each helical flute. This advanced design of the insert placement provides smooth, progressive penetration and cutting action for extended tool life, lower power consumption and up to a 30 percent improvement in surface finish. Cutters range from 2.5 inches to 4.0 inches in diameter, with four to six flutes. Depending on flute length, from six to 14 inserts can be positioned along each flute. Individual coolant jets to each insert provide constant chip evacuation and temperature stability in the cutting zone. The Stellram 5230VS12 cutter represents a combination of advanced tool design and high technology insert grades, resulting in a tool capable of substantially increased productivity and surface finish quality.

continued

For more information:
ATI Stellram
1 Teledyne Place
La Vergne, TN 37086
Phone: (615) 641-4200
www.atistellram.com

Big Kaiser

RELEASES ER COLLET CHUCK SYSTEM

Big Kaiser has recently introduced the Mega ER Grip, a new premium ER collet chuck system featuring a runout accuracy of .00012" (three microns) at 5xD. The Mega ER Grip was designed to outperform all other ER systems in the four most crucial areas of tool holder performance: clamping force, concentricity, rigidity and balance at high spindle speeds. These factors, combined with the system's reliable and stable runout accuracy, amount to significant long-term savings. A major design improvement increases the contact length of the internal taper of the chuck body, reducing the undesired overhang of the collet for significant performance enhancements. "Our tests have shown that Mega ER Grip performs exceedingly well in these four areas," says Jack Burley, Big Kaiser vice president of sales and engineering. "The result is cost and down-time reduction thanks to longer tool life. Customers will also see improvements in machining quality and shorter production times because of reduced cutting vibrations."

For more information:
Big Kaiser
2600 Huntington Blvd.
Hoffman Estates, IL 60192
Phone: (847) 228-7660
www.bigkaiser.com

Wireless Handwheel

ALLOWS FREE MOVEMENT IN WORKING SPACE

Heidenhain recently released an electronic wireless handwheel for use on machine tools. Especially useful on large machine tools, this cordless HR 550 FS handwheel allows the user to concentrate entirely on the action in the machine's working space by enabling remote control datum setting and probing with free and unrestricted movement around the machine. This also offers the user a safer environment as it eliminates the risk of getting caught in handwheel cables. Used in conjunction with the Heidenhain iTNC 530 control, this HR 550 FS communicates with its base via a 2.4 GHz ISM radio band, freely accessible worldwide. The "FS" stands for functional safety, meaning the handwheel corresponds to the valid requirements for safety such as an emergency stop button and permissive buttons. If the machine operator moves out of range, it reacts with a vibration alarm. The colored and raised axis keys of the HR 550 FS permit traverse of up to six NC axes. In addition, the machine manufacturer can configure an axis key for selection of the so-called "virtual tool axis." The handwheel display itself consists of a header and six status lines. It displays important machine conditions and information (e.g., position of the selected axis, spindle speed, feed rate, error messages, active basic rotation and tilted working plane) as well as the functions of the five soft keys, which the machine integrator can assign as desired. In addition, the machine tool integrator can freely assign specific functions to the six function keys featuring LED indicators. The symbols for the axis des-

continued

ignations and the function keys can be exchanged. In the version with mechanical detent, the traverse per stop can be set. The HR 550 FS also has a docking station features an integrated battery charger.

For more information:
Heidenhain Corporation
333 State Parkway
Schaumburg, IL 60173
Phone: (847) 490-1191
www.heidenhain.com

Height Gage

OFFERS USER-FRIENDLY OPTIONS

Suburban Tool, Inc. has released their newest product offering, the Master Height line of height gages. This height gage is available in three different sizes (450, 600 and 1,000 mm) and two different repeatability/error ranges, the Magna (M designator) with magnetic scales and the Ultra (U designator) with glass scales. The Master Height line offers a soft-touch keyboard, swivel adjustment and user-friendly graphics, both USB and RS232 ports for data transfer to PC or printer, motorized and manual movements with rapid jog, air bearing cushion with built-in air pump, multiple reference points, optional printer attachment, millimeter/inch conversion feature, SPC capabilities, 1000-

step memory and 2-D capabilities. The Master Height can also be used as a "go/no go" gage and can provide a quick manual squareness measurement. The Master Height gage is CE approved.

For more information:
Suburban Tool, Inc
4141 N. Atlantic Blvd.
Auburn Hills, MI 48326
Phone: (888) 647-8665
tools@subtool.com
www.subtool.com

Marksman Diagnostic Tool

CONVERTS ULTRASONIC INTO AUDIBLE SOUND

Tracer Products has introduced the Tracerline Marksman ultrasonic diagnostic tool, a highly accurate instrument that converts and amplifies inaudible ultrasonic sound into audible "natural" sound. Now, service technicians can easily hear sounds that signify problems such as air brake leaks, gear and bearing wear, as well as vacuum, EVAP system, exhaust refrigerant and passenger compartment leaks. The Marksman uses a two-tiered process to ensure accurate diagnosis. First, the receiver unit converts inaudible sound into audible sound using a process known as heterodyning. Then, the receiver's Sound Signal Technology fine-tunes the audible sound into the natural sound emitted by the defect itself. A 10-bar LED display indicates the intensity of incoming signals from the problem source to ensure error-free diagnosis.

The Marksman Master Kit comes with a receiver, full-sized headphones,

continued

two anodized probes and an ultrasonic emitter that allows technicians to test for faulty seals, gaskets and weather stripping in passenger compartments, trailer bodies and other unpressurized enclosures. When attached to the receiver, the 12-inch hollow probe accentuates air sounds, while the solid contact probe accentuates sounds of wear or grinding inside gears. Standard nine-volt batteries are included for both the receiver and the emitter. All components are packed in a sturdy storage case with foam insert.

For more information:
Tracer Products
956 Brush Hollow Road
Westbury, NY 11590
Phone: (800) 641-1133
www.tracerline.com

Emuge

INTRODUCES NEW SERIES OF END MILLS

Emuge Corp. has announced the introduction of TiNox-Cut, a new series of end mills specifically developed to provide tool life when machining challenging materials. TiNox-Cut End Mills offer a cutting solution for nickel alloys like Inconel and Stellite, all grades of titanium and tough stainless steels like Super Duplex—materials used extensively in the aerospace, power generation, medical, chemical and food industries, among others.

"The demand for parts and components machined from these materials is on the rise, but the same special properties, like high heat, chemical and abrasion resistance, that make these materials desirable for use in extreme-service applications, also make them difficult to machine," says Stephen Jean, milling products manager, Emuge Corp. "Typically, these

materials burn up cutting tools. Now, with TiNox-Cut End Mills, Emuge has something to combat this."

The new TiNox-Cut End Mills feature a high heat-resistant, lubricious coating and an optimized cutting edge design. This provides long tool life by minimizing friction and efficiently evacuating chips, which is especially important in tough, long-chipping materials. In addition, the tools are made from an extra-tough carbide grade to maximize wear resistance.

For maximum effective cutting lengths, TiNox-Cut End Mills feature reduced neck diameters. Offering machining repeatability and safety, the new end mills combine a tight, h5 shank tolerance with a specially roughened surface finish to maximize tool holder clamping potential.

The TiNox-Cut End Mills are well suited for both roughing and finishing operations. The tools consist of three designs: two four-flute variations for both roughing and finishing and a five-flute extra long finishing tool.

TiNox-Cut roughing/finishing end mills are available with flat ends or with a selection of corner radii. For even more efficient chip evacuation, TiNox four-flute end mills are available with internal coolant/lubricant capability. The roughing/finishing versions are available with a serrated profile for effective chip breaking during roughing operations.

For more information:
Emuge Corp.
1800 Century Drive
West Boylston, MA 01583
Phone: (800) 323-3013
www.emuge.com

Tru-Temp

AVAILABLE FROM BIRCHWOOD CASEY

The 30-minute Tru Temp low temp black oxide process is now available in a new zero-discharge configuration that eliminates the need for a drain connection. This new Tru Temp system from Birchwood Casey utilizes ion exchange technology to purify and

continued

recycle the rinse waters, resulting in a "closed-loop" zero-discharge installation. The technology is available for all size systems, including 40-gallon, 100-gallon and larger capacity custom tank systems. "Ion Exchange equipped Tru Temp systems work well in those installations where it is impossible, or impractical, to send process rinse waters to the drain," says Mark Ruhland, vice president of Birchwood Casey. "In facilities with septic systems, or in plant locations inconvenient to city drain connections, the ion exchange system allows the process line to operate as a self-contained system. By recycling the rinse waters, the need for a drain connection and discharge permit is eliminated."

The primary benefit of the Ion Exchange equipped Tru Temp system is that the process tanks can be physically disconnected from the drain. The Ion Exchange system removes all particulates and dissolved ions from the rinse waters, generating de-ionized water that is reused over and over. The user gets ultra clean rinse tanks, no discharge to the drain, and near zero water consumption. The Tru Temp process is a suitable in-house substitute for the dangerous 290 degrees F hot oxide process. Operating at only 200 degrees F, the Tru Temp system avoids the severe hazards of a boiling tank and is safe to install in any area of the plant. Now with the new Ion Exchange feature, a Tru Temp installation is practical for any location without sewer district restriction. With a fast 30-minute blackening time, Tru Temp forms a durable, black magnetite finish of .000020 inch thickness equal to that of hot black oxide. The in-house process streamlines part movement, provides better control of finished part inventory, and enhances ISO accountability. Most important, it gives the user a "same-day turnaround" capability to satisfy key customers and fill rush orders—without raising finished inventory levels.

Satisfying Mil Spec DTL 13924D and AMS 2485, the Tru Temp process contains no EPA regulated metals. When a city sewer connection is conveniently located, the process rinse waters are normally sewerable as non-hazardous discharge, without waste treatment. For those installations that require zero-discharge from the system, the Ion Exchange option will sat-

isfy those needs.

The Tru Temp 100-gallon line is supplied as a completely pre-engineered process line for a fast setup. The system utilizes seven individual tanks, each measuring 24 x 40 x 28 inches deep, with a 100-gallon capacity. The complete process line, with Ion Exchange, occupies about 120 square feet of floor space and can process up to 4,000 pounds of work per shift.

For more information:
Birchwood Casey
7900 Fuller Road
Eden Prairie, MN 55344
Phone: (952) 937-7931
www.birchwoodcasey.com

ITAMCO

CREATES NEW MANUFACTURING APPS

Indiana Technology and Manufacturing Companies (ITAMCO) recently released two manufacturing applications to assist those involved in the gear industry. The first is a Metal Weight Calculator; it can calculate the weight of various types of metals in all shapes and sizes. The second is a Thermal Expansion Calculator; it can calculate the change in dimensions of a given material when it is heated or cooled. These new applications join earlier ITAMCO releases including a Hardness Conversion application, GearWare, an application that converts different pitch sizes and Feed Rate Calculator, an application that simply calculates feed rates and speeds for the machinist. All of ITAMCO's applications are free and

available at the iTunes website at *http://itunes.apple.com/us/app/metal-weight-calculator/id404879293?mt=8* and *http://itunes.apple.com/us/app/thermal-expansion-calculator/id408896437?mt=8*

For more information:
ITAMCO
6100 Michigan Rd.
Plymouth, IN 46563
Phone: (574) 936-2112
www.itamco.com

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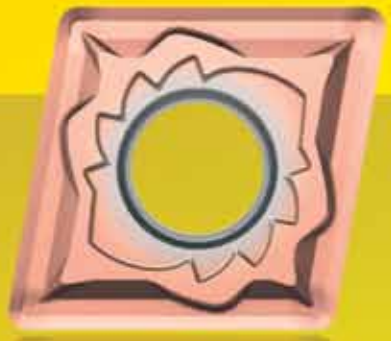
Turning geometries for HRSA and titanium

The six new insert geometries are designed to handle depths of cut from 0.008 - 0.394 inch (0.2 to 10 mm) with great chip control and low tool pressure. Four geometries are introduced for moderate to small depths of cut in light roughing to finishing applications. Two stronger geometries are introduced for larger depths of cut in roughing or light roughing.



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Your success in focus

The Merits of Multifunctional Machining

Flexibility and Productivity Make Solid Case for Machine Tool Integration

Matthew Jaster, Associate Editor

The design of EMAG's VSC 400 DUO WF multifunctional machine is based on the pick-up principle of the EMAG single-spindle turning machine and features both gear turning and gear hobbing operations (courtesy of EMAG).

Increased business in the aerospace, power generation, shipbuilding, automotive and alternative energy industries has led many manufacturers to believe that 2011 might be as good a time as any to invest in new machine tools. This was certainly the case last fall at AMB 2010 in Germany, where 60 percent of attendees planned to make machine investments in the next six months and 30 percent in the next twelve. "According to the results of our survey, visitors' propensity to invest once again matched the same level as that seen at AMB 2008 when the economy was still booming," says Ulrich Kromer, managing director of Messe Stuttgart.

Machine tool investments were also a hot topic at IMTS in Chicago as "sold" signs popped up through the duration of the show. "Those searching for confirmation that manufacturing in the United States is not dying or dead found that it is robust and poised for growth. They clearly understand that investing in the latest technology is the key to being competitive," says Peter Eelman, IMTS vice president of exhibition and communications.

Higher productivity, faster setup times and single unattended operations are just a few of the capabilities gear manufacturers seek in the multifunctional machine tool market.

Though more expensive and robust than dedicated machine tools, many believe these machines represent the

continued

The multifunctional capabilities of the SAMP HG 1200 Invento was on display at IMTS 2010 in Chicago (courtesy of MAG).

Gleason's Agilus features a high-speed tool turret to locate fixed or driven tools for the complete range of turning, drilling and milling operations (courtesy of Gleason).

future of gear manufacturing altogether.

Brian Cluff, vice president at Star-SU, thinks they will be most relevant in the big gear industry. "The people we talk with in the large gear market are looking to combine operations into a single unit to minimize capital investment, maximize machine utilization and reduce space and energy costs for manufacturing very large gearing," Cluff says. "In the medium size gear market users are arranging machines to be automatically loaded (pallet loaders, gantry loaders) to reduce changeover and idle times.

"Spline and some gear cutting are already done using Tsugami screw machines, Mazak Integrex, Bonfiglio lathes and other turning centers," Cluff adds. "This has been going on for some time, but in the 500 mm and above, combo machines for turning, milling and hobbing are not yet a large influence in the technology of gear manufacturing. Combination machines one meter and above will have the greatest impact in large gear manufacturing in the next few years."

The Art of Integration

Combination machines. Integrating a number of different manufacturing technologies into a single machine tool is a growing trend at EMAG LLC. "Multifunctional machine tools make an important contribution to the consolidation of process streams in both soft and hard machining, as they combine turning, milling, gear cutting and grinding operations," says Peter Loetzner, CEO of EMAG.

Apart from eliminating transport and wait-times, they also shorten incidental set-up and non-productive times. When optimally equipped, they can be used as full-fledged turning machines or full-fledged gear hobbing machines. "The machines can be tailored to suit the application, offering the optimal solution for a large variety of manufacturing requirements," Loetzner says.

In the case of multifunctional technology, the most important developments in gear hobbing have been in the areas of high-speed, dry and hard machining. "The driving force behind such innovations is usually the desire for cost reduction or product quality improvement without attendant cost escalation. These new areas of application for gear hobbing operations have depended—to a large degree—on developments and innovations in machine design, tooling materials and tool coating technologies," Loeztner says.

The design of EMAG's VSC 400 DUO WF multifunctional machine is based on the pick-up principle of the EMAG single-spindle turning machine. Both turning and gear hobbing operations are of equal status. The VSC 400 allows for the second operation in the same set-up.

By utilizing the VSC 400, Agco Fendt, a manufacturer and distributor of farm equipment, has brought an overall cost savings of 18.5 percent compared to the previous manufacturing process that used individual machines. The cost of machining an internal clutch plate carrier on the VSC 400 is only 71.5 percent of what it was when the component was made on a number of different machines.

Loetzner believes that the benefits and limitations of process integration are workpiece- and company-specific. "This calls for close scrutiny of all advantages and disadvantages with individual processes on one hand and multifunctional processes or machines on the other."

Machine tool integration in both large and small gears is definitely becoming more feasible in today's manufacturing environment, according to Johannes Brogni, technical director at Gleason Pfauter Maschinenfabrik in Studen, Switzerland. In early 2010, Gleason unveiled the Agilus 180TH, a combination of a lathe and a hobbing machine that accommodates shaft-type parts and is capable of producing disc-type parts as well.

"The biggest advantage of this type of machine is that you can load a forged blank that has been cut to length and centered, and you get a finished part ready for heat treatment," Brogni says. "This concept reduces the throughput time tremendously, provid-

ing the gear producer with a significant cost reduction, especially when he is producing smaller lot sizes of 50 to 500 pieces."

With a long track record in gear processes, Gleason developed the Agilus for the single setup of all shaft- and disc-type cylindrical gears up to 180 mm in diameter with shaft lengths up to 500 mm. It features a high-speed tool turret to locate fixed or driven tools for the complete range of turning, drilling and milling operations.

"One customer running an Agilus machine recently reported that the throughput time of his parts has been reduced from five days to one day, and that he was able to reduce the manufacturing time by 45–50 percent, depending on the parts," Brogni says. "This reduction came primarily from the fact that the operator was able to optimize the process sequence very easily, without the need to consult others."

Additionally, the company has developed the ability to combine the Agilus cell with other manufacturing cells. "This means that we can place other machines like long hole drilling machines, dedicated turning machines, etc., enabling the manufacture of a part from the blank stage until the part is complete and ready to be hardened," Brogni says.

One key to making this technology work is the software. Brogni says the software is one of the major components to the success of the machine—it's also a key challenge. "Two approaches were considered at Gleason; using turning software as the base and adding hobbing software or using Gleason-Pfauter hobbing software as the base and adding turning features. Either approach can work but we chose the latter so that the gear-related technology data and corrections can be handled easily and the hob management is integrated into the software. This has the advantage that the turning programs, which are becoming very simple, can be created on external ISO program generators."

Brogni believes the benefits of multifunctional machines will drive a significant change in manufacturing thinking in the future. "It is possible to integrate processes that could not have been done before, like rough-cut hobbing, chamfering and deburring the part, and then finish hobbing so that the deburred flank is still large enough. When we are looking to machining centers for rotary symmetrical parts we can see that lathes today are capable of performing many more processes beyond turning, like drilling, milling, rolling, etc. I think it is logical that this will also be the case with gears."

With the acquisition of SAMP's gear hobbing line, MAG IAS is able to provide solutions for all processes from the soft blank to the finished gear. This puts the company in the unique position to offer a wide array of multifunctional equipment.

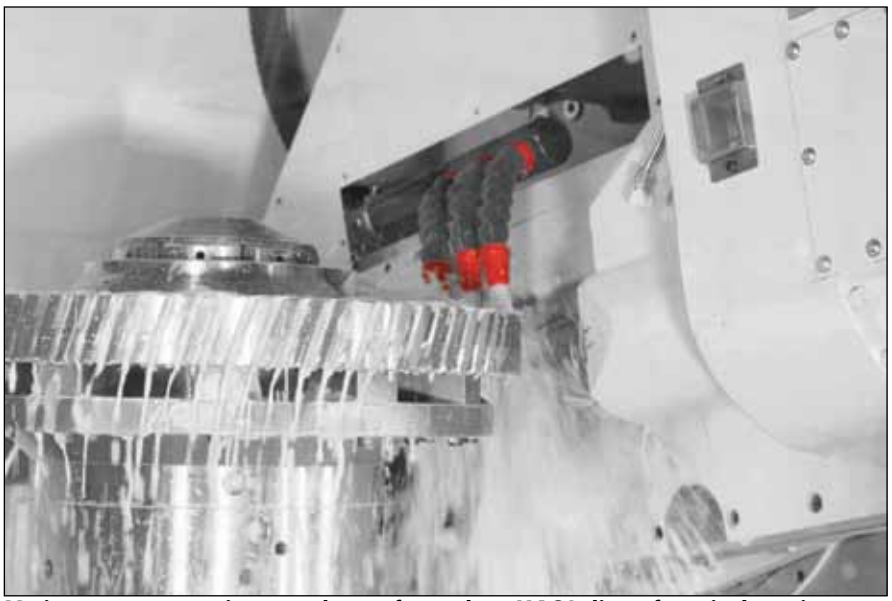
The SAMP HG 1200 Invento, for example, addresses the requirements of large gears with diameters up to 1,200 mm and module 35.0 (40.0) in the energy, transport and construction sectors. It features a twin-table concept, enabling the operator to execute the complete setup and centering process

continued

in masked time while the manufacturing process proceeds on the second work table. Reduction of setup time is not only possible for mass production but also for the manufacturing of small lots.

MAG's own range of vertical turning centers (VTCs) can process the gear in one setup, both the turning and gear cutting. The part setup time and workpiece handling are reduced, which is particularly important for large gears.

"The advantages include faster processing speed and higher throughput. In addition, part accuracy benefits from the one setup process since you don't have the errors inherent in multiple setups. There's also a lower initial investment since one machine can do both turning and cutting. This also saves valuable manufacturing floor space," says Helene Nimmer, global product leader at MAG IAS. "We see multifunctional machine demand growing, especially in the industries that produce large gears. We've applied the 1,000 mm machines and are expanding the technology to larger machines and gears."



Various gear operations can be performed on MAG's line of vertical turning centers (courtesy of MAG).

Through simultaneous five-axis machining, Mazak's Integrex e-670H II can produce complex shaft workpieces containing tapered holes, blisks and spiral bevel gears in a single setup (courtesy of Mazak).

The company has an extremely wide range of products including vertical and horizontal lathes, machining centers, boring mills, agile powertrain machines, profilers, composite processing, software, automation and component production, according to Nimmer. "Relative to gear production, we have turret and ram head vertical turning centers that start at 250 mm and extend to eight meter tables. For the VTC series, one tooling advantage we offer is the ability to use standard modular tools such as KM 80 and Capto."

Multitasking machines. Cutting gears on non-gear machinery is a trend that continues to grow as software programs and machine tool upgrades give users the versatility, functionality and customization to do jobs both in and outside the gear industry.

"Multitasking machine tools can compress the manufacturing cycle by performing a variety of operations without manual intervention," says Mike Finn, development engineer at the Mazak Corporation. "Combining operations such as turning, milling and, now, some forms of gear cutting on a single platform not only minimizes setup time, but also reduces floor space. Plus, the customer gets the service and support benefits that come with a standardized machine tool, as opposed to the challenge of maintaining a special-purpose machine tool, which can become very expensive, especially if not fully utilized."

Mazak, for instance, has a broad range of machine tool experience beyond gears. "We have been creating processes on multitasking machine tools for our customers, and in our own factories, for many years. Adding gear cutting capabilities onto existing multitasking machine platforms and working with customers and suppliers to refine this are in a growing trend," Finn says.

One of the keys to Mazak's success in this market is repeat business. "Our customers who have maintained their competitiveness with multitasking are collaborating with us and our supplier partners to add additional capabilities. They want the benefits of standardized Mazak multitasking machine tools,

but with ultra-tasking capabilities. They're pushing us to add capabilities such as gear cutting, so that they can do that one additional operation while keeping the part on the machine, rather than moving it off to specialized equipment. Exceptional accuracy and ultra-fine synchronization of rotary and linear axes allow quality levels in the AGMA class 8 to class 10 range in certain applications, without adding to the overall cycle time of the workpiece. Combining subsequent process into one, along with additional metal cutting time, increases utilization of the machine tool, thus reducing overall cost per hour to provide additional profits."

The Integrex j-series offers four-axis simultaneous machining with five-axis tip positioning. It features large Y-axis strokes and offers a milling spindle that can be indexed in five degree (one degree optional) increments over a total range from -30 degrees to 190 degrees, allowing outer diameter machining and facing with the same tool. The Integrex e-series is suitable for the production of large parts and performs various gear cutting processes.

"The Mazak e-650H II is available with a unique tool holder that can be automatically loaded onto the milling spindle offering deep-hole drilling operations," Finn says. "It offers 191 Nm of maximum torque and a maximum spindle speed of 400 rpm. It can perform hole-drilling to a maximum depth of 800 mm."

In cooperation with Voith, a major transmission manufacturer in Germany, Heller Machine Tools has developed a process that significantly enhances the productivity of pre-milling and gear milling operations performed on a single five-axis machining center. Both companies have applied for a patent on the jointly developed process.

The process is aimed at manufacturers of vehicles, machines or machine components that can use the machining center for lower volume production of larger gears as well as other machining tasks, according to Tracy Ellis, sales manager, machines at Heller Machine Tools.

Gear milling has recently been an interest of some machine tool builders as it is more efficient to use the existing capability of a five-axis machining center for new applications beyond those typical for machining centers. According to Ellis, gear milling provides an opportunity to use the full potential of its five-axis machining centers from its new F series machines to its heavy-duty MCH-C series.

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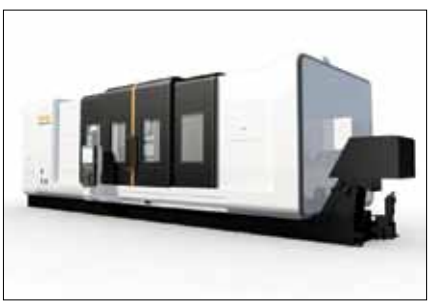

Mazak categorizes its multitasking machines into five levels, allowing customers to navigate the product lines and select the best machine for specific applications (courtesy of Mazak).

For the machining of gears, a module two or smaller fits the capabilities at Index and Traub (courtesy of Index).

Ellis pointed out that traditional gear-making machine manufacturers continue to concentrate on special-purpose machines and tools dedicated to gear machining, but that manufacturers of machining centers can provide complete machining for a wide range of applications as well as solutions for gear modeling using special software. The software permits the user to generate an ideal gear geometry from which the gear-making process can be developed.

A global turning machine manufacturer, Index products include CNC lathes from single-spindle to multi-spindle machines as well as fixed and sliding headstock machines.Tyler Economan, proposal engineering manager at Index Corporation, says, "When a part can be machined in a single-step process, the accuracy is much greater. The result is fewer scrap parts because less handling is required. In addition multifunctional machines can offer lower cost per piece."

The machines at Index are designed to have extreme thermal and dynamic stability, and the engineers are attentive to today's technology demands. "Machining all of the features is much simpler than using fixtures or complicated workholding as in a traditional gear making machine. Another benefit is that this process allows for optimal run-out between the bearing diameter and the gear profile," Economan says.

The Index MultiLine multispindle CNC machines combine the benefits of traditional high production multi spindle automatics with the benefits of modern CNC technology. The MS40 is a new machine that offers multiple operations on small workpieces from bar up to 40 mm or chucking up to 120 mm. "It features six fully independent liquid-cooled, hollow shaft CNC spindle drives each capable of 7,000 rpm."

Without fixed tool assignments, any tool can be used in any position in most scenarios, according to Economan. "The machines have an innovative guide way design that provides high stiffness and dampening, this is very important when machining high precision parts."

Index also includes a simulating and optimizing software system called *Virtual Machine*. This software is a simulation tool for Index machines that features Siemens 840D controls. Users can operate various functions from their offices just like they would at the machine itself.

"With technology continually evolving in the gear industry, Index and Traub are continually designing and offering new machines," Economan says. "Gear machining as an integrated process can be advantageous when the relationships of certain features on the part to the gear form are critical. When it comes to machining gears, a module two or smaller is a good fit for our capabilities."

Brian Nowicki, sales agent for North American Machine, the Depo importer, sees machining centers as a key advantage for the large gears found in the oil/gas, mining and wind energy industries. "While cycle times are not as quick as conventional methods on smaller gears, the benefits come as you get into the larger sizes," Nowicki says. "In the traditional gear cutting world, each of the gear families requires a different type of machine. With this new technology, one machine is equally effective for all gear types within its given diameter range."

Nowicki says a Depo machine was able to perform a project involving double helical gears in 45 hours instead of 150 from a dedicated machine. "The accuracy of the machine, the functionality of the software and the support and knowledge of the engineers are the keys to our success."

Depo's five-and seven-axis vertical and horizontal machining centers include thermal compensation, broken tool detection and workpiece inspection. Depo's unique software package—*Gear Engineer*, *DepoCam* and *Inspect*—are all integrated with its machine tool line and high-end tooling solutions, to produce the gears.

Additionally, the system can do lifting and mounting holes as well as gearboxes. "It's often overlooked that we're selling a machining center that can do much more than dedicated gear cutting machines," Nowicki adds.

He warns that customers should do some research before making a decision on machine tool purchases of this nature. "Everything is about integration today. It's about providing the customer with a complete turnkey process. If you don't have the software or the expertise to back up your equipment, you're going to play catch-up. Depo's ability to simplify the manufacturing process is one of our greatest strengths."

He adds that there are three important factors to take into consideration when shopping for multifunctional machines, "The quality of the gear, the quality of the machine itself and the rotary table. Accuracy plays a major role in what you can or cannot do. If you don't have the sales and support staff that understands gear geometry, you're not going to be happy with the product. The industry is trying to piece together the technology and get the most out of their machines and tools, but you must have experience and knowledge to do it right."

The All for One Philosophy

Multifunctional technology has certainly created a buzz on the trade show circuit recently as more companies come together to share knowledge in their respective areas of expertise. Companies are aggressively expanding product lines to capture new markets—chalk up gear manufacturing as one area of interest.

The impact of MAG's acquisition of SAMP's hobbing machinery line, for example, clearly points to a future where more companies may bring a variety of expertise to a specific industry. Combining MAG's complete range of multifunctional turning products with SAMP's gear cutting products opens an entirely new customer base.

"The marriage of the two technologies and the opportunity for our product leaders to work together will produce new technology for markets that

demand that their machines do more," Nimmer at MAG says. "Since partnerships are the quickest way to bring new technology to the market, we may still see additional joint ventures."

The Mazak Corporation is also currently working with other companies on future business in the gear industry. "We're working with another company to develop optimized models of the spiral bevel gear. Like many in the industry, we're working on a long-term partnership that can only increase the productivity of our machine tools," Finn says. "When we put all of our heads together, it's interesting to see the kind of impact you can have on the engineering side. This seems to be a popular trend at the moment in gear manufacturing."

"With more products to offer and additional knowledge from these mergers, these companies will have more opportunities for new customers and a great customer base," Economan at Index says. "With the current economic climate, it may also be true that some financially weaker companies will consider merging."

More important than what companies are saying about mergers and acquisitions are what they're not saying. Many of the companies interviewed for this article chose not to comment at all on the subject, though a select few hinted at new developments happening in 2011 and 2012.

Future Considerations

While sales agents and engineers are quick to point out why their company's machine tools are the best, customers must look at their current machine capacity and determine what upgrades they can afford and what logistically makes sense.

"Bottom line, traditional gear makers use dedicated machine tools because individually they are the best at whatever it is they do," Nowicki says. "In high production scenarios, the machining centers are not nearly as competitive with cycle times. The dedicated equipment can machine the gears faster, but when you're dealing with critical parts, there are machining centers that can do things that have never been done before."

Any debate on the advantages/disadvantages between multifunctional equipment and dedicated machine tools is not easily answered, according to Brogni at Gleason. "It is dependent upon a wide range of different factors, and can even be different from one manufacturing plant to another that is producing the same part."

In talking with many machine tool users, it's going to take education, awareness and a little faith in new technology for some to incorporate multifunctional machines into existing manufacturing environments.

"We have seen some customers that are not yet ready for this idea. They have existing equipment or organizational issues that prevent them from taking this approach at the moment. It has to do with the education of the machine operators," Brogni says. "Some are skeptical that such a concept will improve their productivity while others understand the benefits when

continued

they see the machine in operation and enthusiastically begin to create ideas for what additional processes might be integrated."

Adds Nowicki at Depo, "Multi-functional is the direction this industry is going. It's been a frequent topic of conversation at trade shows and AGMA meetings. Big gears are coming into play in a variety of industries and the market is hot right now. Maybe you're not considering this technology, but there's a very good chance your competition is."

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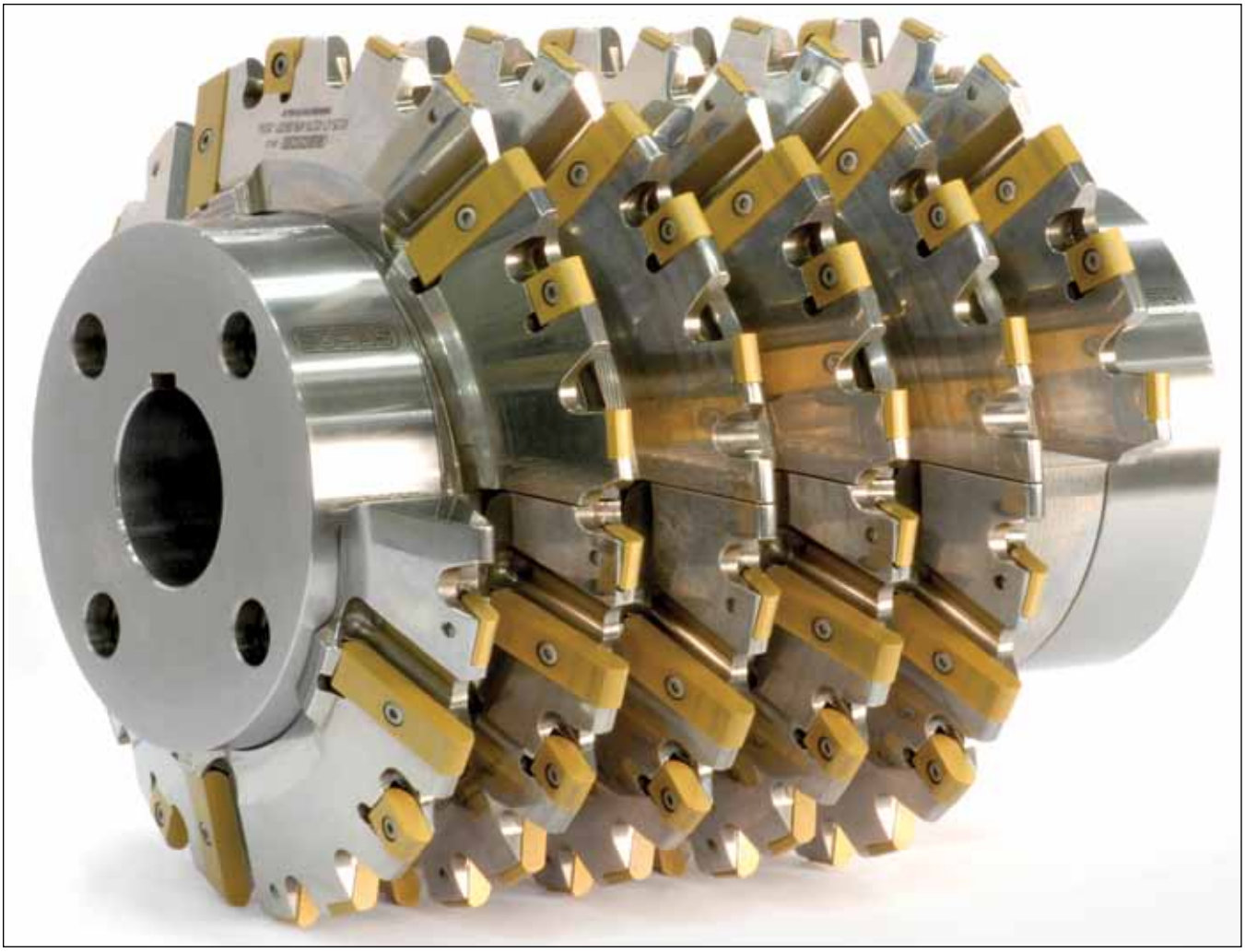

Demand for indexable carbide insert cutting tools has grown over recent years, due in large part to the increased production requirements for wind turbine and other large-module gearing. Shown here is an indexable carbide insert hob from Seco Tools Inc.

Big Gears Better and Faster

CARBIDE INSERT CUTTING TOOLS PROVIDE INCREASED PRODUCTIVITY AND QUALITY

William R. Stott, Managing Editor

Indexable carbide insert cutting tools for gear manufacturing are nothing new. Ingersoll first introduced indexable carbide insert gashing tools in 1977, and carbide insert hobs in 1979. LMT-Fette began making these tools in the mid-1980s.

But big gears have recently become a very big business, thanks in part to the wind turbine industry, but also due to increased production requirements in mining and other energy sectors. The result is that there's been a renewed interest in carbide insert cut-

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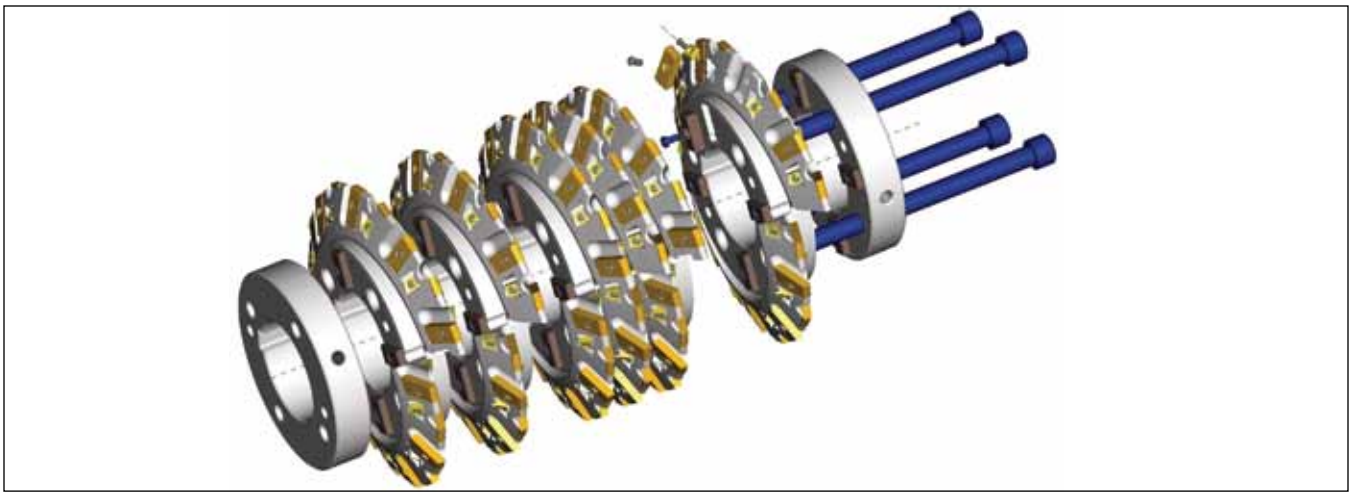
Multi-start hobs are one of the more recent innovations in indexable carbide insert gear tooling, as shown in these tools from a) LMT-Fette and b) Ingersoll Cutting Tools.



Indexable carbide insert hobs are most commonly assembled from individual segments, as shown in this exploded drawing of an Ingersoll hob.

ting tools, and a host of new suppliers have entered the market—especially the U.S. market—over the past few years.

"The manufacturers of large-module gears used in wind energy are focusing to increase their production efficiency by higher cutting speeds and feed rates," says Dr.-Ing. Friedrich Momper, manager of gear products at LMT-Fette. Those higher feeds and speeds require carbide tools rather than the traditional high speed steel, Momper says.

Darryl Witte, vice president of sales at Banyan Global Technologies, agrees. Banyan manufactures a line of carbide insert milling cutters, gear gashers and shapers. "Wind growth has for the first time allowed for higher volume manufacturing of coarse-pitch, or large-module, gears. In that higher production mode, indexable carbide solutions are paramount to improve cost metrics in production of these geared components."

"We have seen a considerable increase in the demand for these tools in finishing and pre-grind applications, for both the indexable gashing tools and indexable hobs and shaper cutters," says Michael Tennutti, senior product manager at Gleason Cutting Tools, which sells indexable tools under the Opti-Cut brand name. "A major driver has been the global energy market, including applications for mining and heavy construction equipment, but especially for wind turbine gearboxes."

Why Carbide Inserts?

The main advantage of indexable

continued

Internal gear gashing is one of the primary uses for indexable carbide insert gear cutting tools. Shown here is an Opti-Cut gear gasher from Gleason Cutting Tools.

Different manufacturers offer different approaches to optimizing the technology. For example, milling cutters from Safety (left) use a wedge-style clamping system to enable greater tooling flexibility. Banyan also uses wedge-style clamps on some of its finishing cutters (right).

carbide insert tooling is that it allows manufacturers of big gears to increase their feeds and speeds without having to go to a solid carbide tool. In fact, beyond a certain size range, solid carbide tools aren't practical or even possible to manufacture.

"Costs aside, some coarse-pitch modules simply cannot be produced in solid carbide, necessitating an inserted blade approach" says Gleason's Tennutti. "Larger modules such as 20 module can now be made in diameters ranging from 350 to 400 mm, which is well beyond the size range possible in solid carbide."

Some manufacturers of these tools offer them in module ranges up to 40, 50 or more.

Because the only alternative to these carbide insert tools is high speed steel (HSS) tools, there is often a dramatic difference in productivity when comparing the options.

"The main advantage over HSS is increased productivity," says Todd Miller, milling tools product manager for Seco Tools. "Carbide can provide cutting speeds 4–8 times faster than HSS tools. This means you can produce more parts in less amount of time."

"In our experience, especially with large gears, we have found it is not uncommon to see 50–75 percent reduction in cycle times compared to HSS," says Frank Berardi, gear machining product manager for Ingersoll Cutting Tools.

Another advantage is that carbide tools can often be run without coolant, which provides additional environmental benefits and cost savings.

But even in module ranges where solid carbide is available, indexable

Gear milling tools are generally optimized per application, with different inserts for profile and root, as shown in this milling cutter from Seco Tools.

Indexable carbide insert shaper cutters are offered by a number of manufacturers, including Ingersoll (right), Banyan (left) and Gleason.

insert tools can offer some advantages.

"Solid carbide tools are very expensive tools to keep on hand," Miller says. "Typically you need three to four of the same tools per job. One in service, one on the shelf ready to go on the machine and one to two getting re-ground and re-coated. Refurbishing is typically done by an outside vendor, which takes time. Indexable carbide inserts are much less expensive and help reduce costly inventories."

LMT-Fette's Momper agrees. "Using indexable type cutting tools overcomes the issue of reconditioning of solid type hobs," Momper says. "If reconditioning (grinding, stripping the old coating and depositing the new coating) is not handled properly, this will lead to loss in an effective utilization of a solid type hob. With the inserts, inspected by the supplier, the customer gets a ready-to-start solution with repeatable accuracy and tool life."

Another benefit of the inserted blade tools is the flexibility allowed by changing out the inserts. This flexibility can allow different parts to be cut with the same cutter body simply by changing the inserts.

"Changes in part material and hardness can be accommodated by simply changing insert grade or edge prep," says Ingersoll's Berardi. "Likewise, slight modifications in tooth involute form can often be accommodated by insert or pocket modifications."

Drawbacks

Taking advantage of carbide tools requires the ability to run at higher speeds and feeds, as well as machinery that is extremely rigid. Because of

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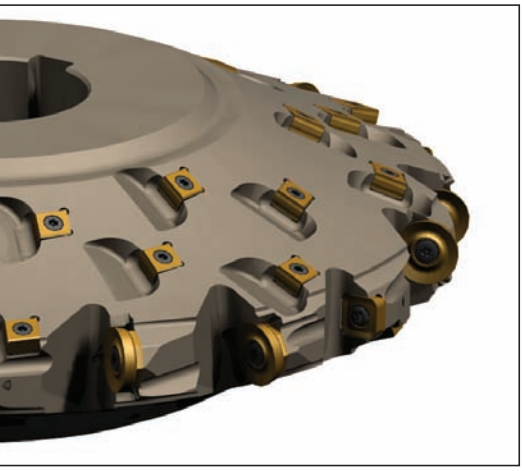

these requirements, you can't just put one of these tools on an old gear gasher and expect it to perform.

"Realistically, the limiting factor in using this technology to its fullest extent has been the available machine tools," says Brian Nowicki, vice president of sales & marketing for Cimtek LLC, which represents Safety Cutting Tools.

Gleason's Tennutti agrees that these tools require modern, rigid machines that have been designed with carbide in mind: "Today's CNC hobbers and shaping machines offer improved stiffness characteristics and increased power ratings, and can take advantage of today's cutting tool materials and coatings. The user can run at much higher speeds and feeds than with high speed steel tools."

Recent Developments

Despite the fact that indexable carbide insert tools have been around for a long time, there continue to be improvements in their design and application, as well as new entrants into the marketplace.

One of the newest competitors in this field is Sandvik, whose CoroMill 170 series of milling cutters was introduced at IMTS 2010. Sandvik has developed this tool specifically with the wind turbine industry in mind, concentrating on module ranges from 12–22, according to Kenneth Accavallo, gear industry applications specialist.

Even though they are a relative newcomer, Sandvik is focused on developing its tools for more and more applications, Accavallo says, and they have also been working hard to develop indexable carbide insert hobs, which the company expects to fully introduce to the market in 2011.

But even at the more established companies in the market, R&D continues with an emphasis on increased quality and productivity.

"Recent emphasis has been in development of carbide milling grade substrates, coatings and post coat processing to increase tool life," says Ingersoll's Berardi. "In addition to grade development, advanced pressing technology has allowed us to develop freer cutting positive geometry inserts in precision tolerances."

Berardi points to Ingersoll's S-Max double positive insert as an example of the latest in insert technology. "Originally developed for our Max-line milling cutters, it has proven to be an effective and economical performer for rough gear gashing. Improved manufacturing techniques in production of cutter bodies, especially insert pocketing, allows us to now produce finish gear cutters to very tight tolerances without the use of shims or adjustment mechanisms. For the customer, this greatly simplifies cutter set-up and tool change. We are applying this same technology for pre-grind and final finish applications, and we can now provide precision pressed and ground concave and convex inserts to cover the entire involute form."

According to Berardi, one of the advantages of Ingersoll's "freer cutting geometries" is that they reduce power consumption on the machine, especially for rough cutting. "This allows us to perform the same cut at higher operat-

ing parameters with little or no increase in horsepower consumption, compared with HSS and solid carbide," Berardi says. "In addition, the double-positve S-Max provides smoother cutting on the tooth flank, which greatly reduces axial forces. This has opened up opportunities for customers who have older equipment, or lower HP machines, to still take advantage of the benefits of indexable tooling."

Improvements in the tools have resulted in improvements in the part quality.

"As we continue to improve finishing capabilities, we are seeing more applications for machining teeth to pre-grind and final finish dimensions," Berardi says. "For many applications, we can achieve the profile and finish tolerance by finish milling or finish hobbing, thus eliminating the need for grinding."

Eliminating the grinding process is also on the minds of engineers at LMT-Fette and Seco.

"With the new gashing cutters and ICI hobs, you can achieve high gear qualities," says LMT-Fette's Momper. "In some cases, grinding processes could be minimized or even become redundant."

"We are now able to achieve gear tolerances of DIN 10 or better, depending on module size, with an indexable carbide tool," says Seco's Todd Miller. "Whenever you can get to a point of eliminating grinding, there are tremendous cost savings available. Grinding machines are very expensive, and the grinding operation is typically much more expensive than milling with carbide tools."

Another recent development in indexable carbide insert hobs is the two-start hob. Ingersoll, Kennametal and LMT-Fette all offer this option.

"This year we introduced a new two-start ICI hob, which can nearly double productivity for machining gears with large numbers of teeth," says Ingersoll's Berardi. "This is a segmented design with the same design features as our single-start hob. Although it's primarily designed for roughing and semi-finishing, for many applications we can achieve finish quality."

At Safety, the gashing tool has also undergone significant development, says Cimtek's Nowicki. Instead of the traditional tangential screw mount used by many manufacturers of gashing tools, Safety employs what Nowicki describes as a "wedge-style clamp."

The wedge provides increased flexibility for the tool, because it allows quick and easy changing of the inserts to accommodate a wide range of pitch/diameter combinations and surface finishes. A change in inserts is likewise all that's needed to switch from internal to external gears, Nowicki says.

Banyan, Gleason and Ingersoll offer indexable insert shaper cutters, but these are also areas where the manufacturers are working to improve the tools.

"For internal gears, we have a new finish gasher with interchangeable hardware that is adaptable for negative or positive inserts with four cutting edges," says Ingersoll's Berardi. "The insert pocket is designed to allow the same tool body to cover a range of

continued

gear diameters of the same module, by changing inserts."

"Another area of great interest is our development of indexable insert roughing shapers," Berardi says. "We've had great success with this product, and we are working on expanding the offering to cover a wider range of sizes. Shapers are still widely used for double-helical gears and shoulder applications where there is no clearance for gashing or hobbing cutters. It is typically a very time-consuming process. With the indexable roughers we can remove the majority of stock, leaving 0.2 mm or less for the finish shaper. This typically results in 50–70 percent reduction in machining time."

The Future

A number of manufacturers are working to increase the size range of gears for which indexable tools are an appropriate option. In particular, smaller gears seem to be one of the next targets.

"We are constantly working on ways to cover a wider range of gear tooth sizes, especially in smaller module gears," says Ingersoll's Berardi. "I believe we will see some breakthrough in this area in the near future."

Kennametal produces inserted blade hobs as small as 4.5 module, according to Klaus Wichmann, manager of gear milling for Kennametal GmbH in Germany. But Wichmann believes modules as small as 3 are possible.

Banyan is also aiming for smaller gears. "We continue to push to smaller pitch sizes, not only for gear, spline and rack milling, but also for finer pitch hobbing, so as to reduce the costs associated with what is commonly viewed as one of—if not the—most expensive tools used in gear manufacturing," says Witte.

Another area that will continue to improve is the customization of the inserts and insert configuration to achieve specific goals.

And, of course, the manufacturers will also continue to work on better insert materials and coatings. "Continued advances in substrate, geometry and PVD coating technology will continue to improve cutting speeds, metal removal rates and ultimately cycle times," says Cimtek's Nowicki.

Conclusion

Even though these tools have been around for a long time, in one form or another, there has clearly been a resurgence in the marketplace, both in the demand for the tools and the number of suppliers who make them. Also, there has been significant research and development on the tools, meaning that they provide greater productivity, higher quality, and more manufacturing options than ever before.

So manufacturers of large-module gears who haven't yet investigated these tools might want to reconsider. The range of suitable applications for indexable carbide insert gear cutting tools has grown considerably, and it appears that it will continue to grow for the foreseeable future.

See pages 46-49 for complete contact information on the companies mentioned in this article.

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Carbide Insert Cutting Tools—The Suppliers

Below are profiles of the major companies who are suppliers of carbide insert cutting tools for gears. The cutting tool ranges are described, and any specialties or unique capabilities are noted.

Banyan Global Technologies

"Our tools are sold as a custom solution for every application," says Darryl Witte, vice president of sales. "We evaluate the machine tool, fixturing and part condition to tailor-fit a tool to the process. Customers have the freedom to purchase the cheapest tool possible, the most cost effective, or the one that will return the highest quality part; every one of which will return a different design with a different cost."

"We at Banyan use our years of metalworking experience to design optimal indexable carbide solutions for both coarse and fine pitch gear cutting."

Solutions offered: Rough and finish gashing cutters for internal or external application from 1–50 module, 1" to 36" diameters. Spline milling tools any size. Indexable shaper cutters for roughing, 2–25 module, indexable hobs from 2–45 module.

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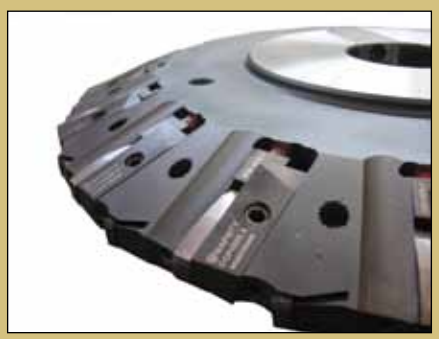
Cimtek LLC



"Safety's biggest advantages lie in multiple areas," says Brian Nowicki, vice president of sales & marketing for Cimtek. "First is Safety's experience. Safety was one of the innovators of gear gashing and has been selling gear gashing tools in Europe for more than 30 years.

"Second, Safety uses a "wedge-style" clamp versus the traditional tangential screw mount. This unique design allows Safety gashers to cut a wide range of pitch/diameter combinations with a single cutter, simply by changing inserts and/or wedges," Nowicki says.

In addition, the unique wedge design allows the gashers to machine both internal and external gears with the same cutter body, or to rough machine and finish machine with the same cutter body, simply by changing inserts, Nowicki says.

Solutions offered: Milling and gashing cutters from module 5–45.

For more information:

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Brian Nowicki, vice president of sales & marketing
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brian@cimtekllc.com
www.cimtekllc.com

Gleason Corporation

"Gleason has considerable knowledge and experience in gear manufacturing, and we have invested significant R&D in the analytical development of the tool tooth profile," says Michael Tennutti, senior product manager for Gleason Cutting Tools. "This allows us to optimize the finishing stock for pre-finish tools, and to improve the final gear accuracy for finishing tools."

"We have also been able to optimize the combination of rake face configuration, edge preparation definition and coating type and thickness for maximum performance of our Opti-Cut inserted carbide tools. These characteristics are all specifically developed for each individual application."

Solutions offered: Carbide insert tools for ID or OD gashing (both roughing and finishing tools), gear shaping and gear hobbing. Carbide insert hobs are available for diameters greater than 125 mm.

For more information:
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sales@gleason.com
www.gleason.com

Ingersoll Cutting Tools

"All of our gashing and hobbing cutters feature the angled insert screw hole, which Ingersoll introduced to provide more secure clamping and easier access for indexing inserts—especially in hob assemblies," says Frank Berardi, product manager for gear machining at Ingersoll Cutting Tools. "It has the added benefit of error-proofing insert orientation."

"The unique segmented design of Ingersoll hobs provides an expandable assembly, and simplifies repair. The spiral segments are manufactured in one setup, ensuring the highest precision possible. Because of this, segments can be ordered separately for replacement or expansion of the assembly. This can be done by the customer, as there are no fitting operations involved."

"Perhaps the greatest advantage we offer is the 30-plus years of experience in designing indexable gear cutting tools. These are highly engineered products, and most often each application requires a unique solution."

Solutions offered: ID and OD roughing gashers for modules 6 and up, ID and OD finishing gashers for modules 6 and up, roughing and finishing gashers with through-tool coolant channels, carbide insert hobs for modules 6 and up, including multi-start hobs and shapers in modules 6–12.

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info@ingersoll-imc.com
www.ingersoll-imc.com

Kennametal

"Kennametal is a pioneer in using positive geometries on the inserts and innovative positioning of the inserts in the body," says Klaus Wichmann, manager of gear milling for Kennametal Technologies GmbH in Germany. "This leads to a very effective and smooth cut. Further, this innovative design helps to reduce the power the machine needs to run the cutter. This saves the machine from wear as well as the cutter itself."

"Kennametal has invested a huge amount of money to increase the manufacturing quality, especially of the tool bodies. We are using a unique and state-of-the-art closed-loop system between the production machine and our measuring and quality station. This brings us 1-2 better quality classes compared to the standard methods."

Solutions offered: Carbide insert gashers (for both internal and external gears) from module 6–40, finishing gashers (for both internal and external

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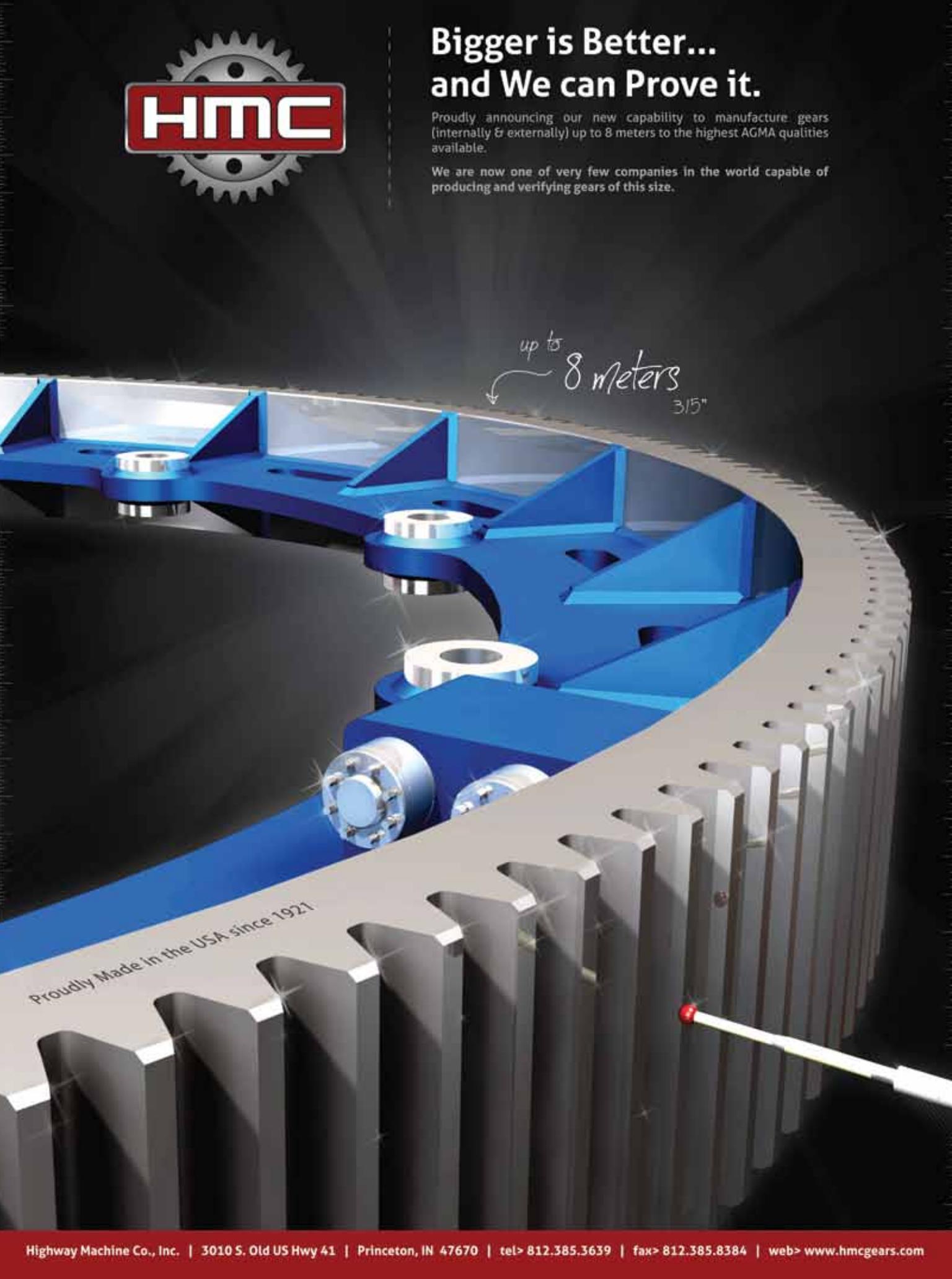
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gears) from module 3–30, hobs, including multiple-start hobs, from modules 6–40, as well as other specialized tools.

For more information:
Kennametal Inc.
1600 Technology Way
Latrobe, PA 15650
Phone: (724) 539-5000
www.kennametal.com

LMT-Fette

According to Dr.-Ing. Friedrich Momper, manager of gear products, LMT-Fette offers:

- A wide range of gear gashers and indexable carbide insert hobs
- Customized tools to the specifi cation of customer profiles
- State-of-the-art carbide grades and coatings, as well as insert geometries tailored for gear cutting processes
- Engineering and application know-how for both solid-type hobs as well as indexable type gear cutters

Solutions offered: Single-start carbide insert gear hobs from modules 5–40, double-start gear hobs, gear roughing cutters with or without internal cooling from modules 6–36, gear finishing cutters with or without internal cooling from modules 8–24.

For more information:
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www.lmt-tools.com

Sandvik Coromant

A relative newcomer to the carbide insert gear cutting industry, Sandvik Coromant has targeted module ranges that are most commonly used in the wind turbine industry, says Kenneth Accavallo, gear industry applications specialist.

Sandvik's first entry into the gear tool market is its Coromill 170 series of milling cutters, designed for roughing gears in modules 12–22. Although Sandvik's range is more limited than other manufacturers, they are also developing additional products for gear manufacturing, including indexable carbide insert hobs, expected to be formally launched in 2011.

Solutions offered: Carbide insert milling cutters in modules 12–22, with carbide insert hobs to be launched in 2011.

For more information:
Sandvik Coromant Company
1702 Nevins Road
Fair Lawn, NJ 07410
Phone: (800) SANDVIK
www.sandvik.coromant.com/us

Seco Tools

"Seco has worked hard developing innovative coatings and carbide grades with superior performance," says Todd Miller, milling tools product manager. "Today, Seco is a leader in coating technologies with the development of our DurAtomic coating. We also have an extensive engineering background with the design and development of milling cutters and tool holders. We have brought all the same technology into the development of our gear milling cutting tools and are continuously improving."

Solutions offered: Carbide insert roughing and finishing tools with modules from 1–50, carbide insert hobs with modules from 6–26.

For more information:
Seco Tools Inc.
2805 Bellingham Drive
Troy, MI 48085
Phone: (248) 528-5200
secotools.us@secotools.com
www.secotools.com

Faster Gashing in Finland

For nearly 50 years, Takoma Gears (Parkano, Finland) has specialized in providing large-scale gears and gear components to customers, mainly in its domestic market. Concentrated heavily in the marine industry, the company prides itself on minimizing lead times and costs while meeting extremely strict quality requirements. Dedication to maintaining these standards leads the company to constantly evaluate its operations and track developments in technology that can lead to process improvement.

Traditionally, Takoma has used HSS hobs for the cutting of gear teeth. In 2009, the company purchased several new machines for the production of large gear components for use on ships. Slewing rings with an outer diameter of approximately 2 meters (6.56 feet) are produced from 42CrMo4 steel and require high dimensional tolerances. Takoma initially began machining the slewing rings' teeth with a specialized gear cutter that provided acceptable quality levels, but was expensive and required lead times of up to 12 weeks to receive. Feeling that a better option must exist, the company contacted a provider of tooling used in many of the secondary operations of its parts.

"We have worked with representatives from Sandvik Coromant for over 30 years in regards to drilling, milling and turning tools," says Jyrki Koitto, production manager at Takoma Gears. "We knew that they were increasing their focus on tooling for cutting gear teeth, so we asked if they had or would be interested in developing a tool that would perform this application for us."

After consulting closely with Koitto and other employees at Takoma, Sandvik Coromant engineers spent several months designing and testing a custom tool optimized for the process. The gear cutting tool that resulted from these efforts was brought to Takoma for multiple tests and runoffs and then implemented with Sandvik Coromant's assistance. It achieved very similar results to the original tool, but with a slightly reduced cost. More importantly, turnaround times for delivery were less than a week, compared to 12 weeks for the old tool. This allowed Takoma to maintain much more flexibility in responding to customer needs. Additionally, while working on this project with Sandvik Coromant, Takoma was exposed to the CoroMill 170, a new cutter for gear milling that the company felt held potential for some of its other applications.

The CoroMill 170 was developed to optimize milling applications in large gears, module 12–22, an area traditionally covered by indexable inserts and HSS tools. The tool provides robust performance through design focus on its shape and providing secure insert seats. Takoma chose to apply a 300 mm (11.81 inch) version of the tool to a marine ring gear measuring approximately 2.5 meters (8.2 feet) in diameter. The part was machined from 34CrMo4 steel.

Takoma had previously used a 230 mm (9.06 inch) HSS hob to cut teeth on the ring gear. Running at a speed of 25 meters/min (82 feet/min) and feed rate of 0.12 mm/rev (0.0047 inch/rev), the operation took 1,260 minutes per component. Upon applying the CoroMill 170, Takoma was able to increase cutting speed and feed rate to 126 meters/min (413 feet/min) and 0.20 mm/rev (0.0079 inch/rev), respectively. This reduced cycle time by nearly 60 percent, to just 510 minutes per component.

"We are now using the CoroMill 170 all of the time and saving a significant amount of time," says Koitto. "By shortening our machining time, it also allows us to reduce turnaround to our customers. Instead of taking five weeks to process an order and provide finished parts, we can now provide customers with the same service in four weeks."

In addition to allowing faster service to their customer, productivity gains from implementation of the CoroMill 170 have resulted in annual cost savings of 20,000 euros.

For more information:

Takoma Gears
Vanhantalontie 3
39700 Parkano
Finland
Phone: +(358) 20-184-7400
www.takoma.fi

*For Sandvik, please see p.49.

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RoboScan system greatly improves grinding quality control of gears and reduces labor time and cost. The system provides grinding inspection based on Barkhausen Noise with minimum operator involvement. Gears are loaded into the system, and the robot takes care of the measurements. Many different surfaces can be measured effectively as the robot selects and uses a variety of sensors automatically. All results are documented on a PC and displayed on the monitor.

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Point-Surface-Origin Macropitting Caused by Geometric Stress Concentration

R.L. Errichello, C. Hewette and R. Eckert

Management Summary

Point-surface-origin (PSO) macropitting occurs at sites of geometric stress concentration (GSC) such as discontinuities in the gear tooth profile caused by micropitting, cusps at the intersection of the involute profile and the trochoidal root fillet, and at edges of prior tooth damage, such as tip-to-root interference. When the profile modifications in the form of tip relief, root relief, or both, are inadequate to compensate for deflection of the gear mesh, tip-to-root interference occurs. The interference can occur at either end of the path of contact, but the damage is usually more severe near the start-of-active-profile (SAP) of the driving gear.

An FZG-C gear set (with no profile modifications) was tested at load stage 9, and three pinion teeth failed by PSO macropitting. It is shown that the root cause of the PSO macropitting was GSC created by tip-to-root interference.

Introduction

Stewart Way (Ref. 1) first described what later became known as point-surface-origin macropitting. The macropits are relatively shallow, but large in area. The fatigue crack grows from a surface origin in a fan-shaped manner until thin flakes of material break out and form a triangular crater. The arrowhead-shaped crater points opposite the direction of rolling (direction of load approach). Crack propagation can extend over large portions of a gear tooth. Way (Ref. 1) also proposed a theory of hydraulic-pressure-propagation to explain the growth of PSO macropits. Lubricant viscosity is an important parameter influencing PSO macropitting, and it has been shown (Ref. 2) that low-viscosity lubricants promote PSO macropitting by hydraulic-pressure-propagation. PSO macropitting results from the combination of low-viscosity lubricant, low specific-film thickness and tangential shear stresses from sliding (Ref. 2). PSO macropitting can originate from surface flaws such as:

- Tip-to-root interference
- Debris dent
- Handling nick
- Edge of macropitting
- Edge of micropitting
- Surface flaws from manufacturing
- Surface non-metallic inclusion
- Surface carbide
- Corrosion pit

This paper discusses PSO macropitting originating from tip-to-root interference. If involute gear teeth were perfectly rigid and without manufacturing errors, they would begin contact at the ideal start-of-active-profile (SAP) point and end contact at the ideal end-of-active-profile (EAP) point.

However, real gears are not rigid, and even without manufacturing errors, tooth deflection causes the teeth to start contact earlier than the ideal SAP, and end contact later than the ideal EAP. In the areas of extended contact at the ends of the path-of-contact, a gear tooth is loaded on its tip corner (intersection between the tooth flank and tooth top-land) and the contact stresses are very high because of geometric stress concentration (GSC). Therefore, to avoid corner contact and the associated high-contact stresses, it is common practice to design gear teeth with tip relief that is sufficient to compensate for tooth deflection and manufacturing errors. However, FZG-C test (spur) gears (FZG-C) are manufactured accurately but without tip relief. Consequently, they inevitably have corner contact when they are tested at high loads. FZG-C gears are discussed in this paper because they demonstrate the consequences of inadequate tip relief.

Objective

This paper demonstrates how gears without tip relief suffer tip-to-root interference that causes GSC and PSO macropitting.

Corner contact. Figure 1 shows the path-of-contact for FZG-C gears that was calculated with *KISSsoft* software (Ref. 3). It shows corner contact occurs when accompanied by early contact between the gear tip and the pinion involute at point A', and continues along the gear tip circle to point A on the line of action. The path-of-contact between points A' and A is non-conjugate and is known by many names, including:

- Tip-to-root interference
- Corner contact
- Contact outside the normal path of contact
- Early contact
- Edge contact
- Extended contact
- Non-conjugate action
- Premature contact
- Prolonged contact
- Top contact
- Tooth interference

Mechanism of tip-to-root interference. Figure 2 shows how the gear tip corner approaches the pinion involute along a trochoidal path that intersects the pinion involute at a point above the usual pinion SAP. Contact between the gear corner and the pinion involute results in very high Hertzian stress—especially if the gear has sharp corners at the tips of its teeth. The high stress and scraping action of the gear corner undercut the pinion involute by removing the material (shown shaded in Fig. 2) and plowing material toward the pinion root. The intersection between the undercut and involute forms a cusp on the pinion flank at point A'. In this paper, damage caused by corner contact will be called tip-to-root interference.

Contact on pinion cusp. Corner contact undercuts the pinion involute and removes the usual SAP (point A) and delays the contact between the pinion and gear until they contact at point A˝ on the line of action as shown in Figure 3. The edge contact that occurs on the pinion cusp causes GSC, as shown by the local maximum Hertzian stress illus-

continued

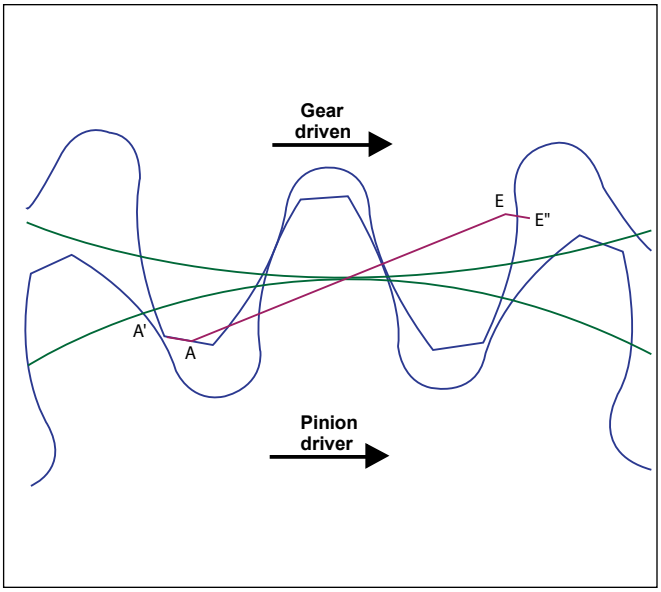

Figure 1—Gear tip approaching pinion involute.

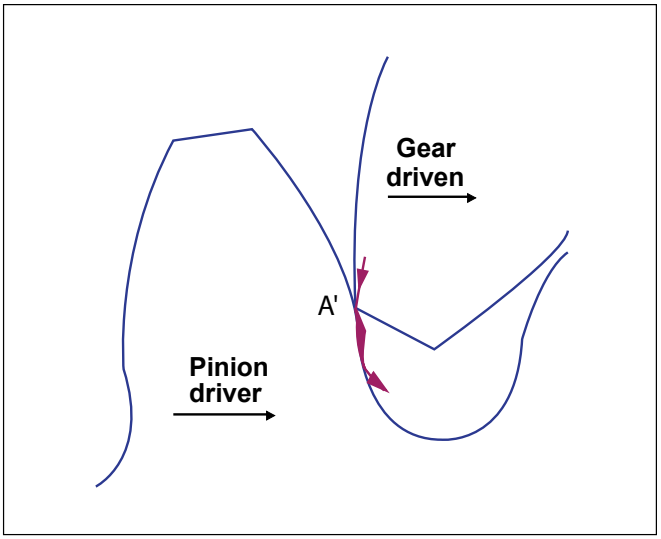

Figure 2—Mechanism of tip-to-root interference.

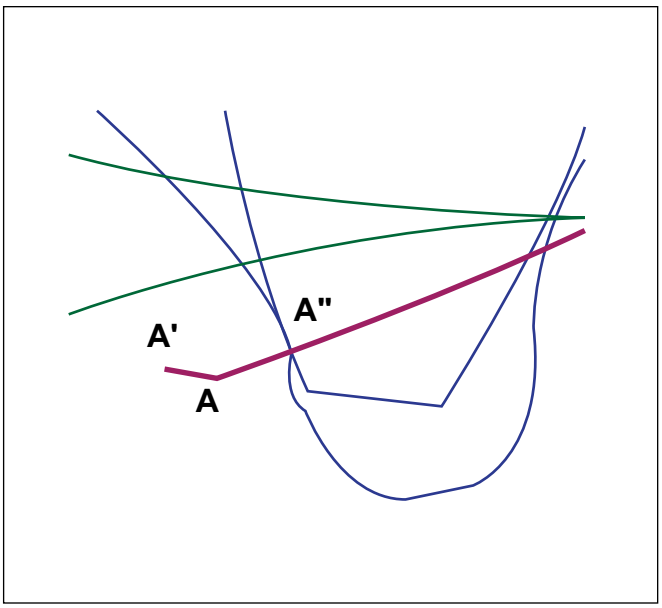

Figure 3—Contact on the pinion cusp.

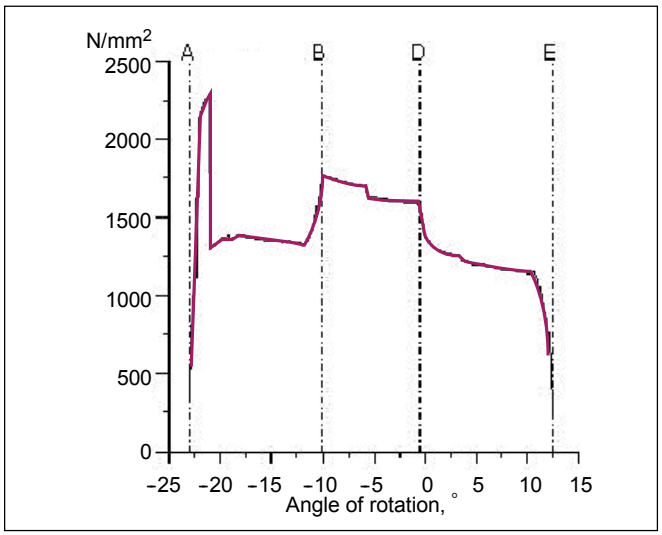

Figure 4—Local maximum Hertzian stress at pinion cusp.

Table 1—Lubricant Properties	
Type	Mineral oil including 325 Neutral and 650 Neutral Group I
Additives	VI-improver, pour point depressant, mild S-P antiscuff
Viscosity at 40˚C	157.2 cSt
Viscosity at 100˚C	18.3 cSt

Figure 5—Damage caused by tip-to-root interference on pinion.

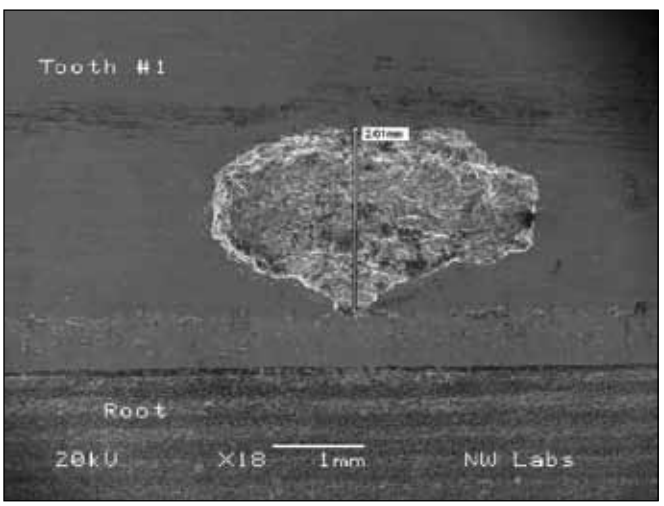

Figure 6—Enlarged view of PSO macropit on pinion.

trated in Figure 4.

FZG-C test gears. An FZG-C gear set was tested at load stage 9 in accordance with the FZG pitting test PT C/9/90 procedure (Ref. 4), except the oil temperature was set to 120°C. Table 1 gives the lubricant properties. The lubricant prevented adhesive and abrasive wear. However, after only

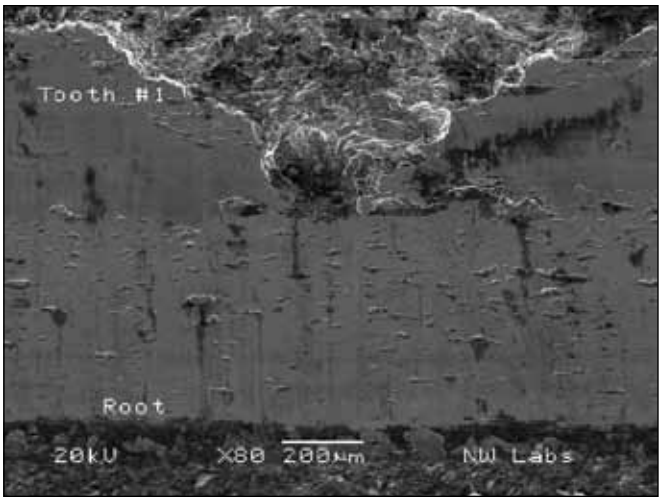

Figure 7—Enlarged view at entrance of PSO macropit on pinion.

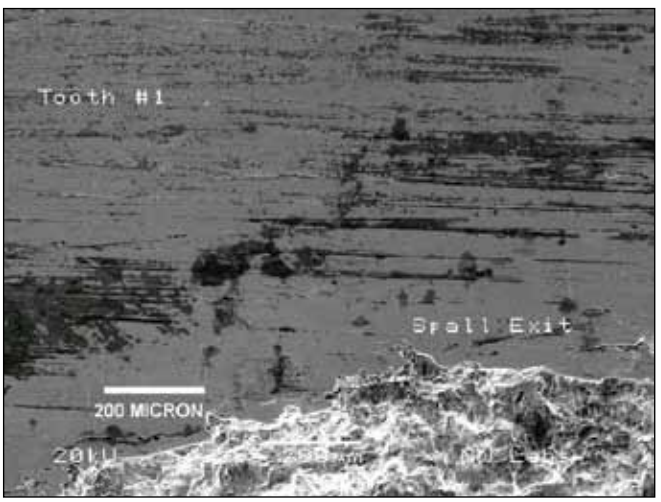

Figure 8—Enlarged view at exit of PSO macropit on pinion.

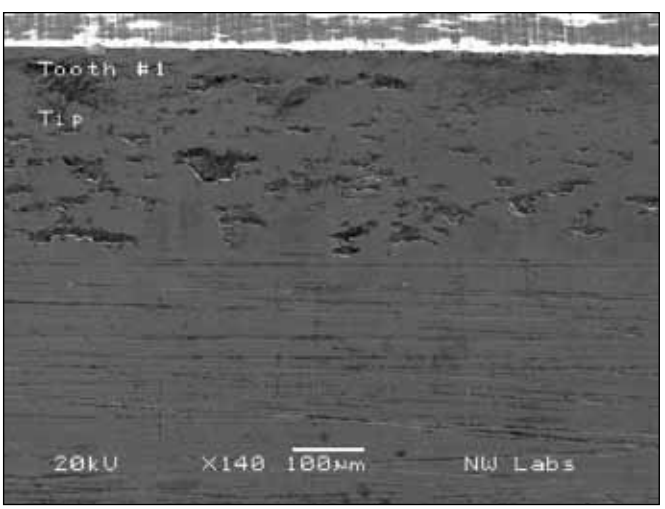

Figure 9—Enlarged view at tip of tooth 1 on pinion.

60 hours the test had to be stopped because macropitting occurred on teeth 1, 9 and 15.

Damage caused by tip-to-root interference. Figure 5 shows tooth number 1 of the FZG-C pinion with damage caused by tip-to-root interference. To the unaided eye, the damage might appear as a polished line along the SAP, and it is often referred to as a "line of hard contact." However, as will be shown, the damage in this example consists of plastic deformation, micropitting and PSO macropitting. In more severe cases the damage can include material transfer resulting from scuffing.

PSO macropitting. Figure 6 is an enlarged view (scanning electron image) of Figure 5 showing the largest PSO macropit—about 2 x 3.5 mm. Figure 7 is an enlarged view at the entrance of the PSO macropit, which initiated at the upper edge of the tip-to-root damage and corresponds to the cusp at point A' (Fig. 2). Below the cusp, the tip-to-root damage produced a 0.5 mm high band of plastically deformed material and a dense field of micropitting. All pinion teeth had similar tip-to-root damage, but in the short run time of 60 hours only three teeth developed relatively large PSO macropits that—in each case—initiated at the cusp.

Figures 5, 6 and 7 show there are many other PSO macropits that have initiated at the cusp but have not yet grown significantly. Figure 8 is an enlarged view at the exit of the PSO macropit. Original grind marks can be seen above the macropit, proving that there was no significant adhesive or abrasive wear on the pinion flanks.

Figure 9 is an enlarged view at the tip of tooth number 1. It shows micropitting caused by tip-to-root interference between the pinion tip and the gear root. Original grind marks are evident below the micropitting, proving that there was no significant adhesive or abrasive wear on the pinion flanks.

Figure 10 shows a PSO macropit that occurred on tooth 15 that measures about 1.8 x 2.8 mm. Two other macropits can be seen initiating at the cusp (upper edge of the tip-to-root damage).

Figure 11 shows a PSO macropit that occurred on tooth 9 that measures about 1.5 x 1.5 mm. At least two other macropits can be seen initiating at the cusp (upper edge of the tip-to-root damage). The micropitting within the band of tip-to-root interference is not as obvious in this light micrograph as it is in the other scanning electron images (Figs. 6, 7 and 10). However, the abrasion within the tip-to-root interference and the original grind marks on the flank are more obvious.

Gear tooth sliding. Figure 12 shows the directions of the rolling (R) and sliding (S) velocities on the driving and driven gear teeth. Contact on the driving 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.

Hertzian fatigue cracks—both macropitting and micropitting—that start at the gear tooth surface grow at a shallow angle to the surface, opposite that of the slide directions. Consequently, as shown in Figure 12, the cracks converge near the pitch line of the driver and diverge near the pitch line of the driven gear.

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

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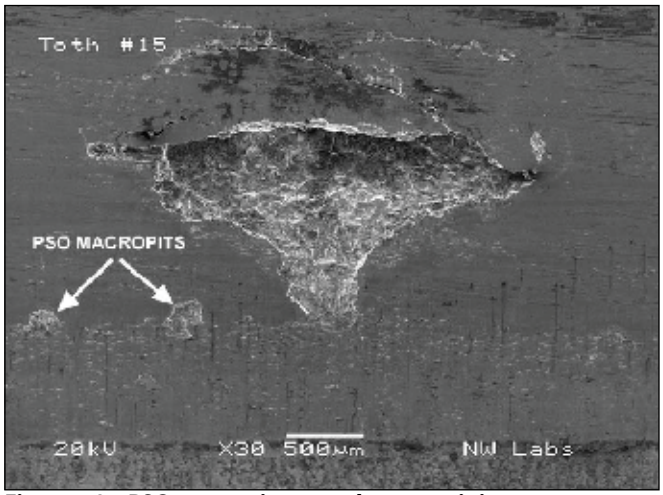

Figure 10—PSO macropit on tooth 15 on pinion.

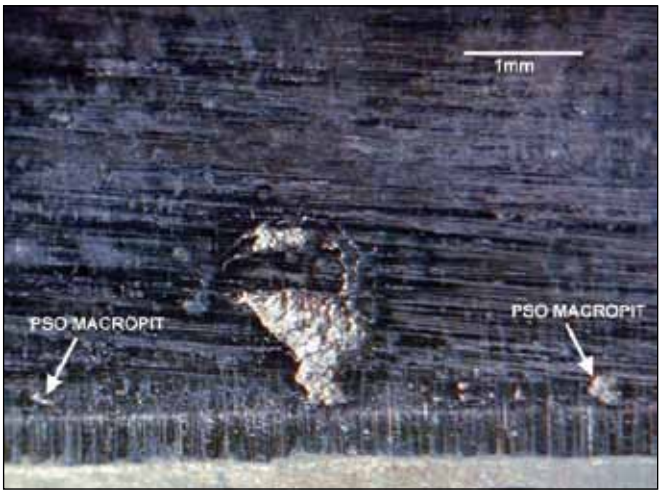

Figure 11—PSO macropit on tooth 9 on pinion.

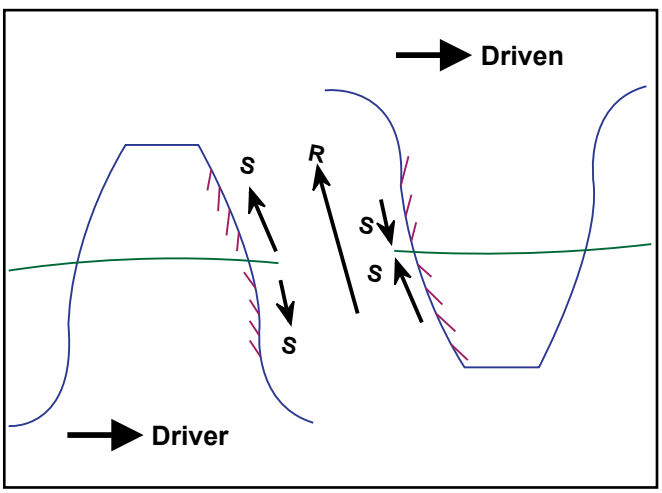

Figure 12—Rolling (R) and sliding (S) directions.

Way (Ref. 1) and verified many times by experiments such as Littmann's (Ref. 2).

Hertzian stress resulting from GSC. GSC associated with contact on the pinion cusp creates a Hertzian stress that is theoretically infinite, but is actually limited to the yield strength of the pinion material. Therefore, the cusp plastically deforms and the GSC is reduced. However, carburized gears have high yield strength, and even though subsequent cyclic stresses are elastic, the stresses are generally high enough to initiate macropitting. Li, et al., (Ref. 5) tested FZG PT-C macropitting gears and found that in all cases PSO macropits initiated at the cusp of the tip-to-root damage. Furthermore, they measured the radius of the cusp on several damaged teeth of a pinion and found it averaged 1.54 mm. They assumed the mating gear radius-of-curvature at point A″ was 26.76 mm and calculated the relative radius-of-curvature was 1.46 mm. For unworn teeth they calculated a relative radius-of-curvature of 6.26 mm. According to Hertzian theory, the difference in relative radius-of-curvature doubles the Hertzian maximum shear stress, but reduces its depth to only half as deep. Consequently, the stress increase resulting from GSC is very significant and it explains why PSO macropits initiate at the cusp.

Jao, et al, (Ref. 6) tested FZG PT-C macropitting gears and FZG GF-C micropitting gears that are identical in all respects except that PT-C gears have a tooth-surface-roughness of Ra = 0.3 μm, whereas GF-C gears have tooth-surface-roughness of Ra = 0.5 μm. With PT-C gears, PSO macropits initiate at the cusp formed by tip-to-root interference. In contrast, the GF-C gears form a band of micropitting at the SAP similar to PT-C gears, but in this case it continues to spread toward the pitch line until forming a wide band of severe micropitting. 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; this macropitting occurs later than with the PT-C gears. The authors concluded that the failure mechanism is different for GF-C gears because their rougher surfaces cause more severe micropitting that removes the cusp at the SAP and thereby prolongs macropitting life.

Conclusions

- The root cause of PSO macropitting is the GSC caused by tip-to-root interference, or GSC caused by edge discontinuities such as the edge of a band of micropitting.
- Tip-to-root interference is caused by corner contact that occurs in gears without adequate tip relief.
- Tip-to-root interference undercuts the involute profile and creates a cusp on the active flank that acts as a point of GSC.
- With FZG PT-C gears, PSO macropits initiate at the cusp formed by tip-to-root interference.
- With FZG GF-C gears, their rougher surfaces cause more severe micropitting that removes the cusp at the SAP—and thereby prolongs macropitting life—

Rainer Eckert's *academic background includes a bachelor of science and engineering degree in 1983 from Technical University of Berlin, where he was also named "Best Graduate of Engineering" in his class; and a master of science and engineering in materials science from the University of Pennsylvania in 1985. He has since 1986 been employed as a forensic engineer and director of the metallurgical services department at Northwest Laboratories in Seattle, WA. Previously, Eckert has worked as both research and consulting assistant at various stops, including the University of Pennsylvania and the Welding Institute of Berlin, and for four years (1979–1983) was a mechanic at his own auto repair shop. Eckert is a member of the American Institute of Metallurgical Engineers, the American Society of Metals and the German Society of Engineers.*

Robert Errichello *heads his own gear consulting firm—GEARTECH—and is a founder of GEARTECH Software, Inc. He is a registered professional engineer and 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. Errichello has over 34 years of industrial experience and has worked for several gear companies. He has been a consultant to the gear industry for the past 19 years; has taught courses in material science, fracture mechanics, vibration and machine design at San Francisco State University and the University of California at Berkeley; and is 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 over 40 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 a 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 recipient of the AGMA TDEC Award and the STLE Wilbur Deutch Memorial Award.*

Chip Hewette *is a lubricant formulator with Afton Chemical Corporation, a worldwide supplier of lubricant additives. His main efforts are in improving vehicle fuel efficiency and reducing noise, vibration and harshness (NVH) in systems such as limited slip differentials. Hewette's background is primarily mechanical engineering, concentrating on product design. His experiences include the design of EGR valves, position sensors and HVAC compressors. Other endeavors have included product warranty management, manufacturing quality and process improvement consulting. He received his B.E. in mechanical engineering from Vanderbilt University in 1983, and is a licensed professional engineer. He holds U.S. patents in a variety of fields. Hewette lives in Henrico, VA with his wife and two daughters.*

until PSO macropitting occurs near the pitch line due to GSC caused by the step in the tooth profile at the upper edge of the micropitting crater.

- PSO macropitting occurs from the combination of low-viscosity lubricant, low specific-film thickness and tangential shear stresses from sliding.
- Negative sliding promotes rapid growth of PSO macropitting by the hydraulic-pressure-propagation mechanism.

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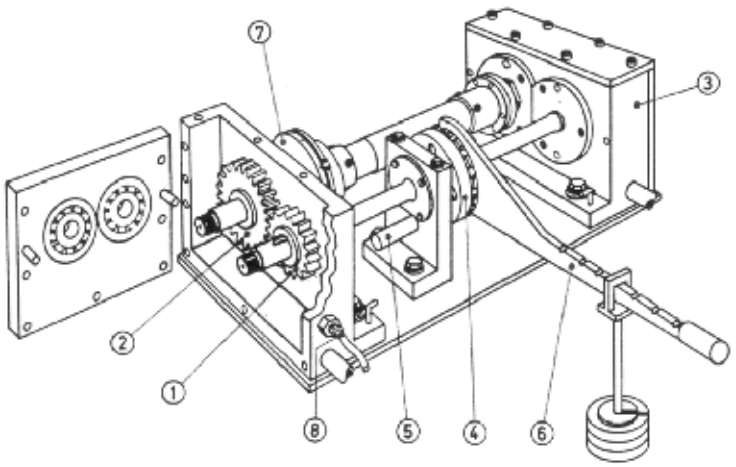
Appendix A



1. pinion
2. gear wheel
3. drive gears
4. load clutch
5. locking pin
6. lever arm with weight pieces
7. torque measuring clutch
8. temperature sensor

FZG test machine

Table A1—Data for Test Gears

Item	Symbol	Unit	FZG PT-C	FZG GF-C
Center distance	a	mm	91.5	
Number of pinion teeth	z_1	---	16	
Number of gear teeth	z_2	---	24	
Normal module	m_n	mm	4.5	
Normal pressure angle	α_n	deg	20	
Helix angle	β	deg	0	
Face width	b	mm	14	
Pinion profile shift coefficient	x_1	---	0.1817	
Gear profile shift coefficient	x_2	---	0,1715	
Pinion tip diameter	d_{a1}	mm	82.46	
Gear tip diameter	d_{a2}	mm	118.36	
Material alloy	---	---	16MnCr5	
Heat treatment	---	---	Carburized	
Flank surface roughness	R_a	µm	0.3 ± 0.1	0.5 ± 0.1
Pitchline velocity	v_t	m/s	8.3	

Measurement of Directly Designed Gears with Symmetric and Asymmetric Teeth

Dr. Alexander L. Kapelevich

(This paper was first presented at the 2010 VDI International Conference on Gears—VDI Wissensforum).

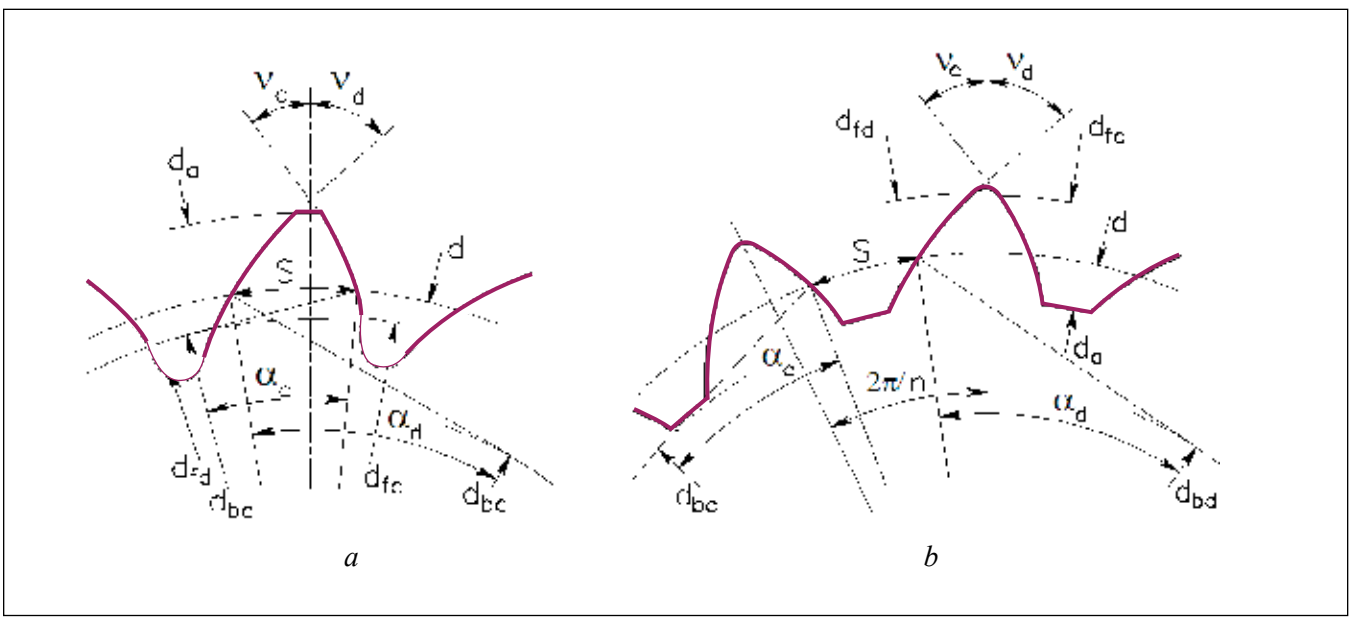


Figure 1—Gear tooth profile: *a* = external gear; *b* = internal gear; d_a = tooth tip circle diameter; d_b = base circle diameter; d_f = form circle diameter; *d* = reference circle diameter; *S*= circular tooth thickness at the reference diameter; α = involute profile (or pressure) angle at the reference diameter; *v* = involute intersection profile angle; *n* = number of teeth; subscripts "*d*" and "*c*" are for the drive and coast flanks of the asymmetric tooth.

Management Summary

In comparison with the traditional gear design approach based on preselected, typically standard generating rack parameters, the Direct Gear Design method provides certain advantages for custom high-performance gear drives that include: increased load capacity, efficiency and lifetime; reduced size, weight, noise, vibrations, cost, etc. However, manufacturing such directly designed gears requires not only custom tooling, but also customization of the gear measurement methodology.

This paper presents definitions of main inspection dimensions and parameters for directly designed spur and helical, external and internal gears with symmetric and asymmetric teeth.

Measurement Over (Between) Balls or Pins

Spur gears. The Direct Gear Design method (Refs. 1–2) presents the gear tooth by two involutes of two base circles with the angular distance between them and tooth tip circle arc (Fig.1). The equally spaced n teeth form the gear. The fillet between teeth is designed independently, thus providing minimum bending-stress concentration and sufficient clearance with the mating tooth-tip in mesh. If the two base circles are identical, the gear teeth are symmetric; if they are different, the teeth are asymmetric.

Measurement over (between) balls or pins for spur gears is defined based on the given:

- Number of teeth n
- Reference circle diameter d
- Involute profile angles at the reference diameter α_d and α_c; for symmetric gears involute profile angle at the reference diameter $\alpha = \alpha_d = \alpha_c$
- Circular tooth thickness at the reference diameter S
- Gear tooth-tip diameter d_a

Initially selected ball or pin diameter D can be adjusted based on the calculation results. The relation between angles v_d and v_c, and α_d and α_c is:

$$\frac{\cos v_d}{\cos v_c} = \frac{\cos\alpha_d}{\cos\alpha_c} = \frac{d_{bd}}{d_{bc}}, \quad (1)$$

where: $d_{bd} = d \times \cos\alpha_d$ and $d_{bc} = d \times \cos\alpha_c$.

Angles v_d and v_c are defined from equations:
For external gear:

$$inv(v_d) + inv(v_c) = inv(\alpha_d) + inv(\alpha_c) + \frac{2 \times S}{d}, \quad (2)$$

For internal gear:

$$inv(v_d) + inv(v_c) = inv(\alpha_d) + inv(\alpha_c) + 2 \times \frac{\pi}{n} - \frac{S}{d}, \quad (3)$$

where: $inv(x) = \tan(x) - x$ is involute function and x is involute profile angle in radians. The centers of the ball or the pin are located on the diameter d_p (Fig. 2), which is:

$$d_p = \frac{d_{bd}}{\cos\alpha_{pd}} = \frac{d_{bc}}{\cos\alpha_{pc}}, \quad (4)$$

where the angles α_{pd} and α_{pc} are defined by equations (Ref. 3):

For external gear:

$$inv(\alpha_{pd}) + inv(\alpha_{pc}) = inv(v_d) + inv(v_c) + \frac{D}{d_{bd}} + \frac{D}{d_{bc}} - \frac{2\pi}{n}, \quad (5)$$

For internal gear:

$$inv(\alpha_{pd}) + inv(\alpha_{pc}) = inv(v_d) + inv(v_c) - \frac{D}{d_{bd}} - \frac{D}{d_{bc}}. \quad (6)$$

The ball or pin touches the gear tooth in the points T_d and T_c. They should be always located on the involute flanks. This condition is described by the following equation:

For external gears:

$$\arccos\frac{d_{bd}}{d_{fd}} < \alpha_{td} < \arccos\frac{d_{bd}}{d_a}, \quad (7)$$

and:

$$\arccos\frac{d_{bc}}{d_{fc}} < \alpha_{tc} < \arccos\frac{d_{bc}}{d_a}; \quad (8)$$

For internal gears:

$$\arccos\frac{d_{bd}}{d_a} < \alpha_{td} < \arccos\frac{d_{bd}}{d_{fd}} \quad (9)$$

and:

$$\arccos\frac{d_{bc}}{d_a} < \alpha_{tc} < \arccos\frac{d_{bc}}{d_{fc}} \quad (10)$$

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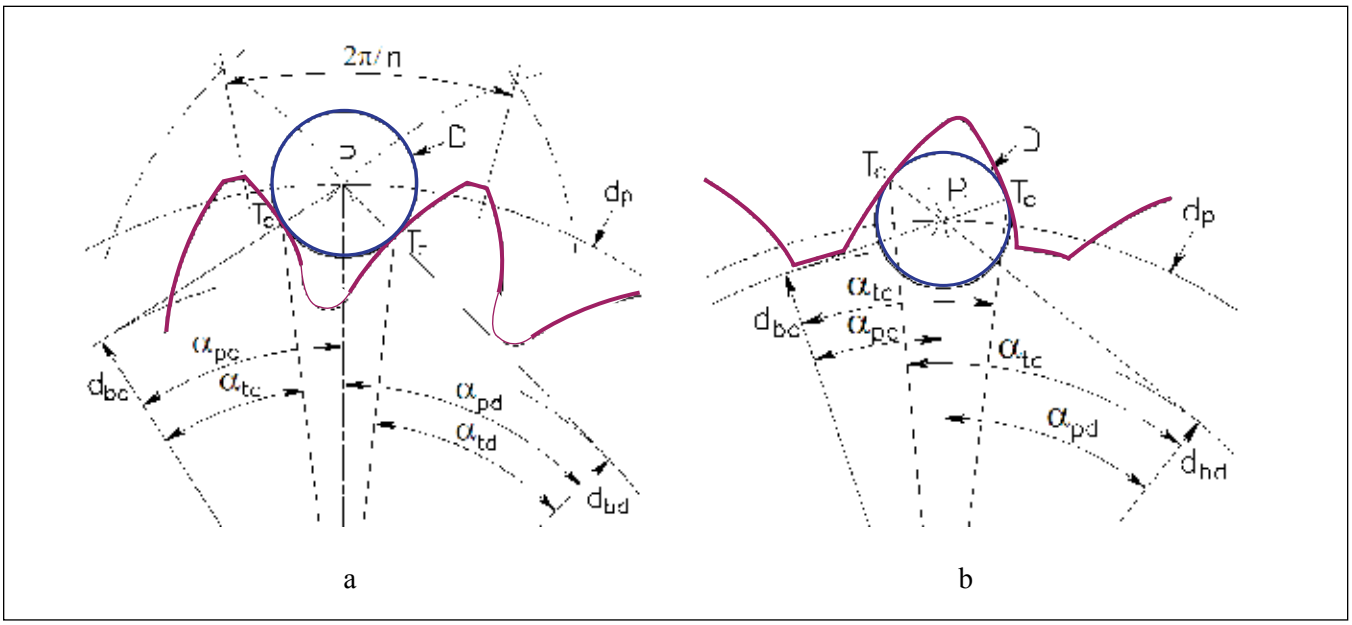

Figure 2—Ball or pin position: *a* = external gear; *b* = internal gear; *D* = ball or pin diameter; *P* = center of the ball or pin; α_{pd} and α_{pc} = involute profile angles at the center of the ball or pin; d_p = ball or pin center location diameter; T_d and T_c = contact points of the ball or pin with the tooth drive and coast tooth flanks; α_{td} and α_{tc} = involute profile angles at the contact points.

The measurement over two balls or pins for the external gear is for even number of teeth (Fig. 3a):

$$M = d_p + D; \tag{11}$$

For odd number of teeth (Fig. 3b):

$$M = d_p \cdot \cos\frac{\pi}{2n} + D. \tag{12}$$

The measurement between two balls or pins for the internal gear is for even number of teeth (Fig. 4a):

$$M = d_p - D; \tag{13}$$

For odd number of teeth (Fig. 4b):

$$M = d_p \cdot \cos\frac{\pi}{2n} - D. \tag{14}$$

For inspection convenience the measurement over balls or pins for external gears should be $M > d_a$ and the measurement between balls or pins for internal gears should be $M < d_a$. These and conditions (Eqs. 7–10) define the ball or pin diameter.

Helical gears. Measurement over (between) balls or over pins for helical gears is defined based on the given:

- Number of teeth n
- Reference circle diameter d
- Normal involute profile angles at the reference diameter α_{nd} and α_{nc}; for symmetric gears $\alpha_n = \alpha_{nd} = \alpha_{nc}$
- Normal circular tooth thickness at the reference diameter S_n
- Helix angle at the reference diameter β
- Gear tooth-tip diameter d_a

Cylindrical pins cannot be used to measure the internal helical gears, because the pin surface cannot be tangent to the internal helical gear flanks. The transverse tooth thickness at the reference diameter S is:

$$S = S_n / \cos\beta. \tag{15}$$

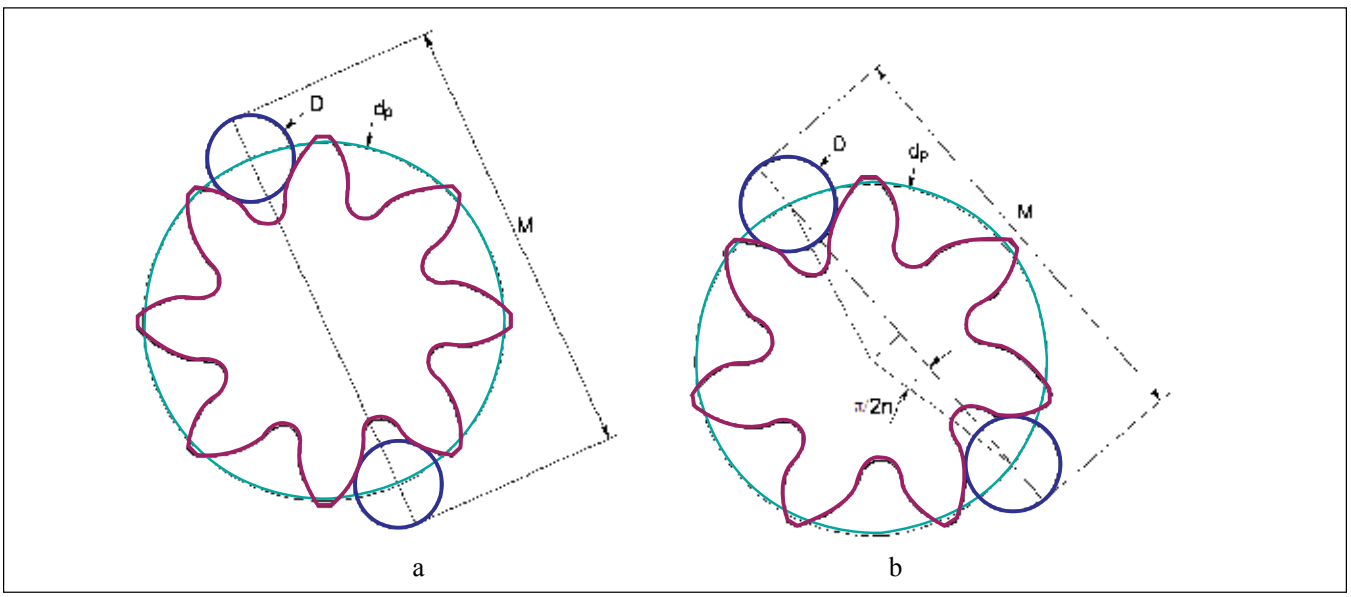

Figure 3—Measurement over balls or pins for external gears: *a* = even number of teeth; *b* = odd number of teeth.

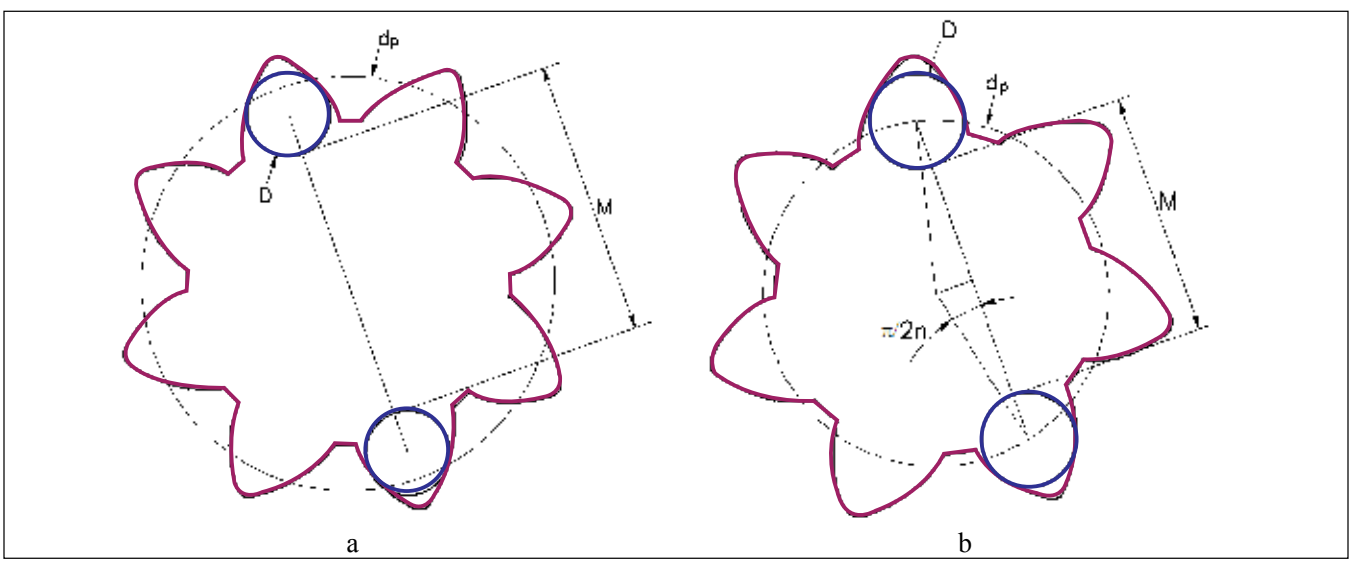

Figure 4—Measurement between balls or pins for internal gears: *a* = even number of teeth; *b* = odd number of teeth.

The transverse involute profile angles at the reference diameter α_d and α_c are:

$$\alpha_d = \arctan \frac{tan\ \alpha_{nd}}{\cos \beta}, \quad (16)$$

$$\alpha_c = \arctan \frac{tan\ \alpha_{nc}}{\cos \beta}. \quad (17)$$

The helix angles at the drive and coast base diameters β_{bd} and β_{bc} are:

$$\beta_{bd} = \arctan(\tan \beta \times \cos \alpha_d), \quad (18)$$

$$\beta_{bc} = \arctan(\tan \beta \times \cos \alpha_c). \quad (19)$$

The centers of the ball or the pin (for external gear with even number of teeth) are located on the diameter d_p that, defined by the equation (4), where the angles α_{pd} and α_{pc} are defined by:

For external helical gear:

$$inv(\alpha_{pd}) + inv(\alpha_{pc}) = inv(\nu_d) + inv(\nu_c) + \frac{D}{d_{bd} \times \cos \beta_{bd}} + \frac{D}{d_{bc} \times \cos \beta_{bc}} - \frac{2\pi}{n}, \quad (20)$$

For internal helical gear (for measurement over balls):

$$inv(\alpha_{pd}) + inv(\alpha_{pc}) = inv(\nu_d) + inv(\nu_c) - \frac{D}{d_{bd} \times \cos \beta_{bd}} - \frac{D}{d_{bc} \times \cos \beta_{bc}}. \quad (21)$$

The ball or pin diameters should also satisfy Equations 7–10. Measurements over two balls for external helical gears (Fig. 5) and between two balls for internal helical gears (Fig. 6) are defined by Equations 11–13 and 14, accordingly.

Measurement over two pins for external helical gears with even number of teeth is also defined by Equation 11.

For external helical gears with odd number of teeth, the shortest distance L between the pin centers does not lay in the transverse section of the circle diameter d_p. This distance and measurement over two pins for external helical gears with odd number of teeth definition is described in Reference 4. The transverse distance L_t between the ball centers, in case of the odd number of teeth, is always greater than the distance L that is (Fig.7):

$$L = \frac{d_p}{2 \times \tan\beta_p} \sqrt{\lambda^2 + 4 \times (\tan\beta_p \times \cos(\frac{\pi}{2n} + \frac{\lambda}{2}))^2}, \quad (22)$$

where the helix angle at the pin center diameter βp is:

$$\beta_p = \arctan(\frac{d_p}{d} \times \tan\beta), \quad (23)$$

and the angle λ is a solution of the equation:

$$\frac{\lambda}{\tan\beta_p} - \sin(\frac{\pi}{n} + \lambda) = 0. \quad (24)$$

Then the measurement over two pins for external helical gears with odd number of teeth (Fig. 8) is:

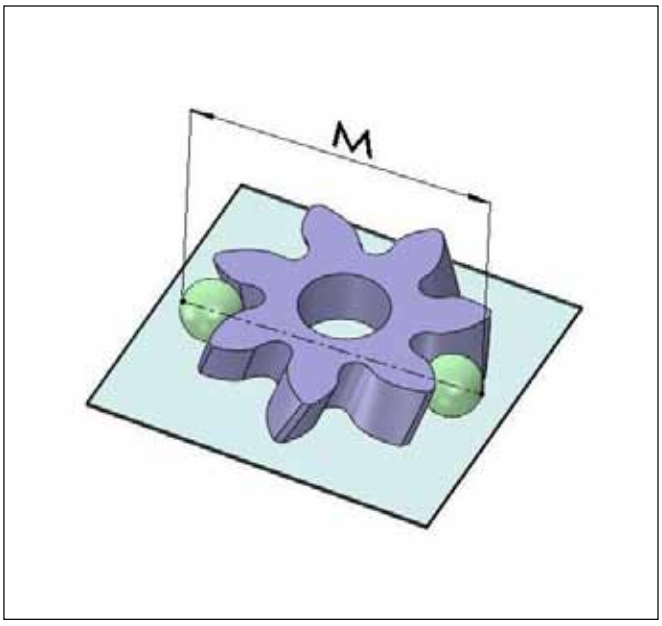

Figure 5—Measurement over balls of the external helical gear.

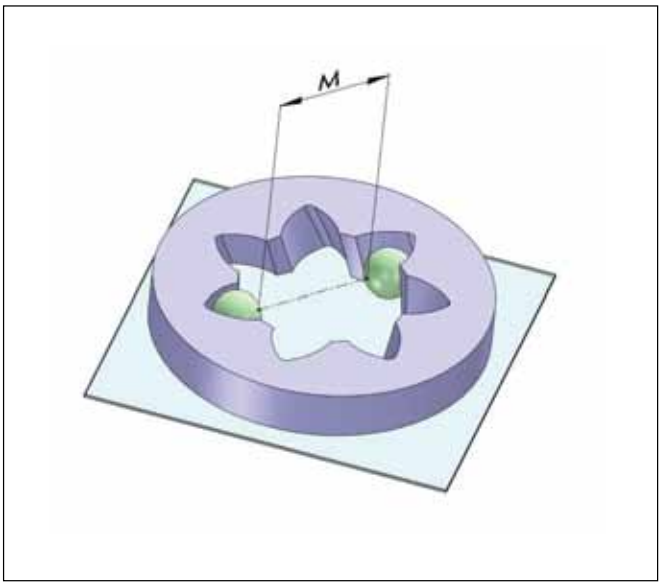

Figure 6—Measurement between balls of the internal helical gear.

$$M = L + D. \quad (25)$$

Span Measurement

Span measurement is the measurement of the distance across several teeth, along a line tangent to the base cylinder (Ref. 5). This kind of inspection is used for gears with external teeth. It is also applied only for gears with symmetric teeth, because it is impossible to have a common tangent line to two concentric base cylinders of asymmetric tooth flanks.

Span measurement over n_w teeth (Fig. 9) is:

$$W = (S_b + (n_w - 1) \times p_b) \times \cos \beta_b, \quad (26)$$

where S_b is the tooth thickness at the base diameter:

$$S_b = S \times \cos \alpha + d_b \times inv(\alpha), \quad (27)$$

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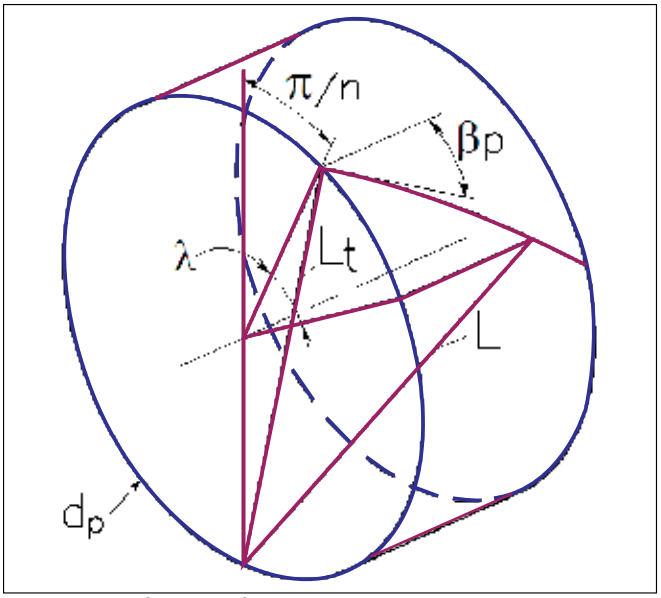

Figure 7—Definition of the distance between the pin centers for the helical gears with odd number of teeth.

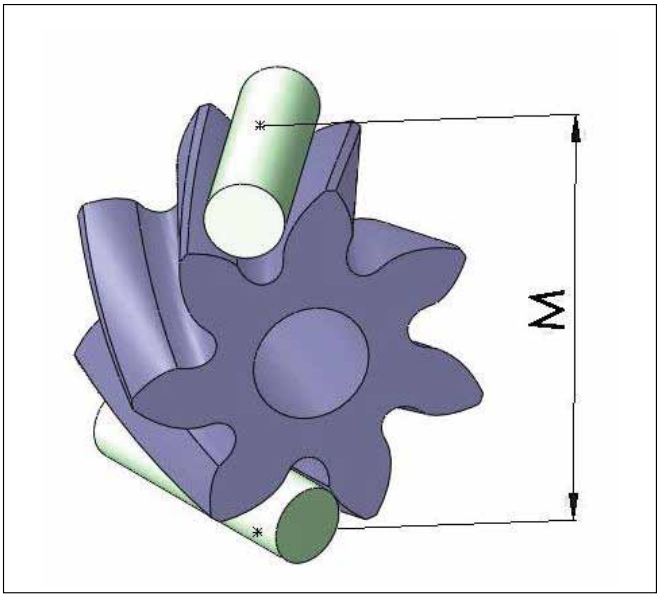

Figure 8—Measurement over pins of the external helical gear with odd number of teeth.

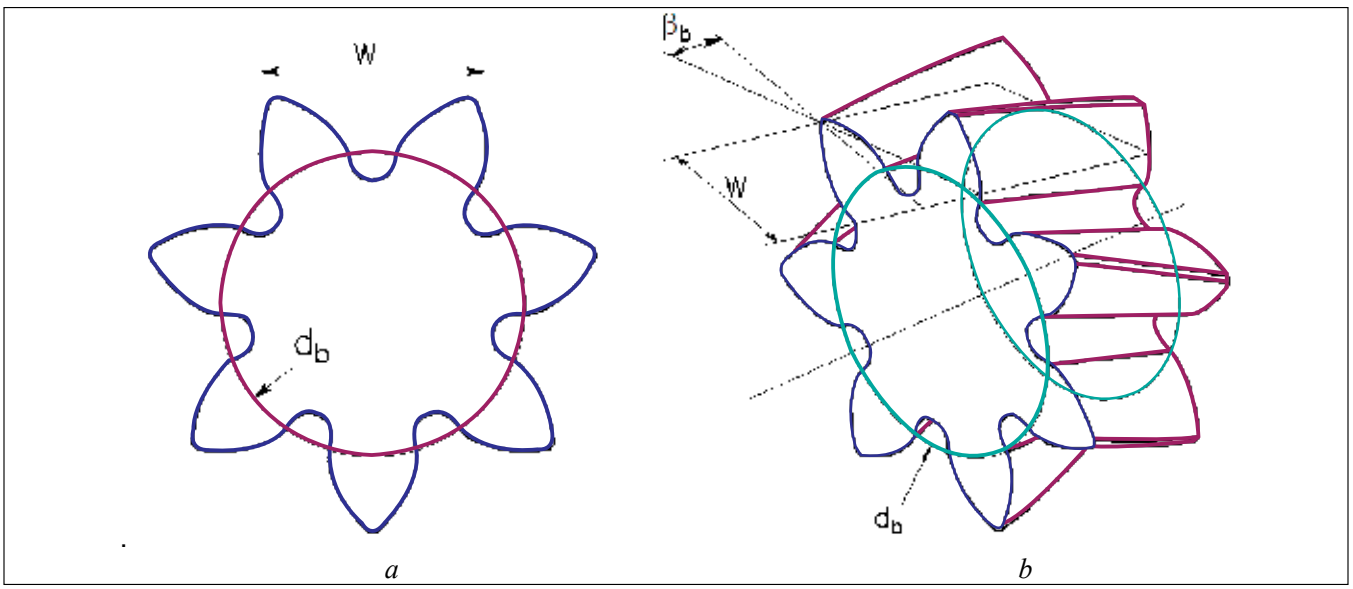

Figure 9—Span measurement; *a* = spur gear; *b* = helical gear.

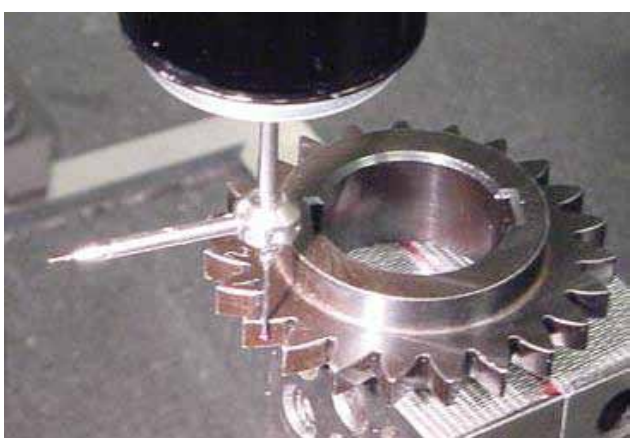

Figure 10—CMM measurement of asymmetric gear.

p_b is the circular pitch at the base diameter

$$p_b = \frac{\pi \times d_b}{n}, \tag{28}$$

n_w is number of teeth for span measurement

$$2 \le n_w \le n_{wmax}, \tag{29}$$

n_{wmax} is maximum number of teeth

$$n_{wmax} = \frac{\sqrt{d_a^2 - d_b^2} - S_b}{p_b}. \tag{30}$$

Calipers, micrometers or special gages are used for span measurement.

CMM Gear Inspection

CMM gear inspection (Fig. 10) allows mapping the whole

surface of all teeth including the fillet profiles. However, it is typically used to control the involute accuracy. Although the gear tooth fillet is an area of maximum bending stress concentration, its profile and accuracy are marginally defined on the gear drawing by typically very generous root diameter tolerance and, in some cases, by the minimum fillet radius. The Direct Gear Design method optimizes the gear tooth fillet profile for minimum bending stress concentration (Ref. 6). For such critical- application gears the tooth fillet profile must be clearly specified, toleranced and inspected.

The whole tooth (including the fillet) CAD profile at the average material condition presented as the B-spline or the tangent arcs accompany the gear drawing for the CMM inspection. The data set also includes the involute flank and fillet profile tolerances that are established by the designer depending on the gear accuracy and also the manufacturing technology. The CMM is programmed to indicate if the inspected tooth profile points lay within the corridor defined by the CAD tooth profile ± profile tolerance. A similar inspection technique is used to inspect curved surfaces, for example, of the airfoil air compressor or gas turbine blades.

Summary and Conclusion

This paper has covered the measurement specifics of the symmetric and asymmetric gears that are designed using the Direct Gear Design method. They are:

- A defined measurement over (or between) balls and pins for external and internal gears
- A defined span measurement for external gears with symmetric teeth
- Descriptions of some CMM inspection issues for directly designed gears

Presented materials should be helpful for manufacturing custom gears with symmetric and asymmetric teeth.

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1. Kapelevich, A.L. "Geometry and Design of Involute Spur Gears with Asymmetric Teeth," *Mechanism and Machine Theory*, 35 (2000), 117–130.
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Dr. Alexander L. Kapelevich *possesses more than 30 years custom gear research and design experience, as well as over 100 successfully accomplished projects for a variety of gear applications and clients. His company, AKGears, provides consulting services—from complete geartrain design (for customers without sufficient gear expertise) to retouching (typically tooth and fillet profile optimization) of existing customers' designs—in the following areas: traditional or direct gear design; current design refinement; R&D; and failure-and-testing analysis. The company provides gear drive design optimization for increased load capacity; size and weight reduction; noise and vibration reduction; higher gear efficiency; backlash minimization; increased lifetime; higher reliability; cost reduction; and gear ratio modification and adjustment. Kapelevich is the author of numerous technical publications and patents, and is a member of the AGMA Aerospace and Plastic Gearing Committees, SME, ASME and SAE International. He holds a Ph.D. in mechanical engineering from Moscow State Technical University and a Masters Degree in mechanical engineering from the Moscow Aviation Institute.*

Tribology Aspects in Angular Transmission Systems

Part IV:
Spiral Bevel Gears

Dr. Hermann Stadtfeld

(This article is part four of an eight-part series on the tribology aspects of angular gear drives. Each article will be presented first and exclusively by Gear Technology, but the entire series will be included in Dr. Stadtfeld's upcoming book on the subject, which is scheduled for release in 2011.)

Dr. Hermann Stadtfeld *received a bachelor's degree in 1978 and in 1982 a master's degree in mechanical engineering at the Technical University in Aachen, Germany. He then worked as a scientist at the Machine Tool Laboratory of the Technical University of Aachen. In 1987, he received his Ph.D. and accepted the position as head of engineering and R&D of the Bevel Gear Machine Tool Division of Oerlikon Buehrle AG in Zurich, Switzerland. In 1992, Dr. Stadtfeld accepted a position as visiting professor at the Rochester Institute of Technology. From 1994 until 2002, he worked for The Gleason Works in Rochester, New York—first as director of R&D and then as vice president of R&D. After an absence from Gleason between 2002 to 2005, when Dr. Stadtfeld established a gear research company in Germany and taught gear technology as a professor at the University of Ilmenau, he returned to the Gleason Corporation, where he holds today the position of vice president-bevel gear technology and R&D. Dr. Stadtfeld has published more than 200 technical papers and eight books on bevel gear technology. He holds more than 40 international patents on gear design and gear process, as well as tools and machines.*

Design

If two axes are positioned in space and the task is to transmit motion and torque between them using some kind of gears, the following cases are commonly known:

- Axes are parallel → cylindrical gears (line contact)
- Axes intersect under an angle → bevel gears (line contact)
- Axes cross under an angle → crossed helical gears (point contact)
- Axes cross under an angle (mostly 90°) → worm gear drives (line contact)
- Axes cross under any angle → hypoid gears (line contact)

The axes of spiral bevel gears in most cases intersect under an angle of 90°. This so-called shaft angle can be larger or smaller than 90°; however, the axes always intersect, which means they have, at their crossing point, no offset between them (*Author's Note*: *see upcoming chapter on "hypoid gears"*). The pitch surfaces are cones calculated with the following formula:

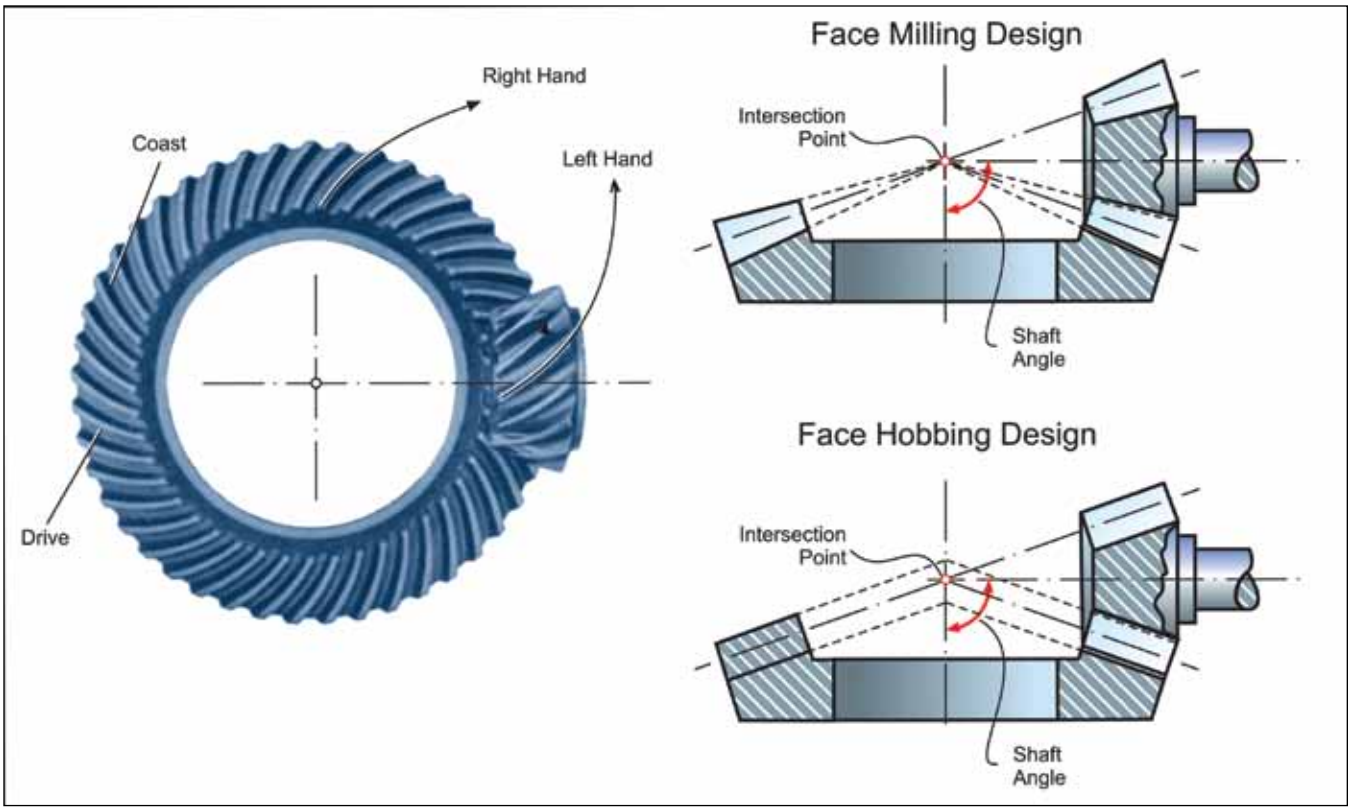

Figure 1—Spiral bevel gear geometry.

$$z_1/z_2 = \sin\gamma_1/\sin\gamma_2$$

$$\Sigma = \gamma_1 + \gamma_2$$

in case of $\Sigma = 90°$:

$$\gamma_1 = \arctan(z_1/z_2)$$
$$\gamma_2 = 90° - \gamma_1$$

where:

z_1	Number of pinion teeth
z_2	Number of gear teeth
γ_1	Pinion pitch angle
Σ	Shaft angle
γ_2	Gear pitch angle

Spiral bevel gears have a parallel-depth profile along the face width if they are manufactured in the continuous face hobbing process or a tapered-depth profile along the face width if the manufacturing is done using the single-indexing face milling process.

Spiral bevel gear teeth follow in the face width direction a curve on the conical gear and pinion body that lies under an angle to a cone element (spiral angle). The tooth lead function in the face width direction—if unrolled into a plane—is an epicycloid or a circle, depending on the manufacturing method. The tooth profile is a spherical involute in a parallel-depth tooth system; it is an octoid in a tapered-depth tooth system. The tooth form with a spherical involute will result in line contact between two mating flanks in each angular position if no crowning has been applied. With an octoid, there will be an initial, "natural-profile" crowning and, depending on the machining set-up, some flank twist. Both effects are utilized with certain corrective machine settings in order to generate the desired crowning (*see also "General Explanation of Theoretical Bevel Gear Analysis"*).

The photo of a spiral bevel gear set in Figure 1 explains the definition of right-hand and left-hand spiral direction, and indicates the coast- and drive-side gear flanks. The cross-sectional drawings to the right in Figure 1 illustrate the blank design for face milling on top (tapered-depth teeth) and face hobbing design at the bottom (parallel-depth teeth).

Analysis

Since the mentioned distortions in tapered-depth tooth systems are detected by comparison with conjugate mating flanks, it is possible to define potential contact lines that would apply if the distortions are removed or if load-affected deflections allow for a contact spread. In order to allow for deflections of tooth surfaces, shafts, bearings and gearbox housing without unwanted edge contact, a crowning in face width and profile direction is applied. A

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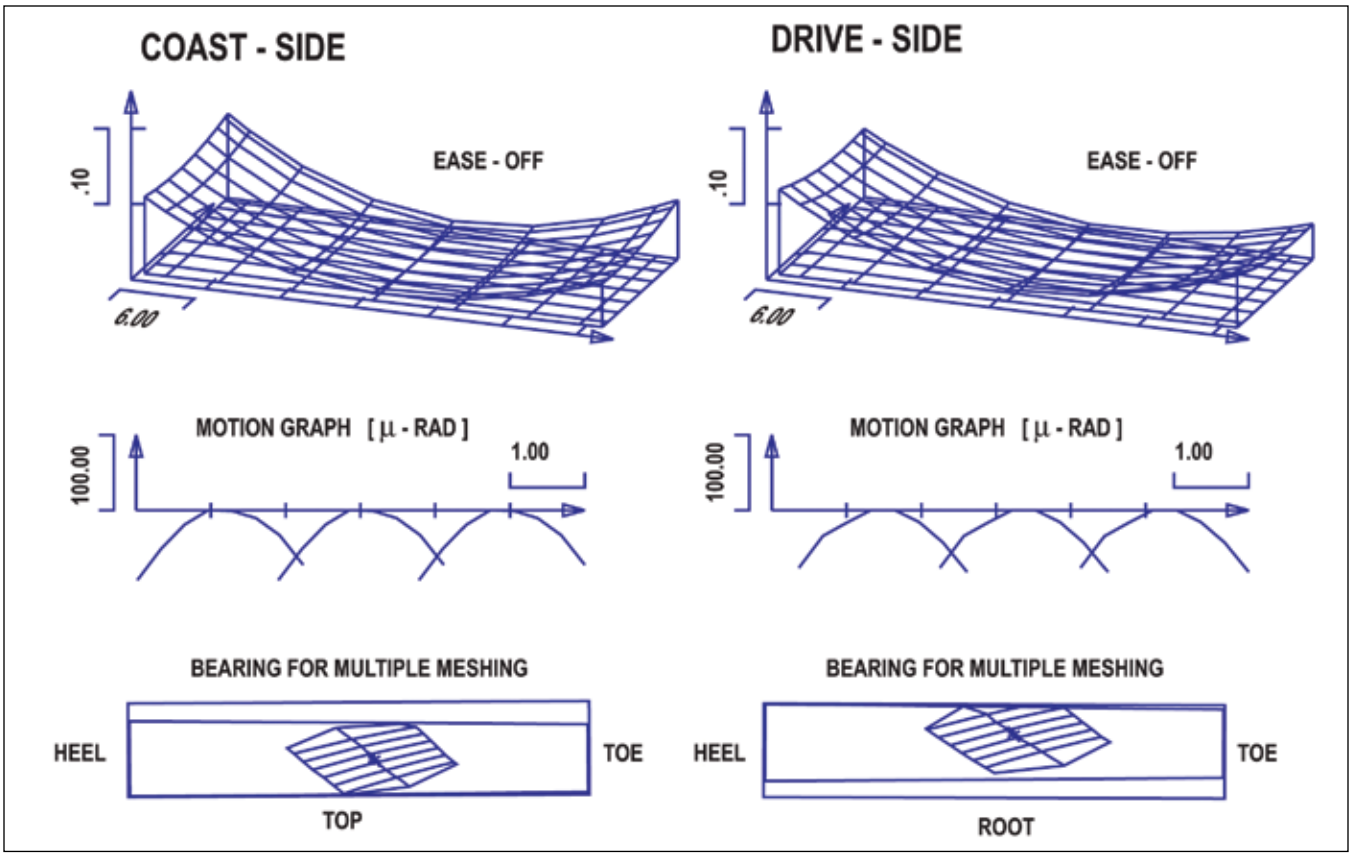

Figure 2—Tooth contact analysis of a spiral bevel gear set.

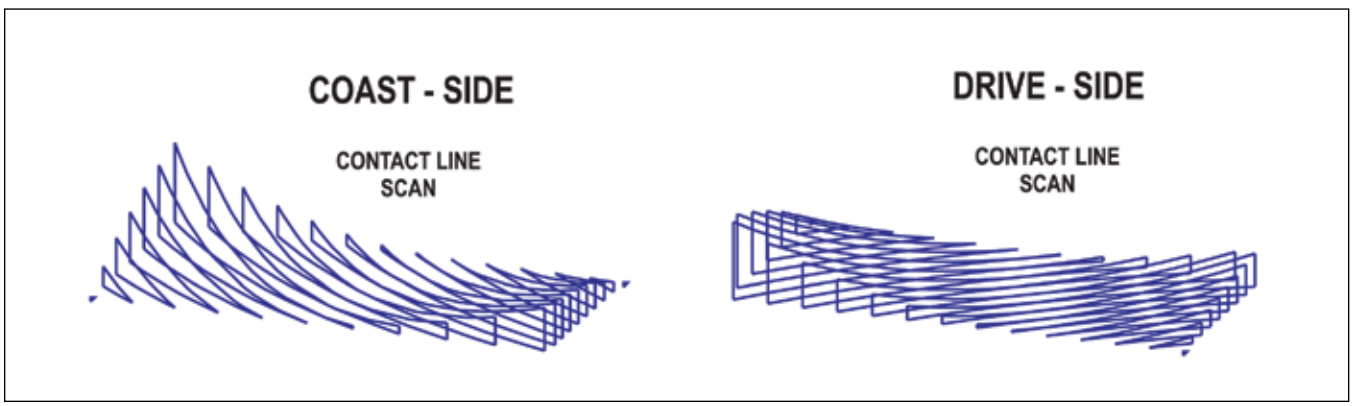

Figure 3—Contact-line scan of a spiral bevel gear set.

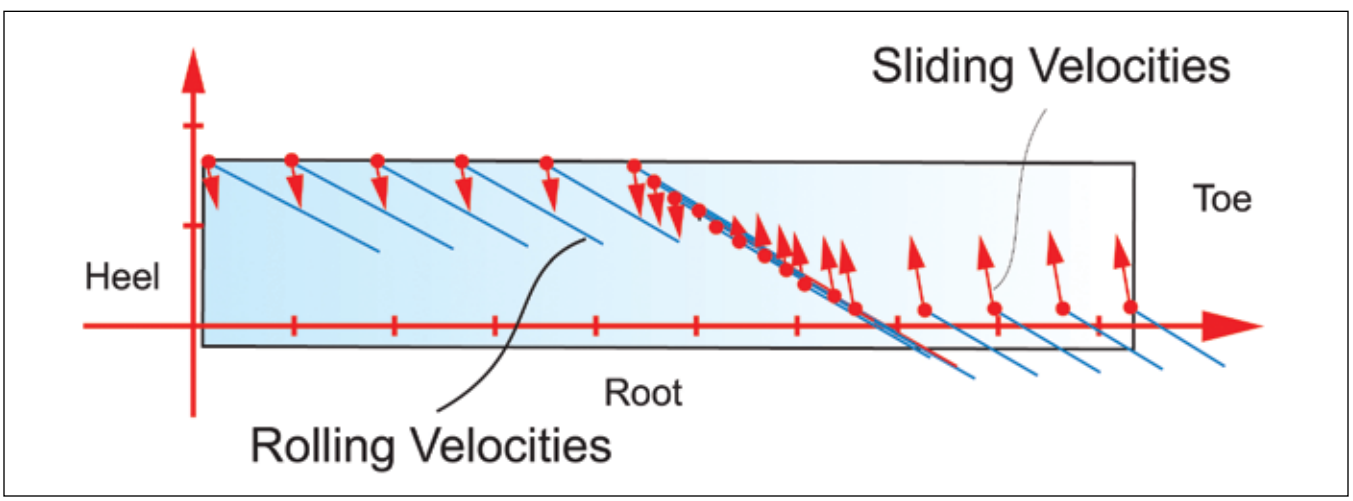

Figure 4—Rolling- and sliding-velocities of a spiral bevel gear set in path-of-contact points.

theoretical tooth contact analysis (TCA) previous to gear manufacturing can be performed in order to observe the effect of the crowning in connection with the basic characteristic of the particular gear set. This also allows the possibility to return to the basic dimensions in order to optimize them if the analysis results show any deficiencies. Figure 2 shows the result of a TCA of a typical spiral bevel gear set.

The two columns in Figure 2 represent the analysis results of the two mating flank combinations (*see also "General Explanation of Theoretical Bevel Gear Analysis*"). The top graphics show the ease-off topographies. The surface above the presentation grid shows the consolidation of the pinion and gear crowning. The ease-offs in Figure 2 have a combination of length- and profile-crowning to the extent that a clearance along the boundary of the teeth is established.

Below each ease-off, the motion transmission graphs of the particular mating flank pair are shown. The motion transmission graphs show the angular variation of the driven gear in the case of a pinion that rotates with a constant, angular velocity. The graphs are drawn for the rotation and mesh of three consecutive pairs of teeth. While the ease-off requires a sufficient amount of crowning in order to prevent edge contact and to allow for load-affected deflections, the crowning in turn causes proportional amounts of angular motion variation of about 60 micro radians in this example.

At the bottom of Figure 2, the tooth contact pattern is plotted inside of the gear tooth projection. These contact patterns are calculated for zero-load and a virtual-marking-compound film of 6 µm thickness. This basically duplicates the tooth contact by rolling the real version of the analyzed gear set under light load on a roll tester, while the gear member is coated with a marking-compound layer of about 6 µm thickness. The contact lines lie under an angle to the face width direction, depending basically on the spiral angle. The path-of-contact connects the beginning and end of meshing, and its orientation is nearly perpendicular to the contact lines.

The crowning reflected in the ease-off results in a located contact zone within the boundaries of the gear tooth. A smaller tooth contact area generally results from large magnitudes in the ease-off and motion graph, and vice versa.

Figure 3 shows 20 discrete, potential contact lines with their individual crowning amounts along their length (contact-line scan). The gap geometry in contact-line direction can be influenced by a change in ease-off topography and optimized regarding the gap kinematic cases (*see also "General Explanation of Theoretical Bevel Gear Analysis," Fig. 8*). The gap geometry perpendicular to the contact-line direction (not exactly the same as the path-of-contact direction) does not significantly depend on the ease-off topography; rather, it is mainly dominated by the geometry of the mating tooth profiles.

Figure 4 shows the sliding- and rolling-velocity vectors of a typical spiral bevel gear set for each path-of-contact point for the 20 discussed roll positions; each vector is projected to the tangential plane at the point-of-origin of the vector. The velocity vectors are drawn inside the gear tooth projection plane. The points-of-origin of both—rolling- and sliding-velocity vectors—are grouped along the path-of-contact, which is found as the connection of the minima of the individual lines in the contact-line scan graphic (Fig. 4). The velocity vectors can be separated in a component in contact-line direction and a component perpendicular to that in order to investigate the hydrodynamic lubrication properties. This is accomplished by utilizing the information from the contact-line scan (curvature and curvature change) and the tooth surface curvatures perpendicular to the contact-line direction (*see also "General Explanation of Theoretical Bevel Gear Analysis," Figure 8, cases 1–6*).

Regarding the discussed spiral bevel gear set, the sliding-velocity vectors are basically profile-oriented. In the top area (left, Fig. 4), the sliding vectors point down. Moving along the path-of-contact from top to bottom (left-to-right, Fig. 4), the sliding velocity reduces its magnitude and reaches a magnitude of zero at the pitch line. Below the pitch line, the sliding velocity develops, growing positive magnitudes (towards the bottom of the gear tooth). The maximal magnitude of the sliding velocities (top-versus-root) is a result of the distance from the pitch line. As such, the distance between the lowest active flank line to the pitch line is larger than the distance from the pitch line to the top. The rolling-velocity vectors point to the bottom and to the right, and all have basically the same orientation. The orientation is a result of the spiral angle (zero spiral angle delivers profile-oriented sliding). The larger magnitude of the rolling velocity at the heel-top (left) is caused by the larger circumferential speed at the outer diameter.

continued

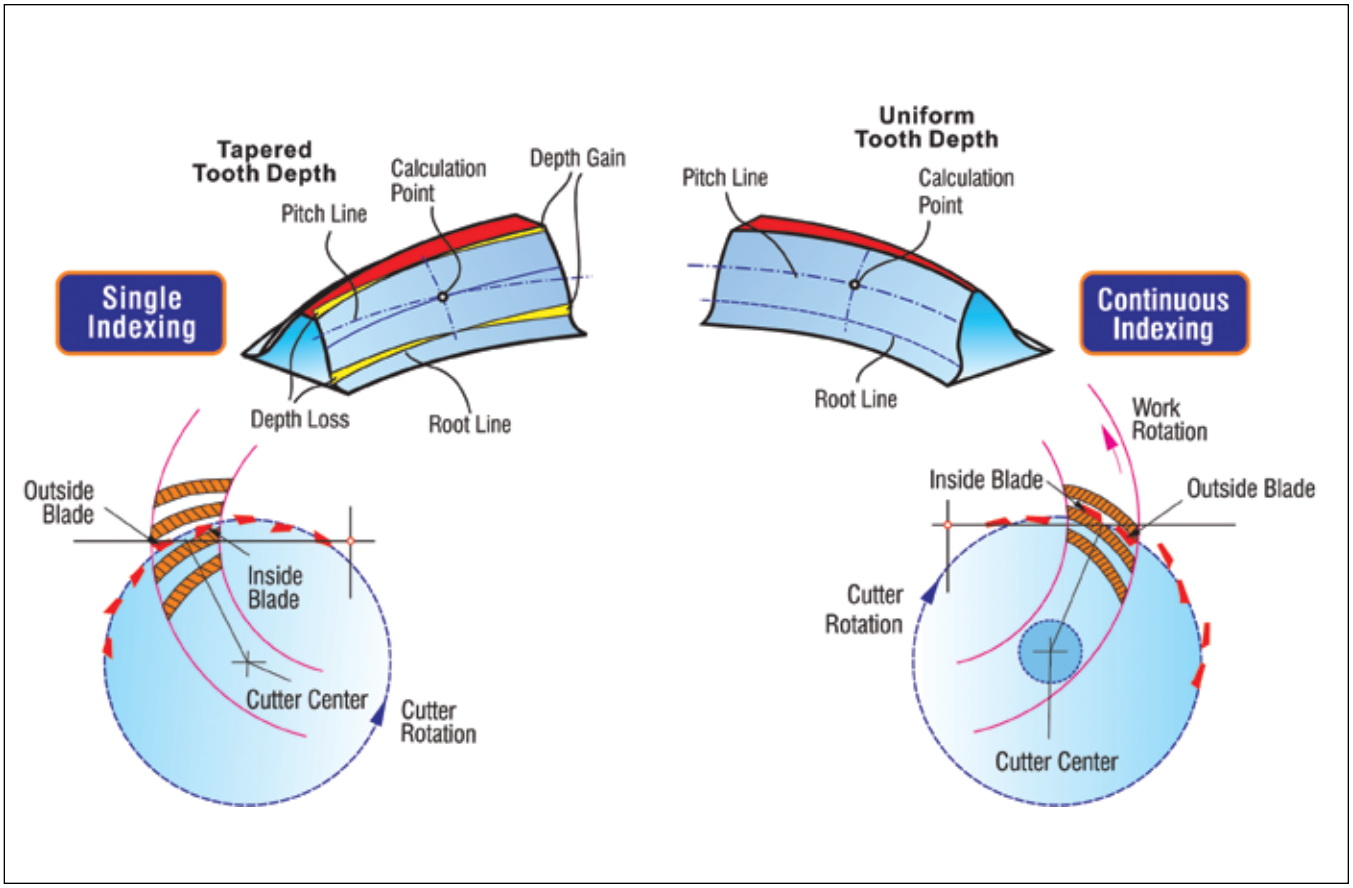

Figure 5—Left: face milling; Right: face hobbing.

Figure 6—Spiral bevel gear cutting with face hobbing cutter (continuous process).

It thus becomes evident that a complex gap-and-velocity evaluation of a variety of discrete points considering the two principal curvature directions is important in spiral bevel gears to attain reliable results about the lubrication mechanics.

Manufacturing

Spiral bevel gears are manufactured in a continuous-indexing face hobbing process or in a single-indexing face milling process. In the face milling process, the blades are oriented around a circle and pass through one slot (while they plunge or generate the flanks of that particular slot), as illustrated in Figure 5, left. The work is not performing any indexing rotation. At the blade tip and in equidistant planes—normal to the cutter head axis—the slot width produced has a constant width between toe and heel. In order to achieve a proportionally changing slot width (and tooth thickness), the root line of face milled bevel gears is inclined versus the pitch line (Fig. 5, left). This modification has to be implemented in both members, which is why the face angle requires the same modification as the root angle of the mating member.

In face hobbing (Fig. 5, above), a group of

mostly one inside and one outside blade passes through one slot, while the work rotates with:

$\omega_{Work} = \omega_{Cutter}$ • (Number of Cutter Blade Groups) / (Number of Work Teeth)

The blades in one group are positioned along a spiral where the sum of the blade groups is oriented around a circle with equal distance to the cutter head center. Due to the described kinematic, the flank lines of the outer- and inner-flank are epicycloids that divide slot width and tooth thickness in equal fractions of the circumference—at any point along the face width. The result is a "natural" slot width taper proportional to the distance from the pitch apex. A root angle modification is not required—or useful—due to the already-existing perfect fit of mating teeth and slots.

Figure 6 is a photo of the view into the work chamber of a free-form bevel and hypoid gear cutting machine during high-speed dry-cutting of a spiral bevel gear. The face cutter head has coated carbide stick blades which are arranged in blade groups for a continuous face hobbing process.

Hard-finishing after heat treatment of face milled spiral bevel gears is generally done by grinding. The grinding wheel resembles the cutter head geometry, while the grinding machine uses the same set-up geometry and kinematics as the cutting machine for the previous soft machining. Hard-finishing of face hobbed spiral bevel gears is generally done by lapping. Pinion and gear are rolled under light torque while a lapping compound of a silicone-carbide oil mixture is present between the flanks. Lapping causes abrasive grain to become imbedded in the flank surfaces, which might lead to several problems such as wear, temperature and lowered efficiency.

Application

Most spiral bevel gears to be used in power transmissions are manufactured from carburized steel and undergo case-hardening to a surface hardness of 60 Rockwell C (HRC) and a core hardness of 36 HRC. Because of the higher pinion revolutions, it is advisable to give the pinion a higher hardness than the ring gear (e.g., pinion 62 HRC, gear 59 HRC).

Regarding surface durability, spiral bevel gears are very similar to helical gears. At the pitch line, the sliding velocity is zero and the rolling velocity under certain loads cannot maintain a surface-separating lubrication film. The result is pitting along the pitch line that can destroy the tooth surfaces and even lead to tooth flank fracture. However, it is possible that the pitting can be stabilized if the damage-causing condition is not prevalent in the duty cycle. Figure 7 is a photograph of typical pitch-line-pitting on a spiral bevel ring gear flank surface. This effect is not as common as in straight bevel gears due to the more favorable direction of the rolling velocities.

Spiral bevel gears have axial forces that can be calculated by applying a normal-force vector at the position of the mean point at each member (*see also "General Explanation of Theoretical Bevel Gear Analysis*"). The force-vector normal to the transmitting flank is separated in its X, Y and Z components (Fig. 8).

The relationship in Figure 8 leads to the following formulas, which can be used to calculate bearing force components in a Cartesian coordinate system and assign them to the bearing load calculation in a CAD system:

continued

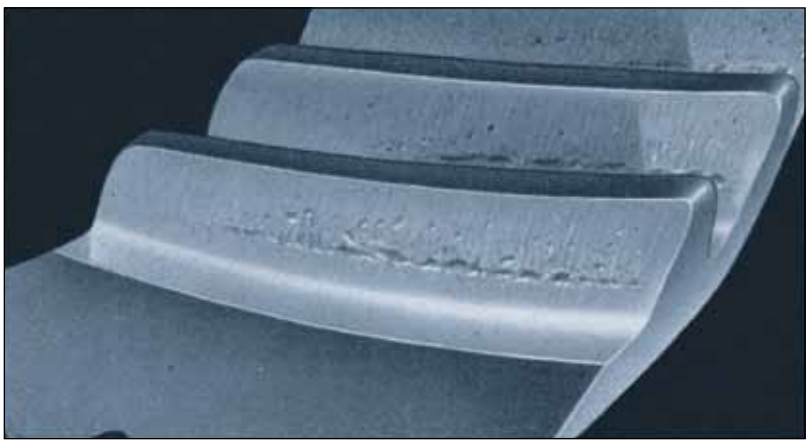

Figure 7—Pitch-line pitting on a spiral bevel gear surface.

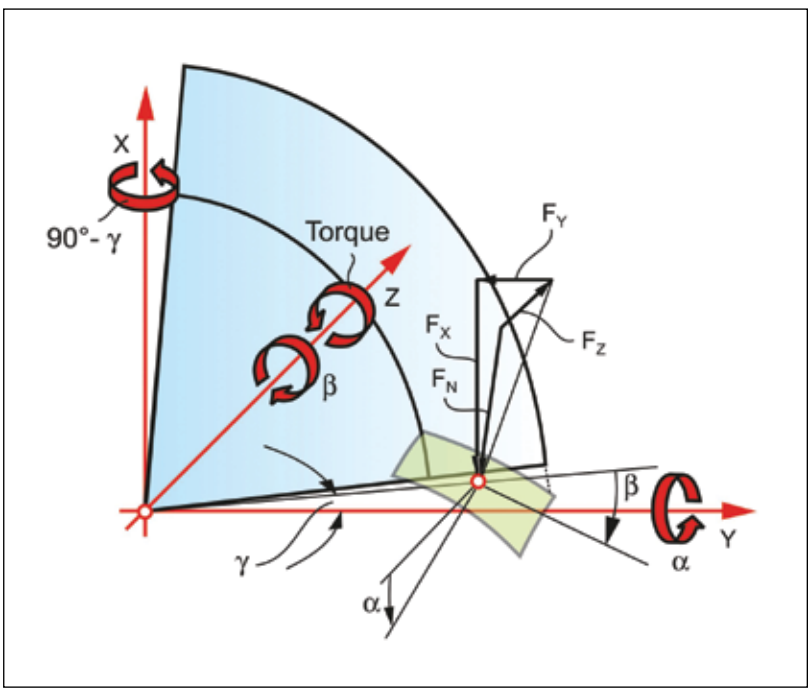

Figure 8—Force diagram for calculation of bearing loads.

$$F_x = -T / (A_m \bullet \sin\gamma)$$

$$F_y = -T \bullet (\sin\gamma \bullet \sin\beta \bullet \cos\alpha + \cos\gamma \bullet \sin\alpha) / (A_m \bullet \sin\gamma \bullet \cos\beta \bullet \cos\alpha)$$

$$F_z = -T \bullet (\cos\gamma \bullet \sin\beta \bullet \cos\alpha - \sin\gamma \bullet \sin\alpha) / (A_m \bullet \sin\gamma \bullet \cos\beta \bullet \cos\alpha)$$

where:

T	Torque of observed member
A_m	Mean cone distance
γ	Pitch angle
β	Spiral angle
α	Pressure angle
F_x, F_y, F_z	Bearing load force components

The bearing force calculation formulas are based on the assumption that one pair of teeth transmits the torque with one normal force vector in the mean point of the flank pair. The results are good approximations that reflect the real bearing loads for multiple teeth meshing within an acceptable tolerance. A precise calculation is, for example, possible with the Gleason bevel and hypoid gear software.

The introduction of spiral angles lead to a face-contact-ratio that in turn reduces the tooth root thickness. The tooth thickness counts are squared in a simplified root bending stress calculation using a deflection beam analogy. The thickness reduces by: cos (spiral angle). The face contact ratio increases are simplified by: tan (spiral angle). Those formulas applied to a numerical example will always show an advantage of the spiral angle in root bending strength. However, the crowning of real bevel gears will always cause one pair of teeth to transmit an over-proportionate high share of the load, while the one or two additionally involved tooth pairs will only share a small percentage of the load. Finite element calculations can be useful in finding the optimal spiral angle for maximal root strength. In general, bevel gears not ground or lapped after heat treatment show the highest root strength and the lowest spiral angles. This explains why in those cases the straight bevel gear remains the bevel gear of choice.

Spiral bevel gears can operate with regular transmission oil or, in case of low RPMs, with a grease filling. In cases of circumferential speeds above 10 m/min, a sump lubrication with regular transmission oil is recommended. The oil level has to cover the face width of those teeth lowest in the sump. More oil causes foaming, cavitations and unnecessary energy loss; there is no requirement for any lubrication additives. The preferred operating direction of spiral bevel gears is the drive-side, where the convex gear flank and the concave pinion flank mesh. In the drive-direction (Fig. 8), the forces between the two mating members bend the pinion sideways and axially, away from the gear, generating the most backlash. Coast-side operation reduces the backlash—in extreme cases—to zero, which interrupts any lubricant flank separation and leads to immediate surface damage, often followed by tooth fracture.

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(Ed.'s Note: Next issue—"Face Gears")

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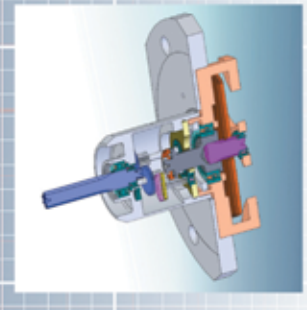

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Now, More Than Ever

GEAR EDUCATION AND TRAINING VITAL TO SELLERS, BUYERS AND NATIONAL SECURITY

Jack McGuinn, Senior Editor

When it comes to expert training for an industry as complex as gear design and manufacturing, programs like the AGMA-supported Manufacturing Technology Institute at Chicago's Richard J. Daley Community College are carrying more than their share of the load (courtesy AGMA).

You wouldn't know it from the weekly or monthly unemployment figures, but manufacturing job openings have actually increased in recent years.

That's the good news.

But here's the rub—most of those opportunities exist only for highly skilled, often degreed, workers. Indeed, in the past decade, manufacturers represented a 44 percent increase in workers with an advanced degree.

And that's all well and good for United States competitiveness around the globe. But when looking at the gear industry's workforce needs, that's not the whole story. Certainly, gearmakers seek out and employ well-educated designers and engineers, etc. But there still remains the crying need for skilled people to understand and operate the highly sophisticated machinery and other equipment that is vital to a successful operation. Without that, what remains is a "too many generals and not enough foot soldiers" scenario in which dearly expensive machinery sits on the shop floor without fully realizing its potential capabilities and productivity.

continued

But one thing is certain: the unheralded and—some might say—under-appreciated U.S. gear industry knows how to take care of its own, and has been doing so for many years. As those reading this already know, the vagaries and complexities inherent in making gears go well beyond what might be expected in a typical manufacturing setting; this is not assembly line work.

With that said, it's good to know that gear training and education continue unabated around the country, whether at universities, community colleges, AGMA, or commercial training provided by leading machinery manufacturers and others. What follows is a look at some of those institutions fighting the good fight despite, in most cases, little or no help from government. This is by no means an exhaustive survey of existing gear-learning opportunities. For those we've left out this time around, we'd love to hear from you for future discussion.

The Daley College Manufacturing Technology Institute benefits from the strong support of AGMA and participating gear industry companies, as evidenced by the gear-specific equipment and machinery available to all students (courtesy AGMA).

American Gear Manufacturers Association (AGMA)

AGMA, of course, is the industry's association headmaster, if you will. We talked with AGMA education manager Jan Alfieri to get some background perspective and a glimpse of future plans. Following are her remarks.

"In the mid 1990s, several AGMA members worked together to create our training school for gear manufacturing taught at the Daley College in Chicago. This week-long school includes both a classroom and a factory floor component where students learn the basics of gear manufacturing.

"A bit later we added the option for individual companies to have an instructor come to their plant for two or three days to provide individualized instruction. And, as time went on, our instructors—Geoff Ashcroft and Ron Green from their company, Gear Consulting Group—added courses at regional sites for companies that could not justify a dedicated course but wanted additional training for some employees.

"With funding from the AGMA Foundation, we extended these courses by developing three online modules in a Workforce Training Series. This series includes Fundamentals of Gearing, Parallel Gear Inspection and Hobbing. We have had over two thousand individuals register to use these courses over the last three years. Interestingly, over 40 percent of the registrants have over two years of engineering experience.

"A number of our member companies have established this as a requirement for their employees. Because of the exam, companies are using these courses as an element in their formal training program and to help meet requirements of management systems programs such as ISO 9000.

"To meet the need for advanced engineering programs, AGMA has sought independent consultant members to develop and present courses and continues to seek experienced instructors. Our current instructors include Robert Errichello, who presents Gear Failure Analysis, an extremely popular course that is taught twice a year and sells out each time. In addition, Ray Drago has developed five advanced courses which he and his associates present each year—Detailed Gear Design, Gearbox CSI, Gear Manufacturing & Inspection, Materials & Metallurgy and Gearbox System Design.

Jan Alfieri, AGMA education manager (courtesy AGMA).

"In 2009 the AGMA Foundation granted assistance to AGMA to create an online version of Detailed Gear Design: Beyond Simple Service Factors. The online video course contains 15 one-hour modules and will debut in January.

"Our Technical Division provides other, subject-specific seminars and workshops as needed, and they bring the industry together each fall for the Fall Technical Meeting, a series of 15–20 technical papers and special presentations. The 2010 FTM had exceptional response from industry, with 150 attendees, of which over half were younger engineers and first-time attendees."

(*Alfieri welcomes any suggestions, course proposals and interest in becoming an instructor for AGMA. You can contact her at* alfieri@agma.org *or 703-838-0055. You can also visit the AGMA website for information on all AGMA education opportunities* www.agma.org.)

Geoffrey Ashcroft of Gear Consulting Group.

Gear Consulting Group

Gear Consulting Group (GCG) was formed as a company to service the gear industry in various capacities including, but not limited to, education. Presentation of the educational programs is the main responsibility of Geoffrey Ashcroft, former vice president of American Pfauter and a mechanical and manufacturing engineer with a broad experience of gear manufacturing on three continents over a career spanning 50-plus years. He is currently a director of Overton-Chicago Gear. Following are his remarks.

"For the last ten years GCG has partnered with AGMA to produce and present these programs on a regional basis around the country, and they are open to all comers. Usually these seminars are hosted by an AGMA member company—at their place of operations—allowing for demonstration of the processes. In addition, AGMA offers the same school on an in-plant basis for a single company.

"The theme of the gear schools produced by GCG is that of a logical approach to troubleshooting the manufacturing process and includes a gear technology section that is considered a 'must' for a proper understanding of the process. Included in the usual curriculum are modules on inspection, gear hobbing, shaping and shaving as well as cutting tool materials, tool maintenance and tool failure analysis. Both traditional as well as state-of-the-art methods are covered. Attendees are encouraged to bring examples of their own problems for analysis.

"In addition to the standard curriculum, GCG produces custom programs for training and developing manufacturing personnel based on the type of industry and product of a specific client. A library of some 40 different modules has been produced over the last 10 years.

"The structure of the program is aimed to be of benefit to a variety of people—from operators through manufacturing engineers—and carries certification by AGMA."

In Ashcroft's view, and that of many others, "There is a lack of structured education available to people in the gear industry," and the scant number of formal schools discussed in this article is clear evidence of that. "This," he adds, "coupled with elimination of apprenticeships, leaves a large part of this country's valuable and intelligent workforce without the tools to constantly improve the process and take care of day-to-day problems."

Gear Failure Analysis (GFA) Seminar (Robert Errichello)

As mentioned above, Robert Errichello's twice-yearly Gear Failure Analysis seminar is among the most popular

continued

and respected learning opportunities AGMA offers.

Gear Technology (GT): How long have you been presenting this course?

Robert Errichello (RE): We started the GFA Seminar for AGMA in 1992 and have conducted it twice each year since then.

GT: Given your broad range of experience, is there a particular reason for focusing on gear failure as opposed to other topics?

Expert instruction and hands-on learning opportunities for students of all ages—and genders—are available at the Richard J. Daley Community College (DCC)/AGMA-sponsored Manufacturing Technology Institute (courtesy AGMA).

All Gear Research Institute equipment will be made available for Penn State University's first-ever undergraduate gear training program (courtesy Gear Research Institute).

Robert Errichello, GEARTECH president and *Gear Technology* technical editor (courtesy Robert Errichello).

RE: We started with seminars on gear design and gear lubrication and gravitated to GFA because it became a large part of our consulting work and we got many requests from clients and attendees at seminars for GFA. Early in my career as a gear designer I realized that knowledge of how gears failed was necessary to be able to design reliable gears.

GT: Who typically attends your class?

RE: We get a wide range of new and experienced mechanical engineers, failure analysts, metallurgists, lubrication engineers, equipment operators and maintenance technicians from many different industries including the oil and gas, mining, wind turbines, aerospace, automotive, marine and lubricant and additive companies.

GT: Who *should* attend your class?

RE: Anyone interested in how gears work and how they fail. Many students re-take the course to refresh their knowledge and gain updated material.

GT: Are you the sole instructor?

RE: No, Jane Muller handles all logistics and instructs students during the practical workshop.

GT: Is the fee typically paid by attendees' employers or is it on their own dime?

RE: Usually paid by employers, but sometimes consultants pay their own way.

GT: Is there any room for college-level students?

RE: The course is ideal for college-level students. Generally junior- and senior-level engineering students have the necessary background in stress analysis and strength of materials courses.

GT: Can you comment a bit on the course manual? I saw somewhere it alone is worth the cost of the seminar.

RE: The course manual includes copies of all text slides and most photo slides so students can concentrate on the presentation rather than note taking. It includes a textbook for the gear failure analyst that explains how to manage a gear failure analysis and describes gear tooth failure modes, root causes and remedies. Furthermore, there is a wealth of reference information.

GT: Are there any frustrations in teaching the class? Do you find today's attendees as engaged as in previous times?

RE: The only frustration is time. It takes careful management of time to balance scope with attention to detail. Today's attendees are more engaged than ever. Part of the reason for the enhanced interest is the recent interest in wind turbines and the challenging demands that wind turbines require from gearboxes.

GT: How did the class come about? Was it your initiative or AGMA's?

RE: I don't recall who first thought of the class. I've been an AGMA member since the mid 1960s and have been active on many committees, so the GFA seminar was a natu-

ral consequence of my experience.

GT: Considering the other AGMA-sponsored seminars, how would you rate gear failure analysis in terms of complexity?

RE: It's complex because of the scope. However, concepts are easy to understand and we find students that win the prizes are often those with the least formal education. The most challenging part of GFA is correctly identifying the failure mode. Once the failure mode is known, the textbook and other sources of information can be used to understand the mechanisms, root causes and remedies.

GT: To what extent is your proprietary *GEARTECH* software used in the class?

RE: We don't use the software because of time constraints. However, we discuss software capability for predicting failure modes and how one should use calculations to support conclusions regarding root causes. Lastly, an important feature of the class is the informal atmosphere and the personal attention each student receives. Students love the location, which is in scenic Montana and close to Yellowstone Park. The course is intensive but very rewarding (especially for those students who win prizes).

Richard J. Daley Community College (DCC) (Chicago, IL)

In tandem with its strong relationship with AGMA, Daley Community College is doing more than its part in helping to shake off some of the rust in Rust Belt cities like Chicago. Ray Prendergast, the recently appointed director of the school's Manufacturing Technology Institute, provides us with some insights on the school and its role in helping to provide skilled workers for the gear industry.

GT: Does DCC offer credited coursework in gearing/manufacturing?

Ray Prendergast (RP): At the moment Daley is only offering non-credit skills training in gear manufacturing. I would like to develop credit courses in the near future.

Ray Prendergast, director of Richard J. Daley Community College (DCC) Manufacturing Technology Institute (courtesy DCC).

GT: Is the Manufacturing Productivity Program the core offering for gearing, etc?

RP: Our Manufacturing Productivity degree focuses on CNC machining, which of course is an essential part of gear manufacturing. I would like to add manual gear hobbing and gear shaping as an elective credit class for students who work in the field.

The AGMA-Daley Gear School was started around 1993 and Daley College did draft a program for training that included four credit hours, but I think it was never approved. Today gears are produced on CNC machines but the manual training in hobbing, shaping and gear inspection connects the computerized machine tool operator, the manufacturing engineer, the

continued

sales reps, etc., to the gear manufacturing processes in a way that can't be done through push buttons and G-code.

GT: Is there a higher level of instruction beyond that?

RP: Currently not at Daley College.

GT: What is the background of the instructors?

RP: They all have extensive experience in gear manufacturing. In addition to set-up and operation of production equipment, they also have experience in sales and service of gear cutting machinery and quality assurance.

GT: How does the Certificate Program in manufacturing differ from the Manufacturing Productivity courses?

RP: The certificate program is shorter, only about half of the AAS (Associate's) degree program. Ideally, the certificate is a milepost on the way to the AAS degree. Of course, for working adults even a 'two-year' AAS degree can take four years or longer. Work and family life come first, so students may complete the program in straight-line fashion. This is why most of our classes are in the evenings and on Saturdays. Soon the college will be offering Sunday classes as well. We are dedicated to serving working adults, especially in manufacturing where the majority of our AAS degree students are already in the industry.

GT: Does the gear manufacturing program receive any funding from industry?

RP: We receive considerable support from industry. For example, Northstar Aerospace Chicago is donating gear measuring equipment. Employees of several gear manufacturers serve on our advisory board and hire our graduates. I have not solicited monetary donations from the industry yet, but I feel that we have a lot of support already.

GT: Is the bulk of funding from Chicago and/or Illinois taxpayers?

RP: The Daley-AGMA gear school is funded by fees. Companies and individuals pay the tuition. There is no government funding for it.

GT: Any help from Washington?

RP: Not specifically for gear training, but there is funding through WIA (Workforce Investment Act) and TAA (Trade Act Program), and financial aid through Pell grants.

GT: Is there by any chance a "study abroad" –e.g., Germany—program available for manufacturing students?

RP: No—interesting idea though!

GT: Is there an outreach program in place for attracting young people—not just the disadvantaged—to a career in gear technology/manufacturing?

RP: Yes. I'm on the advisory board of Austin Polytechincal Academy (in Chicago) and I was on the design team for this manufacturing-themed high school. I am marketing machining careers to students there and so are other advisory council members including Arrow Gear, Brad Foote Gear and Bison Gear. I also work with Chicago-area Curie and Gage Park High Schools and Prosser Career Academy, and we will be reaching out to Simeon Career Academy as well. These are all schools with manufacturing career programs.

GT: What would you like to see done on a national level to attract young people to manufacturing?

RP: We have to convince people, especially parents, that

there are great careers in manufacturing. It is remarkable that even with the high unemployment rate of today there are still many job openings, particularly in manufacturing. In fact, there was a remarkable two-week period at the end of October/beginning of November when a large number of job postings ran across my desk, including:

Company A is planning to hire 10 to 15 maintenance mechanics, along with a large number of semi-skilled machine operators.

Company B opened up their Maintenance Technician Apprenticeships. They have tested applicants and will create a long-term list for hiring.

Gear Manufacturer C has several openings for CNC machinist trainees, starting at $14.73/hr.

Gear Manufacturer D is getting ready to hire about eight CNC machinists.

Company E has several openings for CNC machinists.

Company F and Headhunter G need automation technicians.

All of these jobs are good-paying 'middle skills' jobs, and remarkably, this is what entry-level employment looks like in today's manufacturing! There are jobs, but you can't get them without skills.

GT: What percentage of students completes the gearing/manufacturing program?

RP: Almost 100 percent complete the gear school, which is a one-week program. For our CNC machininst training I don't have the numbers yet.

GT: Should graduates expect to be fully qualified for at least an 'entry level' job in gearing?

RP: Students that complete our AAS degree in Manufacturing Productivity are qualified in CNC mills and lathes, but not in hobbing or shaping. The gear school students are already in the field.

GT: Are scholarships available?

RP: Yes for the AAS degree program.

GT: Is gear design and software taught?

RP: Not at this time. But that is something I would like to add.

Beyond the industry-specific education outlets described above, there do exist four-year colleges and universities in the country offering highly relevant core programs and graduate studies in mechanical engineering, if not hands-on, gearing-specific studies. Two such schools are Ohio State University and Penn State University, both of which are very well-known for their post-graduate Gear Lab and Gear Research Institute (GRI), respectively. We talked to important players from each—Dr. Ahmet Kahraman (OSU/Gear Lab) and Suren Rao (Penn State/GRI).

In an exciting development announced at the AGMA Fall Technical Meeting, it was learned that Penn State will in 2011 offer an upper-class (Junior/Senior) undergraduate program under the auspices of the university. Although the initial effort is small in scale, one can only hope that other learning institutions will soon step up and follow suit.

Penn State University/GRI

GT: What circumstances came together to compel a

continued

decision to begin an undergraduate program for gear training?

Suren Rao (SR): A number of gear-related companies indicated that a significant portion of their expert workforce would be retiring in the next 5–10 years. Also, some of their recent technical hires had been laid off in the 2008 downturn and had since left the business. These organizations indicated that they needed assistance to recruit and maintain their technical human resources.

Suren Rao, Gear Research Institute managing director (courtesy GRI).

GT: Will the program/curriculum be administered by GRI or the university?

SR: All aspects of this program will be administered by the University. Students selected will be already enrolled in Penn State with junior/senior standing and will work at GRI's laboratories at ARL/Penn State for wages and/or independent study credits, if appropriate.

GT: How many students will be accepted?

SR: Our current sponsored efforts can absorb about five students. More can be trained if additional sponsored projects happen.

GT: Are you hiring additional instructors for the program?

SR: No, they will work with existing faculty and staff.

GT: Any thoughts on why more U.S. schools aren't doing this?

SR: There are very few schools in the country with a dedicated gear research program.

GT: Are you receiving any support (not necessarily financial) from NASA or the aerospace industry?

SR: Not specifically for this effort, but selected students can work on projects sponsored by the aerospace industry.

GT: To what extent—if any—will GRI receive financial assistance from either industry or state/federal government for the school?

SR: GRI is currently seeking industry funds to pay the wages for students in this program while they are at Penn State.

GT: Are there recruitment/outreach programs in place or contemplated to help boost enrollment?

SR: We are just getting the word out through AGMA and now through *Gear Technology* magazine.

GT: What will be the enrollment requirements (grades)?

SR: We will focus on junior/senior ME (mechanical engineering), ESM (engineering, science and mathematics, and Materials Science students who would be eligible to go on to a graduate degree.

GT: Are scholarships in place at this time?

SR: The GRI has been utilizing its discretionary funds, supplemented by corporate membership fees, to sponsor one undergraduate for the last 3–4 years. No other scholarships are in place at this time.

GT: Please describe the intern program for onsite experience.

SR: Students will participate in ongoing sponsored projects. This will include setting up test machines, inspecting test specimens including test gears, preparing metallurgical samples and conducting metallurgical evaluations of microstructure, hardness, residual stresses and retained austenite. Students can also be involved in the design of special test fixtures and test specimens and minor machining and fabrication to complete and experimental set-up. The student will be expected to work for the sponsor as a summer job at the sponsor's facility and as required by the sponsor.

GT: Please describe how the "sponsor" process works. Why is that necessary?

SR: A commitment to support the student during the academic semester at Penn State is all that is needed. We estimate that to be about $4,000 per semester (about 10–15 hrs/week for 16 weeks), as a grant to GRI.

GT: Please explain how sponsors can recruit a graduate for employment.

SR: The student commits to spending the summer at the sponsor's facility. This is an opportunity for the company to get to know the individual and for the individual to get to know the company. If a mutual relationship develops we anticipate this will lead to recruitment.

GT: Will the undergrads have full access to GRI equipment, etc.?

SR: Yes, they will be trained by the existing faculty, staff and engineering technicians and provided full access as they demonstrate competence. We, the Board of Trustees of the Gear Research Institute, believe this is a mutually beneficial golden opportunity. The GRI fulfills its mission while the gear industry finds its future employees.

Ohio State University/Gear Lab

It's almost pointless to talk about OSU's undergraduate mechanical and aerospace engineering program without acknowledging its industry-vital Gear Lab, so we've done both. Following are remarks from Gear Lab director Dr. Ahmet Kahraman.

GT: After some 30 years, what's new at the Gear Lab?

Dr. Ahmet Kahraman, director of Ohio State University's Gear Lab (courtesy Gear Lab).

Ahmet Kahraman (AK): Gear Lab was established 30 years ago by Professor Donald Houser as a consortium of a few companies. Over the years it grew exponentially, reaching the current membership of nearly 60 companies from automotive, aerospace, off-highway vehicle and industrial gearbox sectors. The original focus of Gear Lab under the name of Gear Dynamics and Gear Noise Research Laboratory was on gear design, dynamics and noise. With the expanding membership, other areas of gearing such as fatigue, lubrication, efficiency became to form a substantial portion of the Lab's portfolio. In order to reflect this better, name of the lab was changed in 2006 to Gear and

continued

Power Transmission Research Laboratory. At the same time, the University received a generous gift from the Gleason Family Foundation, in return naming the facilities of Gear Lab as 'Gleason Gear and Power Transmission Research Laboratories.' Most recently, Pratt & Whitney initiated an extensive collaboration with Gear Lab to form The Center of Excellence in Gearbox Technology at Ohio State.

GT: Are Gear Lab participants primarily OSU grads?

AK: The researchers in Gear Lab consist of full-time research engineers, graduate research associates (Ph.D. and M.S. students) and undergraduate research assistants. Our graduate research associates come from Ohio State as well as other prominent U.S. and foreign universities.

GT: What funding—if any—do you receive from gear-related industries?

AK: Gear Lab uses two funding mechanisms. One mechanism consists of Gear Research Consortium fund where each member company pays a certain yearly membership fee. With this, member companies gain access to Gear Lab research supported by the Consortium as well as Gear Lab gear design and analysis software. The second mechanism is through individual grants from companies and government agencies. The findings from these research projects are shared only with the sponsor. In addition, Pratt & Whitney Center of Excellence in Gearbox Technology is funded by a block grant by Pratt & Whitney. These various forms of fund support about 20 graduate researchers, 10 undergraduate researchers, five full-time research staff members as well as experimental activities of Gear Lab.

GT: What are the enrollment requirements for the Gear Lab? Are there scholarships/grants and if so who funds them?

AK: The graduate research assistants must meet the requirements of the Graduate School of the Ohio State University.

GT: Has OSU ever considered beginning an undergraduate program in gear training? What would be the challenge in doing so?

AK: Undergraduate curriculum in the Department of the Mechanical and Aerospace Engineering is set up in such a way that such an undergrad specialization on gears is not possible. Students learn about the basics of gear design and geometry in the machine elements courses and specialize further in certain areas of gearing during their graduate studies if they choose to work at Gear Lab.

GT: To what extent are undergrads involved in the Gear Lab? What sort of course work credit do they receive?

AK: Gear Lab supports a number of undergraduate research assistants with the intent to expose them to gear research early in their education. Many of these undergraduate assistants are later recruited to become graduate researchers in the Lab. Students do not receive course credit for their work at Gear Lab.

GT: Regarding the extremely popular and necessary Gear Dynamics/Gear Noise course, who typically attends? Is there sponsorship involved from businesses?

AK: Attendees form by a wide spectrum that includes drivetrain/powertrain engineers to gear designers to NVH specialists and supervisors. Since the conception of the basic course in 1978, more than 1,650 engineers attended these courses globally. Each attendee pays a registration fee. The Gear Research Consortium members receive discounts.

GT: What kind of internships exists through Gear Lab?

AK: There are two types. Many Gear Lab undergraduate or graduate research assistants take on summer internships at various gear and powertrain companies. Gear Lab not only encourages such internships but helps students to find such opportunities for them to gain real-life gearing experience. The other type is when students or scholars from other institutions or countries come to work with us. At any given time, we might host up to five such visiting scholars.

GT: Are Gear Lab instructors fulltime staff? Are there "guest" instructors from related industries?

AK: The research of Gear Lab is supervised by full time faculty members. Time to time, Gear Lab sponsors seminars by experts from the industry.

GT: Not to be flip, but why is a course on gear dynamics/noise needed? What challenges are still present after 30 years of teaching the course?

AK: Gear dynamics and gear noise remains to be a critical issue in gearbox and powertrain applications. Even though significant gains have been accomplished over the years through modeling tools and experimental studies, the requirements have also become more stringent. In other words, we have a moving target. In addition, efforts to optimize gears for other functional attributes, say efficiency, often result in increased noise. Therefore, design solutions that balance the durability, efficiency and noise aspect of the gear performance are becoming a must.

GT: What is the enrollment cost for the Gear Lab?

AK: Gear Lab is not a gear school. It is a research group dedicated to gear and power transmission applications. Assuming that the graduate researchers are meant by "enrollment" they are supported through a stipend and tuition waiver through the Gear Lab funds.

GT: Is there a time-definite duration—i.e., a determined curriculum for instruction? Or do enrollees "cherry pick" courses of greatest interest to them?

AK: The Gear Lab researchers choose courses based on their specialization and research interest including math and statistics courses.

GT: Where do successful Gear Lab graduates typically go from there? How many would you say go into teaching?

AK: A great majority of our graduates are hired by companies to work on gear and transmission- related assignments. Over the years, more than 150 alumni of Gear Lab with M.S. or Ph.D. degrees went on to work for the gear industry.

GT: Do you have any particular outreach or recruitment programs in place for the Gear Lab?

AK: Gear Lab continuously recruits researchers from U.S. universities as well as prominent schools from the Far East, India and Middle East.

GT: How do you think attracting young people to the gear industry can best be done?

AK: Best way is to provide them with interesting and challenging gear problems to show them (i) gears are indeed highly engineered, precision components, (ii) they are criti-

cal to almost every sector, and (iii) a specialization in gears is a smart thing to do.

Brigham Young University (BYU)

While BYU does not offer core programs in gear instruction, it boasts a history of machine design, manufacturing technology and research. It has established itself particularly in student-led automotive-related competitions around the world addressing heat treating, metallurgy, NC machining, assembly tolerances, etc. Professor and AGMA member Kenneth Chase—and a presenter at last year's FTM—provided the following information on what his school and department are doing to advance drivetrain and other gear-related areas of learning.

Undergraduate/Gear-Related Topics

Machine Design—"General machine design, which includes the analysis and design of gears, shafts and bearings, subjected to static, dynamic and fatigue loading, and sized, based on the AGMA standards. Gearboxes and transmissions, both manual and automatic, are also treated.

"The school also houses an extensive collection of failure specimens, including gears, bearings, shafts, etc. Included, is the J. O. Almen Collection, which is the lifetime collection of the vice president of engineering at General Motors. It includes documentation and photos, plus copies of his many publications."

Design Competitions

"BYU also has several ongoing design competitions each year, in which teams of students, from more than one department, participate in major design projects involving gear and transmission design. They not only design, but also build and assemble the components, gaining experience with heat treating, metallurgy, NC (numerical control) machining, assembly tolerances, etc. Then, they compete with their vehicle at a national or international event. BYU has a long track record (pardon the pun) of successes in these competitions."

Mini-Baja off-road vehicle. (eight years)—More first-through-fifth-place awards than any other university during the eight years of participation.

Formula SAE race car. (three years)

Formula Hybrid race car. (three years)–Innovation award (2008); 4th place overall (2009)

PACE Collaborative Design (4 years)–Automotive design project.

Two electric passenger vehicles. One project, an automobile donated by Ford, converted to all electric, and driven for three years as a commuter car. Another similar project as well.

Manufacturing Technology Competitions

Electric streamliner (six years)–going for the world record for its class on the Utah Salt Flats.

Research

"The College of Engineering & Technology has pursued several research projects involving gearing and other automotive applications. A current ongoing effort involves the development of Positively Engaged Infinitely Variable (PEIVT) and Continuously Variable Transmissions (CVT)."

Commercial Training

And last, but in no way least, we talked to two leading U.S. and international manufacturers of gear machinery—Gleason Corporation and Koepfer America LLC. While they don't confer degrees, they definitely do their part in straightening out the learning curve when it comes to operating the highly sophisticated machinery they build and sell. Sure, it's in their own best interests, but the fact remains that such teaching/learning modules are extremely important to the gear industry workforce and the customers that buy those machines. We talked with Gleason director of marketing Al Finegan and Koepfer America president Dennis Gimpert.

Gleason

GT: Can you tell me when Gleason began offering gear training?

Al Finegan, Gleason Corp. director of marketing.

Al Finegan (AF): Gleason has always viewed training as an integral part of our (total) solutions.We view training as more than just gear theory and calculations, but also training in machine set-up, operation and maintenance, as well as in the use of cutting tools, workholding and other products. I do not know when Gleason started offering training courses to customers, but it was deeply entrenched in the company when I started my career some 40 years ago, and I suspect it has been an integral part of the business at some level since the beginning of the company. When we made acquisitions in the 1995–2005 period, those companies also had well-established customer training programs.

GT: Would you say it was customer-driven or sales/marketing-driven? Or perhaps both?

AF: Gear manufacturing is a special form of metalworking technology and one that requires special knowledge and skills. Our offerings are not complete without the training to make our customers successful.

GT: Can you guestimate the cost to Gleason for providing this training?

AF: Since training is part of our total solution, I would not venture any kind of estimate of its cost. Similarly, I would not estimate its benefit to the market and to Gleason's business, but we know it is significant.

GT: Would you consider it as just another "cost of doing business"?

AF: As a total gear solutions provider, we take a different view. Training is not a cost of doing business but an investment in our customers; the more they know, the more successful they will be and the better for equipment suppliers like Gleason.

GT: Which area/areas of the training you provide would you say is most requested?

AF: Gear basics, gear theory and operator training are most popular. We offer training through webinars, publications and as direct training at our facilities or our customers' facilities.

GT: Are there any particular differences/challenges in providing training for your foreign customers, like in India

continued

and China?

AF: Gleason offers training in all regions of the world. Location itself is not a factor, but there are language, cultural and other issues that must be considered. Since Gleason has a presence in more than 30 countries around the world, we have the ability to address those issues and provide effective training.

GT: How does the training program respond in adapting new technologies?

AF: While the fundamentals of design and manufacture of gears remain pretty much the same, the software and the hardware evolve at an ever-accelerating rate. Course content must change continuously to keep pace with technological change and with changes in market demographics. Some customers have experienced declines in their overall gear knowledge.

GT: Are there any impending/future changes in store for the training program that you can share at this time?

AF: Nothing specific except again to continue to respond to changes in technology and in the market. For example, we anticipate continued growth in internet-based training.

(I might add) that many of the prior questions seemed to imply that training is something we can choose to offer or not. Again, Gleason believes that training is an integral component of our role as a "full service" gear solutions provider, and not offering training is not a consideration.

GT: Finally, and admittedly a bit off-topic, how does a major player like Gleason strike that delicate balance in providing gear and machinery training in countries like China—especially China—in that the training (and technology) provided affords Chinese companies the eventual wherewithal to begin gobbling up market share there at a company like Gleason's expense?

AF: Interesting question. The alternative is to offer an incomplete solution that guarantees our customers' failure as a gear producer and eventually our own as a supplier. We believe that countries like China and others will naturally evolve to a level of manufacturing capability and technology, with or without Gleason. Our mission is to stay a level ahead of competition, regardless of it source.

Koepfer America LLC

GT: Can you tell me when Koepfer began offering gear training?

Dennis Gimpert (DG): Koepfer America, LLC offered our first formal gear school in 1990, 'Fundamentals of Parallel Axis Gear Manufacturing'. This class has been offered annually with nearly 1,000 students having attended. We also offer regional training as focused events on specific current topics or needs.

Koepfer America LLC president Dennis Gimpert (courtesy Koepfer America).

GT: Would you say it was customer-driven or sales/marketing driven? Or both?

DG: Our training is clearly both customer and sales driven. Training is offered to fulfill part of our mission statement. 'Koepfer America provides industry-leading service and support in an expedient, ethical manner. Our goal is to provide the customer with the ultimate value.

GT: Can you guestimate the cost to Koepfer for providing this training?

DG: Priceless (small joke).

GT: Would you consider it as just another "cost" of doing business?

DG: Today we do not look at our training as a 'cost' but also as an opportunity.

GT: Which area/areas of training you provide would you say is most requested?

DG: Four areas are in demand. First, the fundamentals for new manufacturing engineers and other personnel that are entering the industry. Second, information regarding current technology and gear processing techniques. Third, operational training on machine setup and operation, fixtures, gear blanks, inspection, etc. to maximize the efficiency of the gear manufacturing systems. Fourth, troubleshooting of gear manufacturing problems.

GT: Are there any particular differences/challenges in providing training for your foreign customers in India and China?

AF: This question does not apply to Koepfer America, LLC as we are responsible for only North American operations. It is a question for our parent company, Koepfer, Germany that uses their EMAG group to provide local customer training and support. As our gear industry has become more global a more important role has been taken by the AGMA. I was personally involved with the original formation of the Education Council of the AGMA and helped promote the concepts of web-based training to provide education opportunities globally.

GT: How does the training program respond in adapting new technologies?

DG: Each year we formally review our training program. We utilize feedback from the program attendees as part of this review. We also review current machines, tools and processes and modify our program based upon these trends.

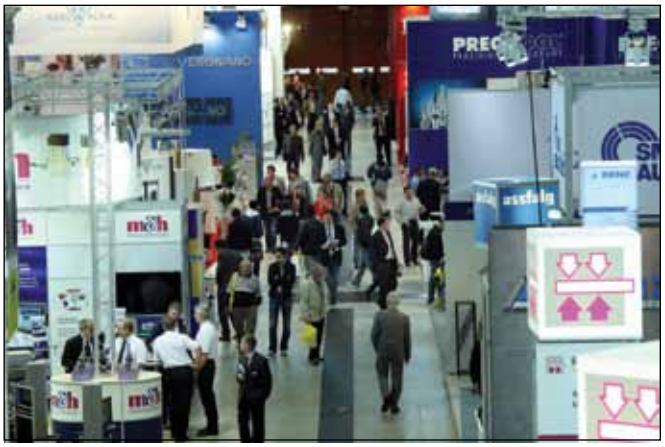
GT: How would you assess or quantify the importance of the value-added component the training provides to the bottom line?

DG: It is difficult to quantify the total value of training as there are many benefits. It can provide basic necessary knowledge for the employee to do his job. It may be a requirement of an ISO-based organization to provide annual training to each employee. It is a big motivational factor that the company is willing to invest in the person. What is the value of 'one' good idea in a company?

Ed.'s Note: *Looking for specifics on the programs and learning opportunities discussed here? Go to the Jan/Feb online issue of* Gear Technology *(*www. geartechnology. com/issues/0111*/) where you'll find comprehensive contact information regarding degree programs, associate degrees, schedules, tuition and fees (where applicable) and locations.*

AMB

POINTS TOWARD RECOVERY



With 86,202 visitors, The International Exhibition for Metal Working (AMB 2010) in Stuttgart, Germany, managed to slightly exceed attendance from the 2008 show (85,143). The metalworking industry celebrated its comeback with visitors from more than 80 countries. In addition, AMB 2010 set a new record with 1,346 exhibitors (2008: 1,306).

The focal points of AMB 2010 were metal cutting and metal removing process machine tools and precision tools. Dr. Wilfried Schäfer, managing director of the Association of German Machine Tool Manufacturers (VDW) said, "In our opinion, AMB 2010 was a great success. Visitors demonstrated a high level of expertise and they were very keen to make investments."

Attendance at AMB 2010 was also worthwhile for manufacturers of precision tools. "Right from the beginning, AMB 2010 was very positive in every respect. The exhibition halls were full every day just 15 minutes after the exhibition opened. Our members were all totally satisfied," said Dr. Wolfgang Sengebusch, managing director of the Precision Tools Association in the German Engineering Federation (VDMA).

"We were extremely busy and welcomed far more visitors to our stand than at AMB 2008, including much larger numbers of foreign visitors. It was noticeable that companies have again relaxed their travel budgets. After three days we had sold more machines than over the entire duration of AMB 2008," said Marcus Kurringer, global head of marketing at Gebr. Heller Maschinenfabrik GmbH in Nürtingen.

Dr. Rüdiger Kapitza, chairman of the board of management of Gildemeister AG, added, "AMB 2010 proved to be very successful for our company and also showed that the demand for machine tools in Germany is picking up again. We achieved excellent results at this important German industry exhibition by selling 260 machines."

Seventy-five percent of visitors came from industry, primarily from the mechanical engineering sector, metalworking and metal processing companies, the automobile industry and tool-making firms. However, the visitors also included employees from metal construction enterprises; component suppliers; the iron, steel and metal goods industry; precision engineering/optics; the electrical engineering and electronics industry; medical technology; commission working companies and the aerospace industry.

Forty-one percent of visitors said that they worked in the area of production/manufacturing. Company management, development and design each accounted for 11 percent of visitors. Ten percent of visitors came from planning and production planning, respectively. Visitors were mainly interested in milling machines, lathes and automatic lathes, machining tools/chucking tools and CAD/CAM/CAE. Exhibitors were therefore extremely satisfied with the expertise of visitors and were expecting good business after the event.

Alain Reynvolet, sales director, Haas Automation Europe, Zaventem, Belgium said, "We had good contacts with trade visitors from Germany, but also from Eastern Europe, Russia, Switzerland, Pakistan, Malaysia and Egypt. Our customers are suppliers from the automobile and aerospace industries. In our opinion, AMB is the barometer for the German market. Following our discussions with customers at AMB, we are confident that the economy is recovering again."

February 15–17—Gear Materials: Selection, Metallurgy, Heat Treatment and Quality Control. Clearwater, FL. Discover how both the gear design engineer and the gear metallurgist can better grasp their related, critical roles in the world of gear processing, heat treatment and inspection. The gear design engineer is responsible for the initial selection of material and heat treatment, but the finalization of both material and thermal processing must be a joint effort. This seminar shows how the gear design engineer first approaches the problem of material selection and heat treatment technology, as influenced by the performance and life requirements of the gear set. It also shows how the gear metallurgist can participate in and thereby optimize the finalized gear manufacturing process. Interspersed in the course are examples of gear-related problems, failures and improved processing procedures. Analyses and comments on a number of relevant failures are given. For more information, contact Jan Alfieri at *alfieri@agma.org*.

March 1–3—Expo Manufactura. 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. For more information, visit *www.expomanufactura.com.mx*.

March 1–6—TIMTOS. Taipei, Taiwan. The 15th Taiwan International Machine Tool Show will be held at the TWTC Taipei World Trade Center (TWTC) Exhibitions Hall 1, 2, 3 and the Nangang Exhibition Center. Taiwan is currently the world's fourth largest manufacturer of machine tools. This year's exhibition is centered on the procurement of top-quality "Made in Taiwan" machine tools and total solutions for the machine industry. The event is estimated to provide spaces and opportunities for more than 910 exhibitors and 44,500 visitors. For more information, visit *www.timtos.com*.

March 8–11—TECMA 2011. Mexico City. Since 1991, TECMA specializes in machine tool technology, related equipment and peripherals. The event is organized by the Mexican Association of Machinery Distributors (AMDM), founded in 1943, to bring together those dedicated to machinery distribution and increase the effectiveness and quality of machine tool services. For more information, visit *www.tecma.org.mx*.

March 15–18—Gear Dynamics and Gear Noise Course. The Ohio State University. The Gear Dynamics and Gear Noise Short Course has been offered for more than 30 years and is considered extremely valuable for gear designers and noise specialists who encounter gear noise and transmission design problems. Attendees will learn how to design gears to minimize the major excitations of gear noise: transmission error, dynamic friction forces and shuttling forces. Fundamentals of gear noise generation and gear noise measurement will be covered along with topics on gear rattle, transmission dynamics and housing acoustics. This course includes extensive demonstrations of specialized gear analysis software in addition to the demonstrations of many Ohio State gear test rigs. A unique feature of the course is the interactive workshop session that invites attendees to discuss their specific gear and transmission noise concerns. The roundtable discussions are intended to foster interactive problem solving on a variety of topics. Cost is $1,950. For more information, contact Jonny Harianto at *harianto.1@osu.edu*.

March 21–24—ProMAT 2011. McCormick Place, Chicago. Find all the material handling and logistics solutions you need to make your supply chain work more profitably. Highlights include: more than 700 exhibits showcasing the latest equipment and technology solutions to help you streamline your operations and improve visibility, maximize efficiency and flexibility, cut costs, speed time to market and reduce your carbon footprint. Registration for ProMAT will also give attendees admittance into Automate 2011. For more information, visit *www.promatshow.com*.

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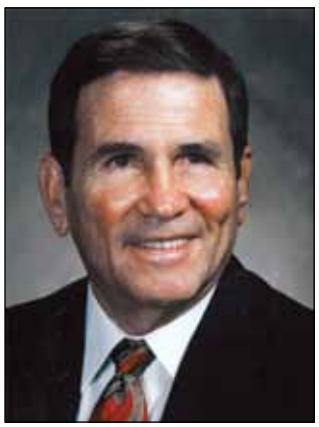
In Memoriam

AGMA Chairman Edwin Ray Haley

1928–2010



Edwin Ray Haley.

Former AGMA chairman Edwin Ray Haley passed away on November 3, 2010 in Jackson, Mississippi. Haley was the AGMA chairman of the board in 1993–1994 and an active member of the AGMA Helical Enclosed Drives Marine Units Committee for more than 20 years. Haley started his career after college working with diesel engine companies. The formal start to his long gear industry career was in 1961, taking a job with Western Gear Corporation.

Haley formed Marine Gears, Inc. in 1973, and later expanded his business by forming Haley Clutch and Coupling and Marine Gears International. The company has been an AGMA member since 1976. Haley was well known in the marine gearing sector and was instrumental in the development of standards for this area of the gearing industry. He was the committee's vice-chairman in 1983 and moved to chair the committee in 1984.

Haley was recognized for his committee service and contributions in 1988 when he received the Association's TDEC (Technical Division Executive Committee) Award. When he was AGMA's chairman he spearheaded a technical meeting between AGMA and the gearing industry in Mexico. AGMA and the gearing industry benefited from his integrity, his stamina and his intelligent contributions to the science of the industry and management of the Association.

"Ray was instrumental in getting the Association to focus more on the international market," says Joe Franklin, president, AGMA. "He proposed and led the board and membership in changing AGMA's bylaws to expand the definition of full member to include manufacturers in Mexico and Canada in addition to the United States. He helped organize a successful technical meeting in Mexico City attended by several AGMA board members as well as a number of gear manufacturers in and around Mexico City."

Franklin adds, "The strongest impression Ray left with me was his high standards and his unbending integrity. He was a football player in college and when there was a difficult matter to decide, he always set the tone when he said, 'we are going to play this one right down the middle' meaning no spin, no politics, no favorites. He and the board looked at the facts and made decisions on what was in the best interest of the association and the industry."

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In Memoriam

Pamela L. Spoden

1949–2010

Pamela L. Spoden.

Pamela L. Spoden, 61, Loves Park, IL, died Sunday December 12, 2010 at SwedishAmerican Hospital following a brief battle with cancer. She was born August 22, 1949 in Rockford, IL to Virginia (Splinter) and Gilbert Spoden, graduating from Boylan Catholic High School in 1967.

In the early 1990s, Spoden began her career in the gear industry working as the corporate travel coordinator for

American Pfauter and Pfauter-Maag Cutting Tools. She worked for Gleason Cutting Tools for a short time after Gleason Corp. acquired Pfauter-Maag, but then followed her boss David Goodfellow to Meritage in 2001 and then to SU America and Star SU in 2003.

Known for a fiery disposition that matched her red hair and a keen sense of humor, Spoden was widely respected for her knowledge of the travel and hotel industries. She often set up entertainment schedules and worked in exhibit booths at IMTS and Gear Expo, booking blocks of rooms and countless dinner reservations, as well as keeping track of booth staff. She will be sorely missed.

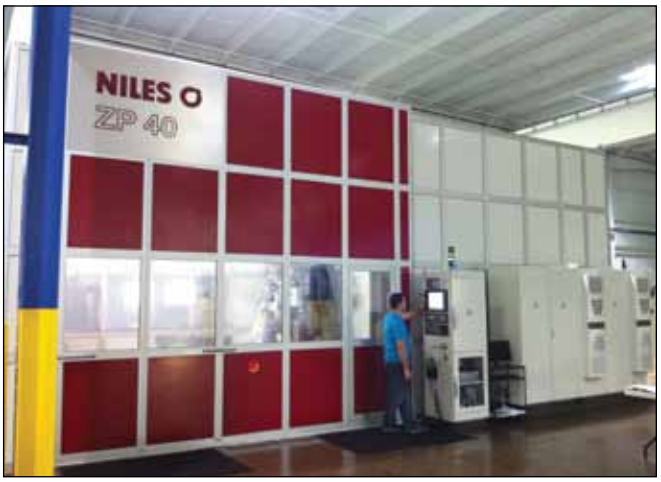
Spoden was a member of St. Bridget Catholic Church and an avid Chicago Bears and Cubs fan. Survivors include: mother Virginia Spoden; sisters Nancy (Chuck) Beck and Beth (Carl) Seaberg; brother Mark (Erin) Spoden; nephews Mark Beck, Chris Beck, Greg (Carrie) Beck, Nick Spoden and Sean Spoden; niece Tia Seaberg and special great-nieces Kennedy and Kysa Beck; aunts Joan Rafferty, Marg Spoden and Eileen Bracke; as well as numerous cousins and friends.

ITAMCO

CONTINUES TECHNOLOGY, CAPABILITY AND INFRASTRUCTURE INITIATIVE

Indiana Tool and Manufacturing Companies (ITAMCO) recently commissioned a new Niles-Kapp ZP 40 gear grinder after realizing a market need for larger and higher precision gearing. Included in the initiative is a 33,000 square foot climate controlled gear grinding area, with 40 ton lifting capacity, the installation of the ZP 40 gear grinder, distortion control technology for carburizing and hardening of ring gears, near net forming technology and software development.

The ZP 40 grinder, capable of grinding 4,000 mm diameter and 1,750 mm face width gears, employs precision finishing of large internal and external gearing using both plated CBN and dressable vitrified grinding wheels. Features include vibration dampening, hydrostatic guideways, a direct drive rotary table, stock dividing, eccentricity software and onboard inspection. The hydrostatic guideways ensure high accuracy over the lifetime of the machine, high overload



ITAMCO recently purchased a Niles-Kapp ZP 40 grinder (courtesy of ITAMCO).

The ZP 40 is capable of grinding 4,000 mm diameter and 1,750 mm face width gears.

capacity and extremely accurate and precise movement of the axes within a few microns, according to the company. This is achieved by maintaining a high thermal stability through temperature-controlled hydrostatic oil. Thermal stability is a critical feature necessary to achieving high accuracy performance, especially with a tall extended column like ITAMCO purchased with the ZP 40.

The machine features profile grinding with five-axis interpolation; an advantage when dealing with complicated tooth profile and lead modifications. Niles-Kapp's stock dividing feature performs a multi-point touch probe analysis of every tooth and makes program adjustments prior to grinding, yielding substantial cycle time savings. The eccentricity compensation software assists in faster setups by reducing the time required to indicate large diameter heavy parts. The onboard inspection feature allows for gear inspection immediately after the gear is ground for quick analysis and verification of the grinding results.

continued

ITAMCO also recently purchased a Zeiss MMZB CMM that enables offline inspection of the gear to confirm the previous data from the ZP 40.

All of these features are focused toward producing large gears of the highest quality. When making the decision to purchase the grinder, the team from Niles-Kapp was confident in the machines' ability to produce gearing to the quality level of DIN 1 or ANSI/AGMA A2 per the AGMA 2015-1-A01 standard (AGMA class Q15 under the old AGMA 2000-A88 standard). ITAMCO has not been disappointed by the results.

The ZP 40 has been installed in ITAMCO's new 33,000 square foot grinding area. This area is located within their Argos, Indiana facility which has a total of 385,000 square feet. ITAMCO felt that their Argos plant best suited this expansion seeing it has over 125,000 square feet of 60 foot high bay areas with up to 80 ton lifting capability. These areas are suitable for large gear drive and complex machine assembly. The ZP 40 is the first of eight CNC gear grinding machines being installed in the new grinding area.

While the economy was stalling in 2008, ITAMCO felt the timing was right to begin these initiatives, which would help to further enhance their ability to work with their customers on complex projects. According David Neidig, vice president of business development, "The company has always operated with the philosophy of investing during depressed markets in preparation of the next upturn."

ITAMCO was started in 1955 and has provided contract manufacturing services for OEMs since its inception. The company services nearly all heavy duty markets from its two ISO 9001:2008 certified facilities in northern Indiana. In an effort to add more value to its customers, ITAMCO has diversified into many areas of manufacturing integration. Joel Neidig, systems engineer at ITAMCO recently gave one of the keynote addresses at the 2010 Autodesk University in Las Vegas. Neidig spoke regarding ITAMCO's beta testing of the *Autodesk Factory Suite*, which ITAMCO used to simulate the construction of the foundation and installation process of the new ZP 40 grinder.

MAG

EXPANDS MACHINE TOOL RANGE

MAG IAS, LLC, a machine tool and factory automation company, is developing a range of larger and more versatile machine tools which will be added to the product lines already produced at its facility in Fond du Lac, Wisconsin. MAG has secured contracts and is in production of a new family of vertical turning centers (VTCs) with table sizes from five to eight meters and facing capacity up to nine meters in diameter. These dual-column machines can handle workpiece loads up to 250,000 kg and feature fixed or adjustable rail styles. In addition, a new model of the large, ram-type horizontal boring machine (HBM) family is under construction in Fond du Lac. The company also recently introduced a new-concept machining system for high-volume production of wind turbine hubs.

"These machines will bring new dimensions in large part production to MAG customers around the world and will be joined by many additional variations in the coming months," says Bill Horwarth, president MAG Americas. "I'm very pleased that we are able to continue aggressive investments in expanding our product portfolio and range of manufacturing solutions for these important industries. We are confident that our business will continue to improve and delighted that customers have put their trust in us with significant new orders from all global regions, including the United States, Europe, Middle East, India and China."

MAG's new machines offer new multi-functional features and green design elements focused on the lowest total

continued

cost of ownership. The company recently demonstrated at the IMTS in Chicago and AMB show in Stuttgart turning machines with grinding and gear hobbing capability, along with mill-turn and turn-mill machines, honing capability and cryogenic machining. MAG designs also make extensive use of environmentally friendly features, including minimal hydraulics and oil systems, reduced need for chillers and ancillary equipment, as well as energy monitoring and conservation capabilities.

Ground up, modular designs allow for economical customization of these machines along with the industry's fastest build and delivery, a hallmark of the Fond du Lac plant's operation, according to Horwarth. This allows manufacturers of extremely large workpieces to have a machine configured to match their exact needs using families of pre-engineered and optimized components such as columns, tables, heads, tool changers, controls, etc. MAG Fond du Lac is currently ramping up production and will begin shipping these new machine tools during the first half of 2011.

Gleason

ESTABLISHES NEWS SALES AND SERVICE OPERATION IN BRAZIL

Gleason do Brasil
Comércio de Máquinas Ltda.

To meet the needs of gear manufacturers in the Brazilian market, Gleason Corporation has expanded its global presence with the formation of Gleason do Brasil Comércio de Máquinas Ltda. based in Sao Paulo, Brazil. Previously, Gleason's activities in Brazil were conducted through its representative "ARBUS" Armando Busseti Máquinas Ltda. While Gleason and ARBUS enjoyed a successful relationship for many years, both companies have decided it is in their mutual best interests to end their relationship. This now creates the opportunity for Gleason to more directly and actively serve the Brazilian market. Both Gleason and ARBUS are committed to a smooth transition of sales and service responsibilities to Gleason do Brasil, and Gleason

thanks ARBUS for its many years of dedicated service.

John J. Perrotti, president and CEO, commented, "Experienced expertise in this market has been retained for the sales and service of all Gleason products and technologies, allowing us to continue seamlessly in the support of customer needs. We are enthusiastic about the new organization in Brazil and look forward to serving our loyal customers in this key market."

Ronson

APPOINTED SOLE AUSTRALIAN AGENT FOR KHK

From left to right: Naoji Kohara, general manager KHK Co. Ltd. Gordon New, general manager at Ronson Gears and Toshi Kohara, president Kohara Gear Industry Co., Ltd. during New's recent visit to Japan (courtesy of Ronson).

Ronson Gears recently announced it has been appointed sole Australian agent for KHK Co. Japan. This partnership will see Ronson Gears increase its 250 stock gear configurations to 7,000, bringing customers faster delivery times and more competitively priced gears, while maintaining its core services and long established standards of quality. Gordon New, managing director at Ronson, said the new relationship with KHK means Ronson Gears' customers can access a much wider range of gears at much faster turnaround times than previously possible.

"Customers will be able to order the more popular line items for next day delivery, with virtually the full range

continued

being accessible for delivery within a week depending on the size of the order," New said. "At the same time, all our traditional custom made gear cutting services will continue as before. We are always looking at ways to improve our offering and we see the new partnership as a significant step in Ronson Gears' growth."

KHK's export manager, Naoji Kohara, says the arrangement with Ronson Gears is very exciting for his company because it expands KHK's market into a key Asia Pacific region and gives Australian consumers access to a vast range of gears at much faster turn-around times. "Some of the stock items now available to customers include ground spurs and helicals, spiral bevel gears, straight cut mitre and bevel gears, ground racks, helical racks, worms and wheels, bevel gear boxes, plastic gears," Kohara said. "We are looking forward to a long and successful association with Ronson Gears."

CORRECTION

In the November/December of *Gear Technology*, the name of AGMA Technical Editor Amy Lane was misspelled.

Gear Technology regrets the error.

—The Editors

Sandvik Coromant

NAMES VERKAMP DIRECTOR, BUSINESS SERVICES


Mike Verkamp

Sandvik Coromant recently announced that Mike Verkamp has been named the company's new director, business services. In this position, Verkamp will track manufacturers' changing needs for services and establish processes, projects and programs that address these needs. "The challenges facing today's manufacturers are constantly evolving and Sandvik Coromant works constantly to address them," says John Israelsson, president of Sandvik Coromant USA. "As director, business services, Mike Verkamp will be applying his expertise and years of experience to better understanding customer needs and creating the programs that meet them."

Verkamp earned a bachelor's degree in industrial management from Purdue University and an MBA from Indiana University. He has been a part of the Sandvik Coromant team for 13 years and held a variety of positions, the most recent of which was director of sales.

Erasteel

INCREASES PRICES ON HSS AND PM STEEL GRADES IN NORTH AMERICA

Erasteel Inc. recently announced a five-percent price raise on all conventional high-speed steel and ASP grades in North America, effective immediately for new inquiries and orders, and effective January 1, 2011 for deliveries of existing orders. All raw material surcharges will remain in effect. The price adjustment is intended to help offset increasing manufacturing costs related to steeply rising production demand and to permit Erasteel to continue to offer the full range of products through their North American distribution system.

Moventas

EXPANDS OPERATIONS IN CHINA

Moventas recently announced it is expanding the company's operations closer to customers. Western customers operating in China, as well as Chinese customers, have long wished for the company to start local manufacturing of industrial gears in China. The Asia Pacific area is a growing market for the industrial gears business. The Suzhou unit, presently a service center, will start manufacturing components and industrial gears and, when needed, customer-specific volume products, all fulfilling Western quality requirements. During 2011, the Suzhou unit will recruit 40–50 new

continued

employees in addition to the current 20 on staff. The recruitment has no effect on employment in Finland.

"Our industrial gears division grows as demand is recovering, hence the Karkkila factory that serves our Western clientele is also currently recruiting," says Moventas CEO & president Jukka Jäämaa.

Manufacturing operations in Suzhou will kick off in the summer of 2011.

Elecon

ACQUIRES BENZLERS-RADICON GROUP

Elecon Engineering Company Limited, a material handling, industrial gears and transmission products manufacturer in India, recently announced the acquisition of the Benzlers-Radicon Group (BR Group). This acquisition will now strengthen Elecon's product development and engineering capabilities and widen its customer base in European, North American and Scandinavian countries. Two of Elecon's group companies have combined to make the acquisition—i.e., Elecon Engineering Co. Ltd. and Power Build Limited (PBL) wherein Elecon Engineering has acquired the European, North American & Swedish business and PBL has acquired the Asian business.

The BR Group is headquartered in the U.K. and based out of primary sites in the U.K., Sweden and Thailand, providing a gateway for the Elecon group to enter the European and Asian markets. In addition, the BR Group also has a presence in the United States through the David Brown Group subsidiary, Cone Drive. With this acquisition Elecon will get a platform to grow its exports to a larger international base.

"This is our first international acquisition and yet another milestone in our company's long-term growth strategy. The combination of strong brands, clear growth plans and a world class supply chain will enhance compelling value-added growth potential for Elecon. The BR Group's business complements our product portfolio and will strengthen our presence in the global market," says Prayasvin Patel, chairman and managing director, Elecon Engineering Group.

Wenzel/Xspect Solutions

RETROFITS CMMS

Wenzel/Xspect Solutions has one of the largest used CMM machine shops in North America for rebuilding and remanufacturing all makes of CMMs. Bryn Edwards, vice president of aftermarket for Wenzel/Xspect Solutions, says, "The introduction of the new Renishaw PH20 5-axis touch-trigger system is providing us with new market opportunities for our aftermarket business because the PH20 has the effect of prolonging the life of many older CMMs by improving their throughput by two to three times."

Edwards explains, "Xspect Solutions' broad experience with the Renishaw REVO system ideally positions us to apply the benefits of the PH20 to all sizes of CMMs, giving the user more throughput because of increased capability and flexibility. The PH20 has a compact design and provides faster calibration, improved metrology and infinite positioning. The unique PH20 head allows measurement points to be taken using only the head and not the CMM structure. The five-axis controlled motion between features eliminates indexing time, thus improving the throughput and allowing larger parts to be measured on the same CMM by minimizing the space required around the part for head rotation. Because the PH20 automatically aligns itself with the part coordinate system, stylus collisions are avoided. The ultimate accuracy of measurement is improved with the PH20 because it uses feature orientation-based calibration and head touches."

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Whether consumed by its romantic charm or simply a casual fan of its Victorian sensibilities, there's a growing interest in all things steampunk lately. From books, television and films to music, art and design, the desire to 'reclaim technology' is getting closer and closer to mainstream pop culture. Wherever you find steampunk, you'll undoubtedly find a gear or two not far behind.

The term 'steampunk' was coined in the 1980s, by author K.W. Jeter. The term, added recently to the Oxford English Dictionary, describes an alternate reality where both the Victorian and Industrial Age coexist with modern technology. Its roots stem from the works of Jules Verne and H.G. Wells and can be found in everything from television shows (*The Wild, Wild West*), films (*Sherlock Holmes*) or graphic novels (*The League of Extraordinary Gentlemen*).

Bruce Rosenbaum, owner of Modvic, a home restoration firm in Massachusetts, didn't find steampunk—it found him.

"My wife and I launched a venture in 2007 to buy and restore old Victorian homes," Rosenbaum says. "As we began redesigning our own kitchen, we liked the idea of combining Victorian design and craftsmanship with modern functionality. People began telling us about this steampunk subculture and it opened a whole new potential audience."

According to Rosenbaum, the steampunk movement has fans from young children to adults in their 70s or 80s. Its ideals go back to a time when inventors and engineers simply wanted people to appreciate their craftsmanship—a time when mechanical components like gears, pulleys and levers were exposed in mechanical devices.

"These machines were open so you could see exactly how they worked and more importantly, you could understand them," Rosenbaum says. "Today, everything is in a black box. There's this alienation when it comes to how things work, and we no longer feel connected or appreciate how things are made. You can watch mechanical devices with gears and you start to understand the logic. That's not the case with technology today."

Rosenbaum has incorporated gears into many of his own designs and recommends artists such as Dale Mathis (*www.theartofdalemathis.com*), a sculptor who combines surrealism with mechanicalism for steampunk-inspired work.

"There's the fantastical side of steampunk, the role-playing games, the goggles, the costumes, etc., and then there's the aesthetics and design of combining Victorian elements into our modern world," Rosenbaum says. "I'm trying to build a bridge between the two, so to speak."

In addition to Modvic, Rosenbaum runs *www.steampuffin.com*, a website that offers unique architectural salvage and antique items that are inspired by the steampunk culture, many that feature gears prominently.

"Steampunk is becoming much more mainstream today for sure," Rosenbaum says. "I'm trying to bring these different worlds together to reinvigorate some of these artifacts from the past. It's thinking in larger terms, it's looking at something old and outdated and finding something useful for it in today's world. It's very liberating."

For information on sponsoring The New England Steampunk Festival at the Charles River Museum of Industry and Innovation, contact Bruce Rosenbaum at (781) 784-0250.

The Executive Desk, created by Dale Mathis, has working gears under its surface. The piece costs $27,000 and is available at *www.steampuffin.com* (all photos courtesy of Bruce Rosenbaum).

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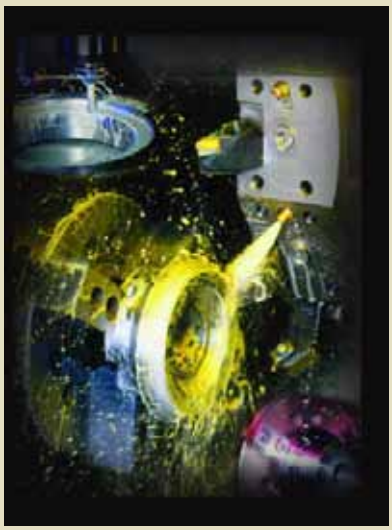

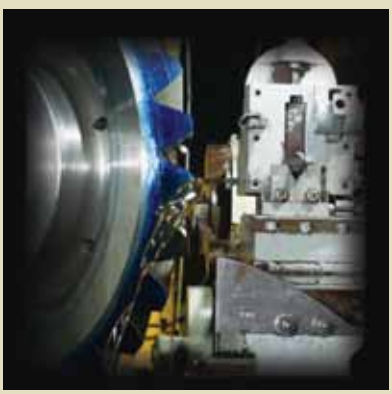

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