January/February 2012

GEAR TECHNOLOGY

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The Journal of Gear Manufacturing

Big Gears

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- *Lubrication of Open Gears*

Global Energy Outlook

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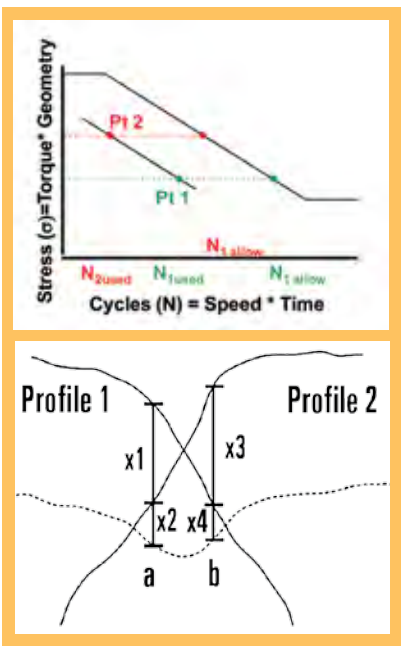

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The Difference Between Busy and Profitable

Over the past several months, many gear manufacturers and industry suppliers have been telling me how busy they are. Their backlogs are the largest in history, their sales the highest they've been in many years. They've invested in new capabilities, new machinery and people.

I continually see reports about improvements in the manufacturing economy is going. The Federal Reserve says manufacturing increased 0.9 percent in December, the biggest gain in a year. The Institute for Supply Management says factory job growth increased by 23,000 workers in December. Even the auto manufacturers seem to be back on track, with the Big Three all posting sales increases in November and December.

So why are many gear manufacturers still struggling to make a profit? In one breath they tell me how busy they are, and in the next how difficult this business has become, with suppliers and customers squeezing them for every penny, fluctuations in the prices of energy and the availability of some raw materials, the difficulty of finding qualified skilled labor, the long delivery times for machinery, cutting tools and supplies. The list goes on. But there may be a solution to at least part of the problem.

I spoke recently with an advertiser in Michigan who complained about the lack of machining capacity in the Detroit metro area. The company wants to subcontract out some work, but can't find anyone who is able and willing to take it on. They need a way to identify shops with available capacity who also have trained, experienced people to do the job.

Shortly after that conversation, I had the opportunity to visit a couple of gear manufacturing job shops—both of which count themselves among the extremely busy, with big backlogs and improving sales. But when I walked the shop floor at these companies, I saw plenty of idle machines—not just workhorse-type machines that are built for cranking out parts, but also specialized machines—the kind with unusual size, type or quality capabilities. Even these extremely busy shops could use more work.

So on one hand, I've got an advertiser who can't find subcontractors; on the other, I've got gear manufacturers—readers—who, even though they're busy, could use a little more work, especially on particular machines or in particular types and ranges. So I got myself to thinking. Shouldn't I be able to help these people? After all, I do publish "The Gear Industry's Information Source," don't I?

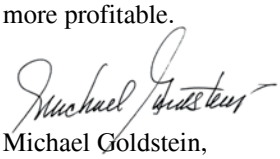
Of course, I would be remiss in my duties as publisher if I didn't point out that advertising would be a great way to let your potential customers know about your extremely large-diameter grinding capacity or your expanded range in bevel gears. It's important that you tell the marketplace about your unique capabilities. While most of you are in the gear business, each of you has a unique combination of expertise, machinery and experience.

Being good at something and not telling customers is like winking in the dark. You know what you're doing, but nobody else does. Advertising in *Gear Technology* or *Power Transmission Engineering* is a great way to get the word out.

But my role as publisher has never been solely about selling advertising. From its inception, this magazine was designed to serve the industry. Supporting the gear industry through education and communication is what we're about. So in addition to encouraging you to advertise, I'm also willing to put my money where my mouth is.

So, effective immediately, if you have excess manufacturing capacity that you'd like filled, tell me (*publisher@geartechnology.com*). Please be as specific as possible. I'll post a notice in our e-mail newsletter and advertise that capacity for free. I'll also post a notice if you want to farm out work but don't know where to turn. The newsletter goes out once a month and reaches 10,000 gear industry professionals, worldwide. These are e-mail addresses that have all been verified within the last month. Goldstein's *Gear Technology* matchmaking service is open for business.

If you get some work or find a new supplier, maybe you'll see that winking is best done in the light, not in the dark. With any luck, you won't just be busier. You'll also be more profitable.



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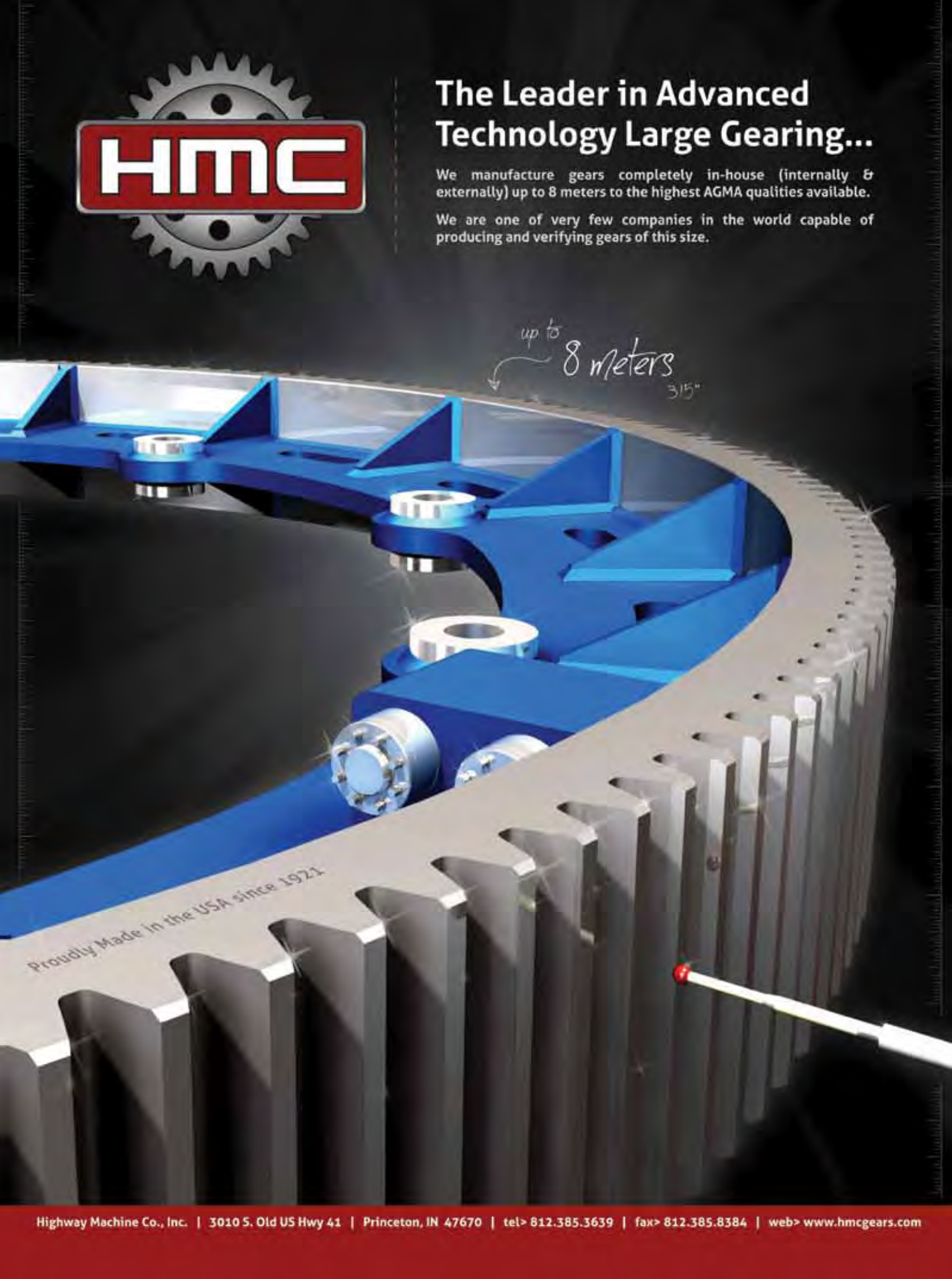
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The Global Challenge to America's Engineering and Innovation Position

John P. Walter, president and CEO, Precipart Corporation
Abby Dress, associate professor, Long Island University

"Analyses of current trends (in the U.S. science and engineering workforce)... indicate serious problems lie ahead that may threaten our long-term prosperity and national security."

—National Science Board, November 2003

That statement was published back in 2003. Since then, the global market has been somewhat of a double-edged sword for American manufacturing companies. While gear companies and other manufacturers have discovered potential new customers, they also have been engaged in a highly competitive climate and difficult global economy over the last couple of years. Perhaps, an overview of the changes and challenges is required to assess future prospects for 2012 and beyond.

Despite the fact the United States is still a leader in innovation and quality, it cannot compete with many of the emerging economies that produce goods cheaper and faster. Factor in new Southeast Asian trade deals that the U.S. administration opened in 2011, and more fuel may be added to the outsourcing fires. Until these economies become more complex and less cost effective, America will remain mostly a buyer, not a seller.

In 2011, only about $4 trillion (Ref. 11) of America's $15 trillion gross domestic product (Ref. 13) came from the manufacturing sector. Since the beginning of this current recession in 2008, 6.5 million jobs also have been erased across the services and goods sectors (Ref. 15). America needs to rebuild on its strengths to revitalize its position in the global marketplace.

Can the U.S. Maintain its Innovation Status?

In the marketplace for high-end products and ideas, the United States certainly can compete. Beyond the information technology hardware and software capability where America still excels today, the U.S. has an outstanding record in custom-designed mechanical components and devices. Many of these are gear-driven solutions, which is why gear companies in 2011 reported that they are busy and at capacity (Ref. 12). In addition to putting a man on the moon and exploring the surface of Mars, the U.S. is responsible for the development of commercial satellites, microwaves, industrial robots, light-emitting diodes, artificial hearts, robotic surgery tools and systems, cordless tools, cell phones, and many more inventions too numerous to mention.

Though these seminal products were created by U.S. engineers and scientists, many of the inventions were exploited by other countries for various reasons. Japan literally capitalized (an interesting word choice here) on the robotic technology developed by George C. Devol and Joseph

continued

F. Engelberger with their Unimation robots on which the whole industry was founded. The Japanese government invited Engelberger to lecture there in 1967, where he was welcomed by an audience of more than 700 executives and engineers (Ref. 4). American industry was slow at the time to catch on, while Japanese industry embraced robot technology. It was not until the 1980s that major companies like General Electric, Westinghouse and IBM plunged into the competitive fray already dominated by the Japanese, and then pioneered robotic neurosurgical tools in 1985 (Ref. 16).

According to the Robotic Industries Association—which represents some 265 leading robot manufacturers, suppliers and integrators—the resurgence of the automotive industry and positive growth in the food and consumer sectors show that North American robot orders jumped 41 percent in just the first half of 2011. These are the best numbers in almost six years. Currently, the United States uses 205,000-plus robots, with more than one million in place worldwide (Ref. 14).

Now the National Robotics Initiative will fund small and large programs spanning the next five years to infuse robots into educational curricula and research for new collaborative and innovative application areas. Supported to the tune of $500 million, it is the kind of program to accelerate innovation and development of the next generation of robots here in the United States. In fact, Precipart Corporation was sought out for its custom precision gear expertise on a prototype program to design the gear mechanisms for the methodical articulated movement of an artificial hand.

"According to the Robotic Industries Association—which represents some 265 leading robot manufacturers, suppliers and integrators—the resurgence of the automotive industry and positive growth in the food and consumer sectors show that North American robot orders jumped 41 percent in just the first half of 2011. These are the best numbers in almost six years."

Of course, there is no question that the United States is a standout in the aviation and aerospace industry. When the Boeing 787 Dreamliner finally completed its maiden flight in December 2009, it landed to the smiles and applause of thousands of engineers and more than 900 small subcontractors (Ref. 8) that helped create and produce it. Even though the 787

is an American success story, the contractor list also included companies from around the world. Boeing said that more than 70 percent of the 787 was outsourced, compared with 50 percent for the Airbus A350 plane (Ref. 8). Boeing considers its engineers and "highly skilled workforce a key asset to developing and delivering world-class aerospace products and services" (Ref. 2). Now that production is underway and the plane is in service, Boeing must book new orders after a three-year delay and reduce production learning curves to keep profitability flowing.

Education is a Priority

Back in 2007, President George Bush, through his Science, Technology and Innovation Office, aimed to strengthen America's competitiveness by improving math and science education and foreign language studies in high schools. He created the American Competitiveness Initiative and provided $5.7 billion initially and $136 billion over the next 10 years (Ref. 3). Funding was designated to train some 70,000 teachers for advanced placement classes in math and science. It was anticipated that 30,000 scientists and engineers would be hired to work as teachers, too. Leaders from the public and private sectors would come together with the education community to better prepare students for the 21st century. Yet the scores of U.S. youth in a global ranking continue to fall.

Educating America's youth should be a priority though, especially if the United States wants to remain competitive. For manufacturing, especially the gear industry, two large groups are needed: engineers to create and machinists to build.

Vocational schools and their respective database portals, however, promote some "sexy" career options, such as IT and technology, massage therapy, culinary and more. Machinist vocations are certainly not in neon type–even though machinist jobs are on the increase and average hourly wages can range from $15 to $25 (Ref. 10). High school counselors should be targeted as influencers to promote these craftsmen opportunities–alongside the highly touted ones in health care like nurses, physical therapists, radiologic technologists and nutritionists.

There is a dwindling pool of machinists nationally. In addition, many high schools over the last 25 years closed their shop classes and training programs as America's manu-

continued

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facturing sector shrunk. Some schools then sent students to off-site training programs to become future mechanics for machines and automobiles. The resulting trend by school guidance counselors to recommend two- and four-year college and its higher paying jobs soon may create a potential void in the manufacturing workforce.

Current machinists are graying. As they begin to retire, they may not be around for the very critical on-the-job training that newly employed machinists require. Though the U.S. economy has shifted from a manufacturing to a service provider, the aerospace and defense industries reportedly will keep demand for machinists high. Yet, according to the U.S. Department of Labor, job opportunities will be good, but the number of workers learning to be machinists will not be sufficient to fill job openings projected through 2018 (Ref. 10).

According the U.S. Department of Education, about 16 million students were enrolled nationally in career and technical education during 2006–2007, compared to 9.6 million in 1999, exceeding the percentage of population growth numbers. With government rules subsequently relaxed for financial aid to these institutions and Pell Grant expansion, the third quarter of 2011 showed those schools increased federal monies to students by a 46 percent increase over the previous year. This support helped offset tuition required for students hard-pressed since the 2008 downturn with limited resources to keep them enrolled in training programs.

"While the AGMA offers training programs, perhaps it should partner with gear companies in an effort to formalize an apprentice system that mirrors the European model. The restructuring of the trade school as it relates to machinists may be what the industry needs right now to secure prepared workers."

While the AGMA offers training programs, perhaps it should partner with gear companies in an effort to formalize an apprentice system that mirrors the European model. The restructuring of the trade school as it relates to machinists may be what the industry needs right now to secure prepared workers.

Designing Careers Still Take Off

It is not rocket science to understand that innovation also comes from applying specialized knowledge to new and different situations. From their early days of the industrial revolu-

tion when engineers were machinist-types, mechanical engineers are still in demand to develop today's technologies and create better products for manufacturability, lower cost, and across different environments. Engineering schools are becoming attractive again as career choices narrow for young Americans.

Today, the American Society of Mechanical Engineers (ASME) touts a membership of 127,000 engineers and associated members worldwide. Mechanical engineering studies have sub-categories like construction and building, energy, environmental engineering and bioengineering, in addition to manufacturing and processing, aerospace and defense, transportation and automotive. Within these areas, there are sub-specialties as well.

The National Science Foundation found that between 2000 and 2008, the total number of four-year engineering degrees awarded in the U.S. increased by about 10,000—to 69,895 with about 82 percent of them male. Women receiving graduate degrees increased in the same period to about 22.5 percent (Ref. 5).

Students still must be better equipped in math and science. A study in late 2009 indicated that U.S. colleges and universities were graduating as many scientists and engineers as ever (Ref. 7). But the study warned that many of America's top students have been lured to careers in finance and consulting since the mid-to-late 1990s, with lower-performing students entering science, technology, engineering and mathematics. Students perceive engineering careers as unstable, since economic conditions seem to dictate hire/layoff calls and, also, foreign outsourcing continues.

Some groups, including IEEE, believe that the study is not specific enough and paints too broad a picture. Its real point is that scientists, like marine biologists or particle physicists, do not create jobs—engineers do. Furthermore, according to a Duke University study, the United States currently is producing more engineers annually than India (Ref. 19).

Perhaps the ASME has helped facilitate the increased pool of engineering students. Since 1996, it has partnered with a group called FIRST, or For Inspiration and Recognition of Science and Technology, to host a major robotics competition for middle and high school students. Using ASME members from the academic and cor-

continued

"Gears remain intrinsic to mechanical engineering requirements. They are the devices that still perform the work."

porate sectors who work with students, the program exposes young people to engineering and the problem-solving in the development of high-tech robots in a real-time schedule.

Gears are Inextricably Tied to Innovation

Gears remain intrinsic to mechanical engineering requirements. They are the devices that still perform the work. The importance of gears is showcased by the Smithsonian's Department of Innovation's new logo, which sports gears as a central graphic element. The Smithsonian also integrated them in its new theme, "Gears of Innovation Turn." Gears are inextricably tied to innovation.

The United States still leads the world when it comes to monies expended for research and the number of patents produced. America's higher education is not in trouble either. It is still the world's best with innovative curricula, as evidenced by the number of world leaders who have come here to take advantage of our educational offerings. With a renewed emphasis on engineering careers, gear manufacturers must take the initiative to develop better, smaller and new designs.

The idea is that America must continue to be forward thinking and take advantage of the economic downturn to create better students, skilled machinists, talented engineers and opportunities for mechanical devices that keep the United States positioned as a leader in engineering and innovation. Competition typically has served as a catalyst in driving Americans to achieve.

"The United States still leads the world when it comes to monies expended for research and the number of patents produced. America's higher education is not in trouble either. It is still the world's best with innovative curricula, as evidenced by the number of world leaders who have come here to take advantage of our higher educational offerings. With a renewed emphasis on engineering careers, gear manufacturers must take the initiative to develop better, smaller and new designs."

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Gleason

INTRODUCES TITAN 1200H HOBBING MACHINE, EXPANDS GENESIS SERIES

Gleason has introduced the Titan 1200H hobbing machine, the first of a new series of Titan hobbers designed for larger cylindrical gears with diameters ranging from 800 mm to 6,400 mm, and modules up to 40 mm. The new Titan 1200H hobbing machine, for workpiece diameters up to 1,200 mm, features a new machine design that optimizes chip disposal for highly productive dry machining, while at the same time greatly improving operator accessibility to the work area to help reduce non-productive time for part and tool changeover. Non-productive time is further reduced through use of a fast, powerful automated ring loader, and Gleason's X-Pandisk workholding system, which automatically clamps and centers parts even as heavy as 2,000 kg. The new machine design also delivers the exceptional system stiffness, rigidity and damping characteristics required for today's most demanding productivity and quality requirements, with a combination of a composite steel machine bed and new patent-pending combination slideway/anti-friction guideway design. In addition, the Titan 1200H's new operator interface, based on the latest Siemens 840D Solution Line CNC control system, enables any machine operator to more quickly and efficiently set up and operate the machine for maximum performance. The new Titan series is also designed to help customers meet the need for greater sustainability, with the latest drive and motor technology and software capabilities to closely monitor and manage energy consumption.

Gleason's Genesis series now includes 260H and 400H vertical gear hobbing machines for the production of spur and helical gears up to 260 mm in diameter, and 400 mm in diameter, respectively, and up to 700 mm of axial travel to accommodate extra-long shafts. The new Genesis gear hobbing machines are particularly well-suited for the demands of today's dry machining environment, featuring an exceptionally clean and uncluttered work chamber and a single-piece mineral cast polymer compos-

ite base/frame with damping and thermal stability.

They are also among the most compact machines in their class, with a slim-profile design that makes it easier to both install the machines and integrate all styles of automation for cell/system application, as well as making it faster and more efficient for operators to manually load/unload parts and tooling.

Additionally, users can choose from two direct drive modular workspindle options, two different high-performance hob heads, multiple tool interfaces, quick-change workholding, and integrated rotary chamfering and deburring to greatly improve the productivity of the widest range of gear hobbing applications, whether small batch or automated high volume production.

Like all the Genesis machines, the new 260H and 400H are designed to simplify and make more efficient every operation and maintenance task. They are equipped with the Siemens 840D CNC control running the latest Gleason Windows-based software. All major service components are consolidated in Easy Access Modules to speed and simplify maintenance. Finally, both machine models are designed to help customers meet the need for greater sustainability with a host of features that greatly reduce energy consumption.

For more information:
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MC Machinery

EXPANDS MILLING LINE

MC Machinery Systems, Inc. expands its product supply chain with the new MC Milling line. The Diamond Cut general milling line is comprised of five series of vertical machining centers and drilling and tapping machines. This addition supports the company's focus on improving its products, services, and product portfolio to support U.S. manufacturers.

The MCV Series is a general purpose machining center featuring two spindle/tooling system types. The CAT-40 tooling system uses an 8,000 rpm motor and the CAT-50 tooling uses a 6,000 rpm motor. It performs well in a wide variety of applications

including fixtures, mold base, and secondary operations. The series comes with coolant-thru-spindle preparation and an M70 Mitsubishi controller. The machine can be equipped with a ZF gearbox to achieve four times the torque of a standard motor.

The DV Series is a general purpose machine, featuring a 15,000 rpm direct drive spindle and CAT-40 tooling. It can accommodate smaller cutting tools for more intricate milling work, and is a popular choice among job shops because of its wide range of applications. The series comes with coolant-thru-spindle preparation and an M70 Mitsubishi controller.

The DM Series features a 20,000 rpm HSK-A63 spindle, and a more rigid and accurate tooling system. This series excels in close-tolerance work and is suitable for applications in mold and die. The 32-position automatic tool changer provides better tool life management and boosts machine productivity. An M720 Mitsubishi controller, linear scales, and roller guideways are standard features of the DM Series.

The SV Series is built with a heavy-duty box way construction in the X, Y, and Z axes, suitable for rigidity and stability in large parts. The machine excels in maximum material removal with its ability to handle bigger tools. The machine features a 10,000 rpm spindle, CAT-50 tooling, and hand-scraped box way guides, for years of accuracy and durability. The series comes with coolant-thru-spindle preparation, an M70 Mitsubishi controller, and optional ZF gearbox for higher torque.

The TV Series of drill/tap machines feature a 24,000 rpm high-speed spindle driven by a 5 hp motor. BBT-30 dual contact tooling delivers extra rigidity and better Z depth control during operation. The fast and simple, two-second tool changes provide multi-axis machining all in one setup. A bi-directional tool magazine is driven through advanced PLC software which is achieved through the M70 Mitsubishi controller. A CAM-driven tool magazine allows rotation and accuracy and smooth motion even while large tools are loading.

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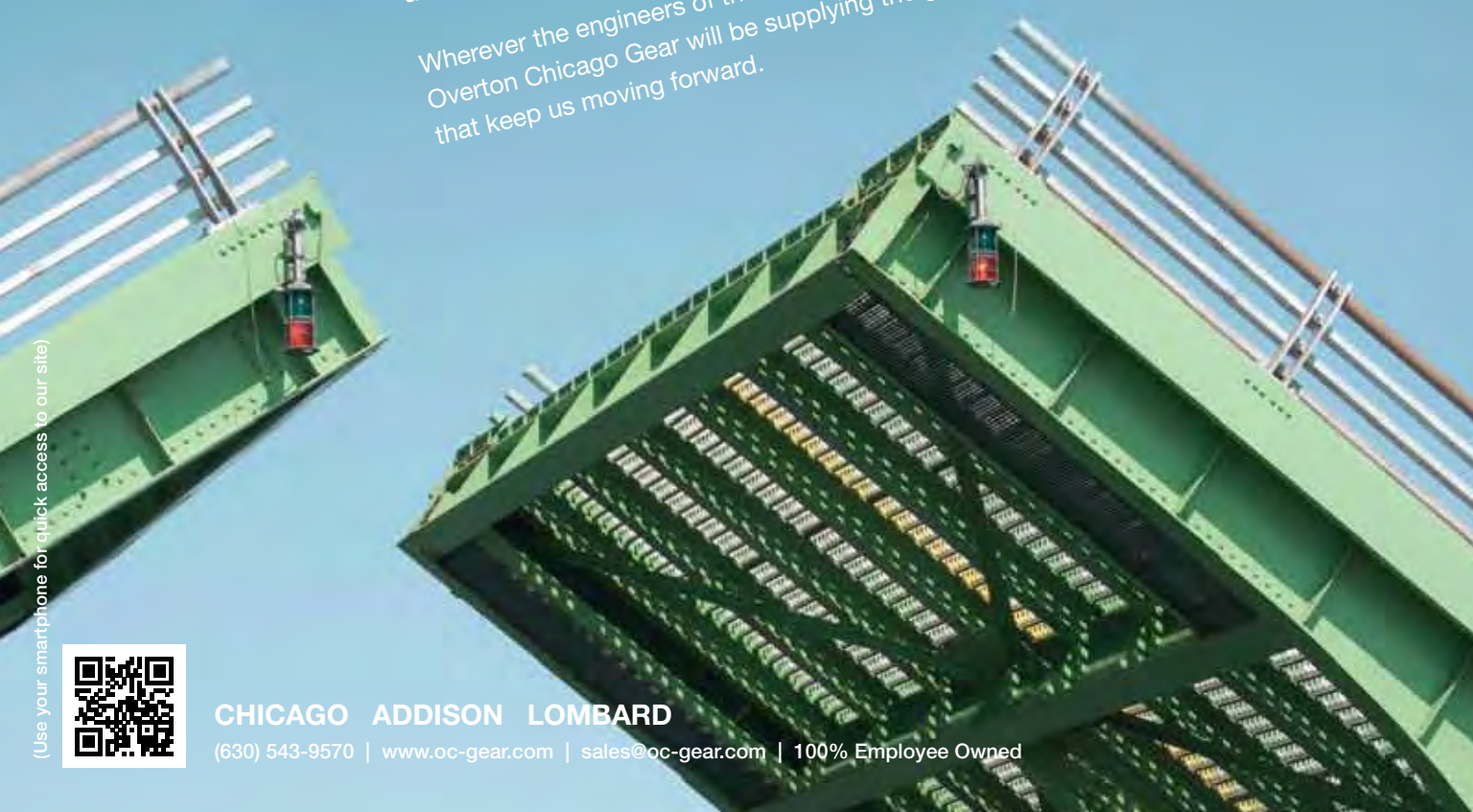

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Sandvik

INTRODUCES NEW TURNING INSERTS

March 1, 2012 sees the introduction of a new range of turning inserts from Sandvik Coromant. Spectrum turning is a minimum program that provides a simplified choice of inserts designed to efficiently machine different materials at various cutting conditions. Suitable for different small batch production, Spectrum turning grades and geometries take away the complication of having several different tools for different jobs. Whether external or internal machining, rough turning or finishing, machining continuously or with interrupted cuts, these inserts have been designed to be as versatile as possible, delivering high performance output in terms of reliability, tool life and chip control. The grades can be used for turning in steels, stainless steels, HRSA, cast irons, titanium and nonferrous materials. Two grades are being launched: GC15 combines high strength micrograin cemented carbide with a thin, PVD coating that adds edge strength and wear resistance. GC30 has high bulk toughness with a gradient cemented carbide substrate and a highly wear- and heat-resistant CVD coating.

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

Index

INTRODUCES MULTI-SPINDLE LATHE

Index recently introduced the new MS22C-8 as part of its Multiline series. The new modular eight-spindle machine opens up additional opportunities for fast multi-spindle parts machining, especially highly complex parts. The Index MS22C-8 NC multi-spindle automatic lathe

has many applications throughout industries ranging from automotive to medical technology. It also produces small batches efficiently and economically. The versatile Index MS22C-8 can be bar-fed or loaded with chucked parts.

The MS22C-8 can accomplish turning, off-center drilling and thread cutting, inclined and cross-drilling, milling, multi-edge turning, hobbing, tooth milling, deep-hole drilling or slotting. Another benefit for the user is that all standard tool holders and tool holder system interfaces can be used with a range of popular adapters (Capto, HSK, VDI, Index systems). Each of the eight spindles, arranged in the well-known Index spindle drum, are assigned two cross-slides which can travel both on the X as well as on the Z-axis. Each cross-slide can be additionally equipped with a Y-axis.

Combined with a total of up to 16 cross-slides, the new eight-spindle machine is therefore a true multi-talent even for highly complex machining. The speed of each of the eight liquid-cooled spindles can be controlled separately. The fluid-cooled spindle drum keeps the thermal growth in the spindle carrier to a minimum. The advantage compared to the previous air-cooling approach is the higher power density in the spindle drum and

continued

the capability of energy recovery from the heated cooling fluid. In addition, the spindle bearing temperature can be kept at a low level, which also prolongs its service life and improves thermal stability.

The cross-slides with integrated drive have a low-mass design with hydrostatic bearing support. Their low moment of inertia and resulting high dynamics facilitate outstanding acceleration in operation. The new MS22C-8 in double four-spindle mode actually runs as two machines working with one another simultaneously on a single base. Every second tool station always has simultaneous access to the same tools. When operated as an eight-spindle machine, the drum indexing angle from spindle to spindle is 45 degrees; if the machine operates with two times four spindles, the drum indexing angle is 90 degrees. Results from double four-spindle machining: two finished parts are produced by the machine per work cycle. In double rear end machining, there are six spindle positions available for front machining the workpiece and two spindle positions for rear end machining, and they all work simultaneously. With this approach, it is possible to machine the rear end of a workpiece during two drum indexing cycles.

After front machining, for which six spindle positions are available, workpieces are picked up by two rear machining units and machined simultaneously on the rear end. Because rear end machining is done during two drum indexing cycles, up to six tools can be used for this simultaneously with the other spindles. And because all cross-slides are located at the same travel angle to one another, free chip flow is guaranteed in each position.

The advantage of hydrostatic sliding guide in the feed axis (Z) is their damping characteristic that prevents the transfer of the machining vibrations to the adjacent slide via the headstock. This helps to mitigate vibration and rattling while workpieces are being machined—even when the most diverse machining processes are being performed concurrently by the eight spindles. For example, one spindle can be used for heavy-duty roughing while high-precision finishing takes place on another spindle without sacrificing surface quality. In addition, the hydrostatic bearing is wear-free—there is neither friction nor a stick-slip effect.

The swiveling synchronous spindles are locked into the end positions by three-part Hirth couplings. The high level of stiffness that this achieves also guarantees that even with

bar diameters up to 24 mm, rear end machining operations with very high cutting volumes and simultaneously high machining precision can be performed.

The Hirth coupling also means it is no longer necessary to electronically compensate at the end position. The mechanical lock ensures optimal stiffness and increases the positioning accuracy. This allows even highly complex components to be produced that require complex cut-off side machining. The swivel movement to the rear end position occurs in less than 0.3 seconds.

The advantage of the front-opening design for the operator is the excellent accessibility during setup and tooling. Moreover, there is the free chip flow down into the chip discharge chute. To save space, the Index engineers simply placed the control cabinet on the machine. This principle of integrating the control cabinet into the machine roof has been applied to Index multi-spindle machines for almost 15 years and has been very well received in the market.

Discharging workpieces damage-free from the work area and placed on pallets in the right position for later treatment, the MS22C-8 can include optional handling solutions: machine- integrated handling with external stacking unit that ensures both destruction-free removal of parts from the machine, including measuring operations for the workpieces if needed. Workpiece data can be fed back directly to the machine control so it can automatically correct its machining parameters.

For more information:
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Noblesville, IN 46060
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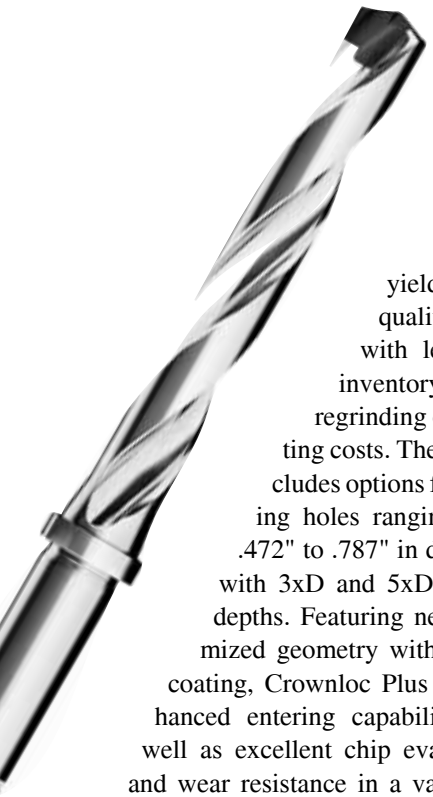
Seco

OFFERS NEW GENERATION OF TIP DRILLS

Seco's new generation of Crownloc Plus exchangeable tip drills takes hole-making to the next level by increasing output and decreasing machining costs. Crownloc Plus saves users money by incorporating several new features that

continued



yield high quality holes with less tool inventory and no regrinding or resetting costs. The line includes options for drilling holes ranging from .472" to .787" in diameter with 3xD and 5xD cutting depths. Featuring new optimized geometry with TiAlN coating, Crownloc Plus has enhanced entering capabilities, as well as excellent chip evacuation and wear resistance in a variety of materials, including stainless steels and superalloys. The line's strong, polished drill body design includes deep and wide flutes and a high-strength locking interface. For best results, Seco recommends using these exchangeable crowns with the following holders: the Weldon DIN 1835 B/DIN 6535 HB, Type 5834 hydraulic chucks (for cylindrical, -R1 shanks only) or Type 5603 shrinkfit holders (for cylindrical, -R1 shanks only). In terms of coolant mix, Seco recommends an emulsion mix between six and eight percent, however, when drilling in stainless steels, superalloys and high strength steels the recommended mix is 10 percent.

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

Mahr

OFFERS SKIDLESS SURFACE GAGE

Mahr Federal will be featuring the addition of a new skidless surface evaluation system to its MarSurf line of mobile surface metrology systems at MD&M West, February 14-16, 2012, at the Anaheim Convention Center, Anaheim, California. Mahr Federal will occupy booth #3069. The new MarSurf M 400 features proprietary motorized probe height adjustment that quickly and automatically zeros the probe in seconds and can cut measurement time in half. The M 400 also features a magnetic, breakaway probe mounting system that protects sensitive probes from accidental damage and facilitates fast probe changes. The MarSurf M 400 measures all common international parameters and features Bluetooth connectivity between the measuring system and the evaluation unit with integrated thermal printer.

Skidless tracing of surface characteristics allows the capture of primary, waviness, and roughness profiles for the evaluation of more complex parameters. The new MarSurf M 400 offers this capability in a very economical, entry-level system, and is the only one to include proprietary auto-probe zeroing, which can dramatically increase the ease and speed of measurement. The magnetic probe mounting system also protects delicate probes and allows probe arms to be rapidly changed with just a touch.

The measuring unit can be used alone in different orientations, in combination with various accessories, or mounted on a measuring stand. A large color display on the evaluation unit provides clear, concise results and intuitive operator guidance. The unit is compatible with all appropriate DIN, ISO, JIS, ASME and MOTIF standards for the measure of most common surface finish parameters from the P, W, and R profiles.

The MarSurf M 400 comes in its own carrying case and includes the M 400 Evaluation Unit with integrated thermal printer, and Bluetooth connectivity with the newly designed SD 26 Drive Unit with the breakaway BFW 250 probe system and standard probe arm. Battery or AC adapter operation extends flexibility, and two USB cables allow connection to a PC or optional use with the drive unit.

For more information:
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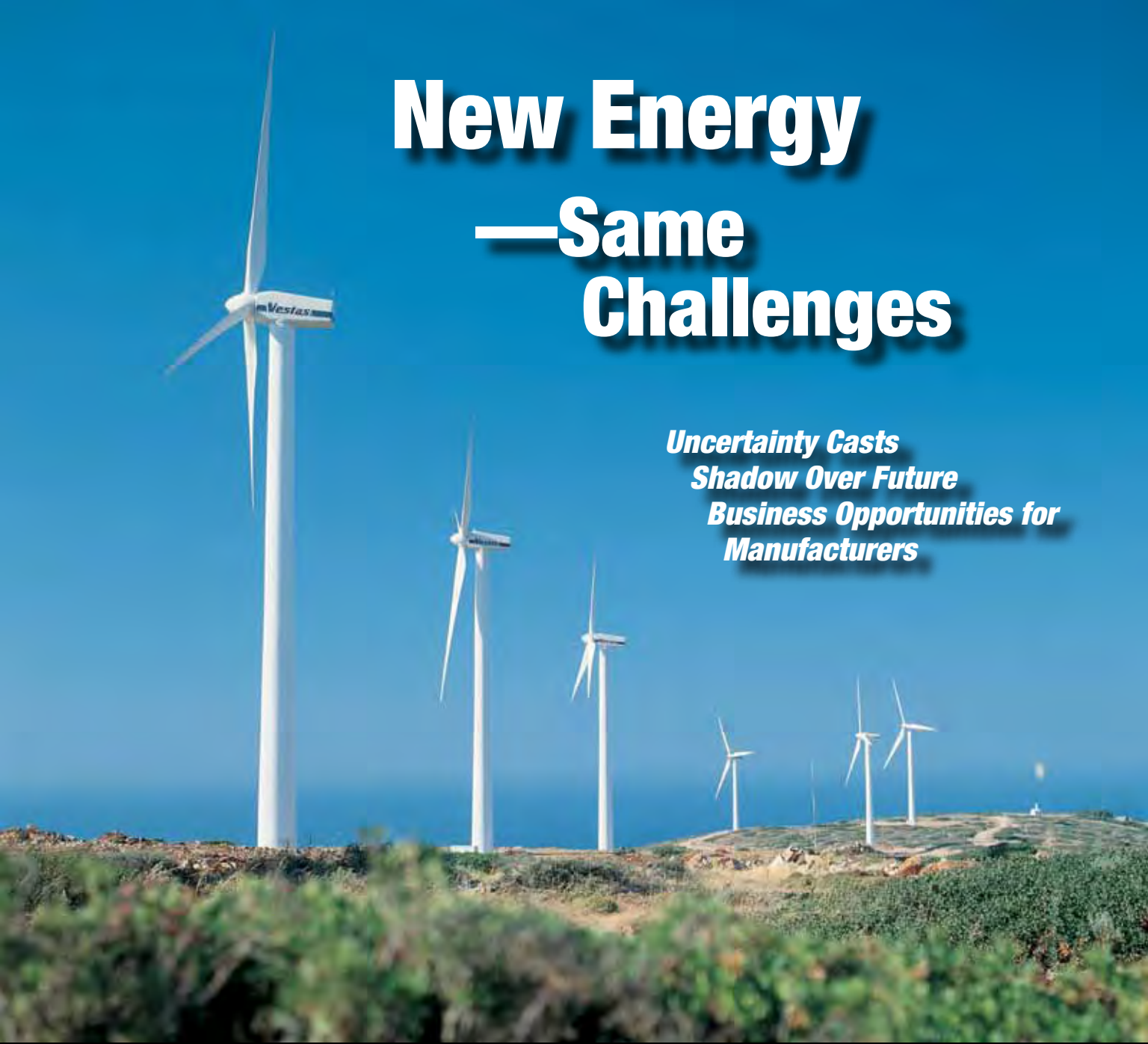


New Energy —Same Challenges

Uncertainty Casts Shadow Over Future Business Opportunities for Manufacturers

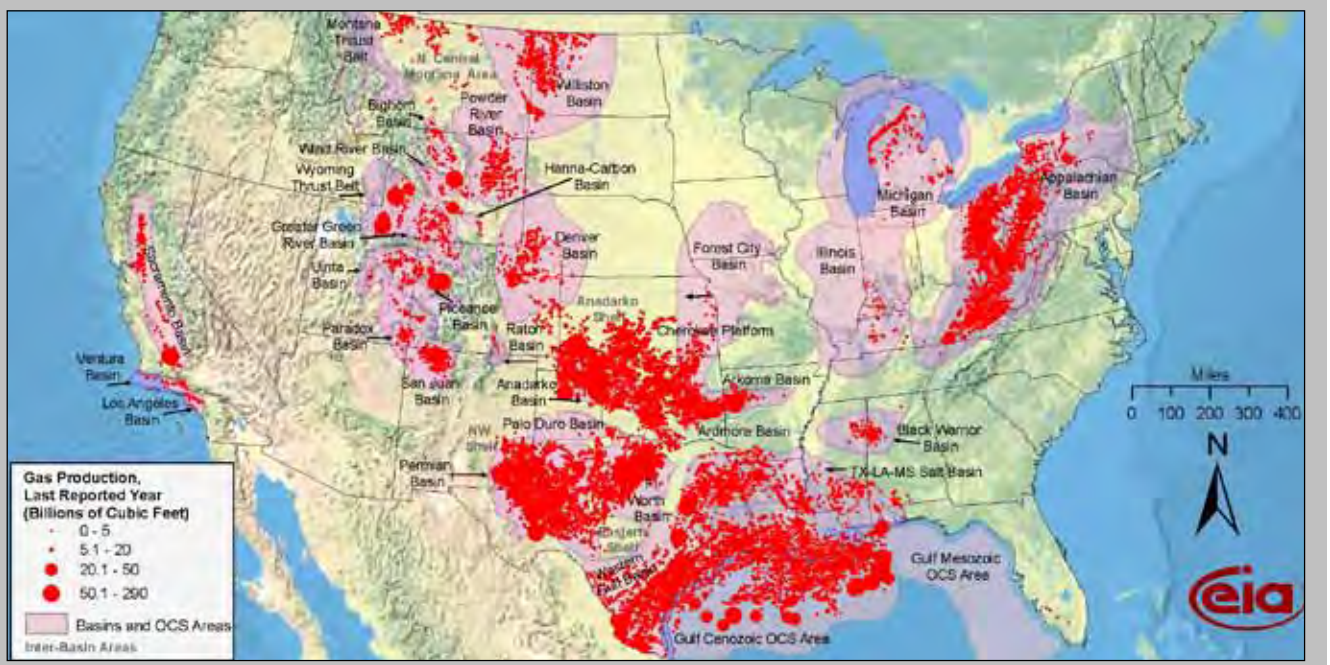
Matthew Jaster, Associate Editor

It's important to have a contingency plan. Call it Plan B, a backup plan or a secondary course of action—just make sure you have one. For many manufacturing companies, the energy industry was going to create an excess of new business opportunities five years ago. It was going to single-handedly resurrect heavy industrial manufacturing in North America, Asia and Europe. Many companies dove head first into renewable energy segments like solar and wind. Others put their resources and equipment into the oil and gas industry. Nuclear energy was being heralded as a clean energy resource that can be affordable and reliable and reduce pollution.

Then the Montara and Macondo oil spills happened, soon to become a public relations nightmare. The Fukushima accident in Japan brought nuclear energy risks back to the forefront. Wind and solar installations battled a "boom or bust" environment with each new government policy. In 2012, there's no denying opportunities in energy still exist, you just need to know the risks that come with them.

"There was tremendous growth in the energy market in 2010 and 2011, but nobody expects that to continue," says Peter Loetzner, CEO of EMAG. "It's important to be diverse so you are not depending on one market and its economic up or down swing."

Current U.S. Conventional Gas Fields Production and Shale Gas Plays in Lower 48 States



Gas production in conventional fields in the lower 48 states (compiled by the U.S. Energy Information Administration).

Current and prospective shale gas plays in the lower 48 states (compiled by the U.S. Energy Information Administration).

"We made a strategic decision to deploy our expertise in tight-tolerance gearing for wind turbines into broader energy and infrastructure markets," says Sergio Gamboa, sales director at Brad Foote Gear Works, a Broadwind Energy company. "Today we are a much more diverse company serving wind, oil and gas, mining and other industries."

Oil and Gas: A Commitment to Efficiency

Europe discusses international standards. The oil and gas industry uses international standards to enhance technical integrity, improve safety, facilitate global operations and reduce the environmental impact of operations worldwide. A lot has been achieved by the industry over the past two decades and the work of the International Association of Oil and Gas Products (OGP) Standards Committee in supporting and promoting the development and use of these international standards has long been established.

The Montara and Macondo oil spills have put a much larger emphasis on the need for robust and comprehensive standards. There is also greater recognition of the role national regulators have to play in the standards development process; i.e., in selecting topics and priorities for standardization, in helping to develop standards themselves, or in using completed standards within the regulatory landscape.

OGP recently welcomed the resolution of the International Regulators Forum (IRF) meeting in November 2011 to support the ISO standard system as the principal system for offshore regulators in order to achieve global offshore standards. At the same time, IRF recognized the crucial role that relevant national and regional standards would continue to play whilst no equivalent ISO (or IEC) standards existed.

IRF is now in the process of setting up a standards subgroup that will engage with the OGP Standards Committee, ISO/TC67 Management Committee and other relevant groups. "IRF is the principal international regulatory forum for offshore safety, so this is an important step which may lead to the more consistent use of international standards by regulators and potentially simplify the movement of rigs and equipment across national borders," says Ross Smith, OGP standards committee chair. "This also applies to those OGP members that use different standards for the same topics. We look forward to working together with IRF in the years to come and will continue to encourage the use of the same international standards worldwide."

Additionally, OGP has launched an industry initiative—GasNaturally. Backed by all the major gas industry associations, the initiative was established to "highlight the many benefits of gas in the context of the European Commission's forthcoming Energy Roadmap 2050." As the initiative points out, "Gas is the cleanest hydrocarbon fuel; it is also an abundant, secure and reliable energy source, making it an attractive, stand-alone energy source

as well as the ideal partner for renewables. Gas is flexible, available and can be stored and transported easily in large quantities. Innovative gas technologies and products are being developed today to increase energy efficiency and to provide new solutions that will help Europe achieve its low-carbon economy objectives."

GasNaturally is a response to the European Commission's call for an inclusive debate on competitive solutions to ensure security of energy supplies while achieving the targeted CO_2 reductions. Converting old, high-carbon power generation to modern gas-fired power plants would help meet the EU's ambitious target of cutting CO_2 emissions in a cost-effective way, the initiative says.

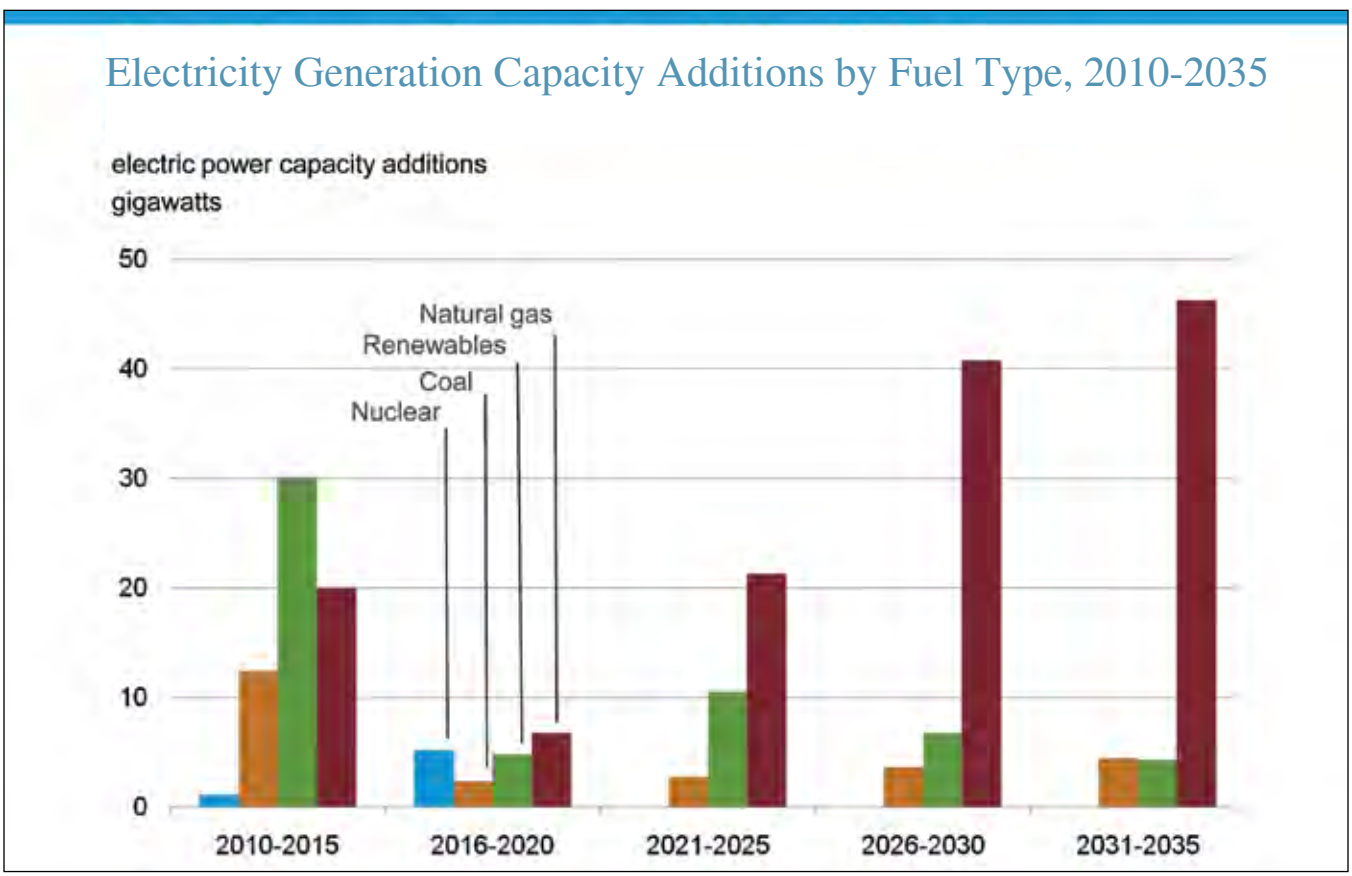
What this means for gear manufacturers. Open any major newspaper in the last three months and you're bound to find an article or two about job creation in the oil and gas industry. Gear manufacturers may want to pay close attention to developments in this energy segment and the potential for future business as long as new regulations and standards continue to develop.

The U.S. shale gas debate. The Marcellus Shale (covering areas in Kentucky, Maryland, New York, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia) contains about 84 trillion cubic feet of undiscovered, technically recoverable natural gas and 3.4 billion barrels of undiscovered, technically recoverable natural gas liquids, according to a recent report from the U.S. Geological Survey (USGS).

While some gear manufacturers have found work in the shale gas arena, the polarizing debate on its environmental—not to mention health impact—continues. In October 2011, the EPA issued initiatives to set discharge standards for wastewater from shale gas extraction. Based on data provided by the industry, it is evident that a portion of the injected fracturing fluid will return to the surface as "flowback," sometimes called "produced water." Up to one million gallons of shale gas wastewater may be produced from a single well within the first 30 days following fracturing. These produced waters generally contain elevated salt content (often expressed as total dissolved solids, or TDS) many times higher than that contained in sea water, conventional pollutants, organics, metals and NORM (naturally occurring radioactive material). Additional data show that flowback waters contain concentrations of some of the fracturing fluid additives.

The EPA plans to reach out to affected stakeholders and to collect information to better characterize shale gas wastewaters and the efficiency of various treatment, re-use and disposal technologies that will reduce shale gas wastewater pollutant discharges, including those technologies currently in use in public and private treatment plants. The EPA will collect financial data on the shale gas industry to determine the affordability of treatment, and will conduct a study of the effects of hydrofracturing on groundwater.

Meanwhile, the Department of Energy is also collecting



U.S. Energy Information Administration 2011 report on electricity generation capacity from 2010-2035.

new information related to shale gas wastewater and its disposal. The two agencies are coordinating and sharing information. Should the new information indicate that shale gas wastewaters are already adequately treated, EPA is open to adjusting its rulemaking plans accordingly.

While some of the shale gas wastewater is re-used or re-injected, a significant amount still requires disposal. Some shale gas wastewater is transported to public and private treatment plants, many of which are not properly equipped to treat this type of wastewater. As a result, pollutants are discharged into surface waters such as rivers, lakes or streams, where they can directly impact aquatic life and drinking water sources. The EPA plans to propose new standards for public comment in 2014.

In September of 2010, Scranton, Pennsylvania residents were warned not to drink well water after methane was detected near drilling sites. Ohio state leaders have ordered four fluid injection wells to shut down in the aftermath of earthquakes near their location in Youngstown in 2011. Currently the federal government is preparing fracking regulations that seem to be upsetting groups like the American Petroleum Institute (*www.api.org*).

"It's going to take more than tweaking current policies at the margins," said API president and CEO Jack Gerard in a speech recently delivered in the nation's capital. "It's going to take a course correction. We must engage the American people on these issues and make energy an important part of our national debate this year."

Gerard said that the State of American energy can be strengthened, bringing more benefits to Americans and that sound policies should encourage all forms of energy. "We must abandon energy rhetoric that pits one resource against another," Gerard said."We need all of our resources—oil and natural gas, coal, nuclear, wind, solar, biofuels and more. Only through smart, realistic deployment of all of America's energy assets can we realize our goal of keeping this country energy secure."

"This is an incredibly new, nascent resource," said Francis O'Sullivan, a research engineer for the MIT Energy Initiative in an MIT *Technology Review* article. "There is not yet enough data to definitively forecast the performance of shale gas deposits over the next 20 to 30 years."

What this means for gear manufacturers. Predictions and politics aside, the geologic and engineering data out there suggests that shale gas could become a key player in the United State's energy market—reducing a reliance on foreign fuel and producing less carbon dioxide than coal. But it's obvious the most important need right now is for further research, particularly with growing environmental and health concerns.

Renewable Energy: A Global Roadmap

Europe. In December 2011, European Energy Commissioner Günther Oettinger called for binding 2030 renewable energy targets to be in place by 2014. At a recent

press conference launching Europe's Energy Roadmap 2050, Oettinger said, "With our roadmap we want to ensure that, for all participants, there should be an interesting discussion on binding targets for renewables by 2030. This should begin now and lead to a decision in two years' time."

The European Commission's Energy Roadmap 2050 shows that a high renewable energy mix including 97 percent of the EU's electricity consumption met by renewable energy, including 49 percent wind power in 2050 would have the same "overall energy system costs" as any other de-carbonization or business as usual scenario.

According to the EWEA, all five de-carbonization scenarios in the Roadmap, as well as the business as usual scenario, show that wind energy will produce more electricity than any other power generating technology by 2050: between 32 and 49 percent of EU power production in the de-carbonization scenarios.

Additionally, the EWEA reports that 2011 was a stable year for the offshore wind industry, with 235 new offshore wind turbines grid-connected, worth approximately 2.4 billion euros. Nine offshore wind farms currently under construction will bring online an additional 2,375 MW, increasing the EU's total installed offshore wind power capacity by 62 percent. Across the EU, a total of 1,371 offshore turbines have now been grid-connected, with a total power capacity of 3,813 MW in 53 wind farms in 10 European countries. EWEA's target for installed EU offshore wind power capacity by 2020 is 40,000 MW, producing approximately four percent of the EU's total electricity consumption.

"The offshore wind sector witnessed a stable market in 2011," says Justin Wilkes, policy director of EWEA. "Despite the economy-wide financial squeeze, 2011 saw a 40 percent increase on the previous year in offshore non-recourse debt financing, up from 1.46 billion euros in 2010 to 2.05 billion euros in 2011. The strong project pipeline and financial developments highlight the importance of countries continuing to provide and develop stable long-term

A long-term production tax credit (PTC) in the United States could benefit wind turbine manufacturers like Siemens (courtesy of Siemens).

frameworks for offshore wind power in order to allow the industry to continue its development."

What this means for gear manufacturers. Offshore wind is a safe bet in Europe, particularly in Britain where 87 percent of all newly installed and grid-connected offshore wind power in 2011 was in British waters. Siemens supplied 80 percent of the MW installed offshore last year while SSE and RWE Innogy were the most active developers and DONG Energy continued to be the most active equity player in offshore wind power.

United States. With the Production Tax Credit (PTC), wind power's key policy incentive, set to expire at the end of the year, industry members and advocates will be pushing for a PTC extension so that the industry can grow to nearly 100,000 jobs just four years from now. Meantime, developers will be busy getting wind farms built and online by the end of 2012.

"American manufacturing jobs are coming back, with tens of thousands of new jobs from wind power," says Denise Bode, AWEA CEO. "But these jobs could vanish if Congress allows the Production Tax Credit to expire, in effect enacting a targeted tax increase and sending our jobs to foreign countries. Congress must act as early in 2012 as possible to keep this American manufacturing success story going."

While the PTC has been around since the 1990s, Congress has extended it mostly in one- and two-year incre-

Siemens supplied 80 percent of the MW installed offshore in 2011 (courtesy of Siemens).

ments and even has allowed the credit to expire on occasion. The result is a boom and bust pattern that is difficult for businesses to plan around. Under-construction numbers are up; 8,400 MW were counted at the end of the third quarter in 2011. Expect them to continue to surge as 2012 gets underway.

In 2012 utilities will continue to embrace the price-locking benefit of wind power by signing long term power contracts for the affordable energy source. The AWEA believes this is because unlike the volatile prices of fossil fuels, wind power's fuel cost is fixed: *zero*. The fuel cost was zero last year, and it's guaranteed to stay at zero in 2012 as well. And wind power chalks up big zeros in other key areas: zero water use, zero air emissions, and zero water pollution.

A new study released this month finds that with a stable tax policy the wind industry can grow to nearly 100,000 American jobs in the next four years. The wind manufacturing sector would grow by one third, to 46,000 American manufacturing jobs. Such job additions will keep the wind sector on track toward supporting the 500,000 jobs by 2030 projected in a report by the U.S. Department of Energy during the George W. Bush administration.

A recently released report from Navigant Consulting also found that if Congress allows the PTC to expire, jobs in the wind industry will be cut in half, meaning a loss of 37,000 American jobs and a one-third cut to American wind manufacturing jobs, while private investment in the industry would drop by nearly two thirds.

What this means for gear manufacturers. With many wind turbines inching closer to the end of their respective life spans, replacement and repair opportunities might prove beneficial to gear manufacturers entrenched in the market. The lingering political "tug of war" for long-term wind poli-

Safety improvements are a priority at the Limerick Nuclear Generation Station located in southeastern Pennsylvania (courtesy of the Nuclear Regulatory Commission).

The United States firmly believes that nuclear power will continue to play a role in the country's clean energy portfolio (courtesy of the Nuclear Regulatory Commission).

cies and credits, however, could hinder new wind installations and force major players to look toward other industries.

A Nuclear Energy Facelift

While all forms of energy come with certain challenges and risks, the Fukushima accident in Japan didn't exactly send a positive message for the future of nuclear power. Since the controversial meltdowns and equipment failures at the Fukushima plant, various energy institutions have come together to weigh in on the future of this clean energy source.

Speaking at the American Tokyo Center in Japan, Daniel Poneman, D.O.E. deputy secretary, spoke about the future of nuclear power in December. "As President Obama made clear, the United States will study the lessons of Fukushima to improve the safety of our reactors, but we continue to believe nuclear power has an important role to play as part of a diversified clean energy portfolio that will promote economic prosperity, enhance our security, and reduce global carbon pollution," Poneman said. "Though the Fukushima accident has heightened awareness about the risks of nuclear energy, we must recognize that the larger energy challenges we faced before the disaster still persist. With population and demographic changes, the demand for global energy resources will continue to grow. The International Energy Agency estimates that by 2035, global demand for electricity will grow 85 percent."

Poneman went on to explain that clean energy resources can offer affordable and reliable electricity for families and businesses in a way that boosts the welfare of future generations. As one of the few large-scale, carbon-free sources of energy available for deployment today, safe, secure nuclear power is an important part of that puzzle.

The World Nuclear Association recently released information on the critical issue of heavy manufacturing of power plants. These findings may be of particular interest to component manufacturers. Three key areas of discussion include:

- The availability of plants to make reactor components.
- Supply challenges in heavy forgings as well as engineered components.
- The integration of international suppliers and vendors.

Though Westinghouse was once an integrated supplier of first- and second-generation nuclear power plants, today's power plants come from a range of international suppliers and vendors. There's also a growing demand for local suppliers, which often means a high level of technology transfer is needed. These suppliers must be qualified and quality-controlled, given the strict requirements in both the design and fabrication of the components. Here in the United States, for example, the American Society of Mechanical Engineers (ASME) nuclear accreditation is known as N-stamp and is internationally recognized. Along with supply/vendor issues, metallurgy poses its own unique set of challenges in the nuclear energy segment. Fourth-generation power plants will operate at higher temperatures and will require new materials. It's an energy segment that is currently going through a variety of changes and technological advancements.

What this means for gear manufacturers. The International Energy Agency wants the world to invest more than 26 trillion in energy solutions over the next two decades. Many believe that nuclear energy will play a large role in this. This means more nuclear power installations and more opportunities for component suppliers to provide critical parts.

Lessons Learned

The economic highs and lows in the energy market are no different than other industrial segments—just ask those involved in automotive. Still, global energy has huge potential if governments and manufacturers can somehow get on the same page. No matter what energy segment you're involved in, the best course of action is to simply keep your options open.

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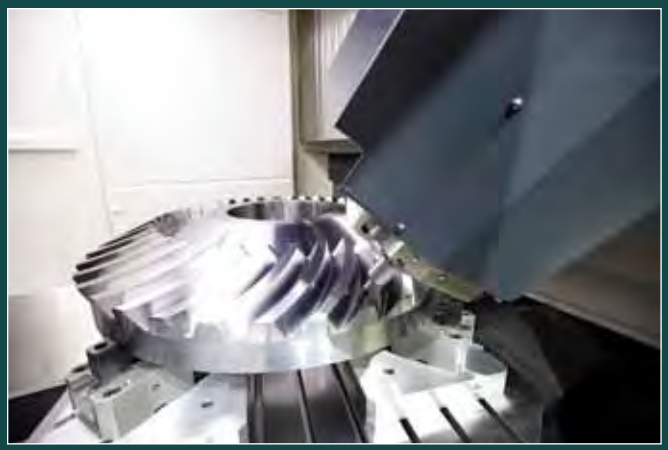

The Latest in Big Gear Machining with DMG/Mori Seiki

Matthew Jaster, Associate Editor

While gear milling was one of the last machining processes to be integrated on CNC machines, the functionality and operability has reached a point where it has become a very efficient and flexible process, particularly for large gears. In 2009, *Gear Technology* focused on DMG America's gear milling on non-dedicated machinery for a product news article. Back then, multifunctional machining was making significant progress in Europe and just beginning to gain momentum within the U.S. gear industry. DMG joined forces with Mori Seiki in 2010 and the company has witnessed a growing interest—most notably in the gear community—in the integration of machine operations. Fast-forward to 2012 and you'll notice that multifunctional machining is playing a much larger role in many gear operations. *Gear Technology* recently caught up with Greg Hyatt, vice president and chief technical officer at DMG/Mori Seiki USA, to discuss the latest gear products, technologies and innovations that are now being integrated into the company's machine tools.

Describe some of DMG's latest gear milling techniques and how they are changing traditional gear milling production.

We have added processes/solutions to address the limitations of traditional hobbing specifically for large gear applications. One addition includes our ball nose-based solution that produces one-off or low-volume gears without any special cutting tools (the hob isn't required, a gasher isn't required). Most large gears are being cut from paper drawings or, if there's a solid model, the gear portion of the solid model may not be accurate. The engineers generally assume the part will be cut on a hobbing machine and that the tool path will not be generated directly from the solid model of the flank geometry, for example. They draw it for illustration purposes only. We had to develop special software to reverse-engineer the correct geometry so that we could drive the tool path for the simple tools. A second addition is invomilling, a multitasking application developed for spur, helical and herringbone gears that uses a disc-shaped milling tool. This utilizes a much simpler tool path. Since none of the CAM suppliers had invented software like this, we developed it ourselves so the customer can easily create the tool path to cut the gears. A third addition is a grinding solution for the finishing of gears where we use a disc-shaped tool similar to Sandvik.

What other products/technologies is DMG/Mori Seiki working on to enhance very large, time-consuming gear machining?

The integration of operations does not have to be constrained to the material removal operations. We're doing more and more inspection within the machine today. For the milling processes, we can measure and cut one tooth complete before we measure a second tooth. We can intentionally cut the first tooth oversized so that we will be absolutely sure it will be a good part. We capture deflection in the workholding, deflection in the cutting tools, thermal error due to imperfectly controlled environments—whatever the errors may be that contribute to the total error of the part. We can cut one part in the machine, measure the part, make the compensation and then cut the gear to tighter tolerances in that first pass. We've partnered with several companies to measure by probing. For other critical features, we have a hydrogage option—an air gage with high pressure that has been re-engineered to use the machines coolant. We can now measure diameters to micron level precision within the machine tool. Basically, we can pursue micron level inspection accuracy in a machine that doesn't have micron level positioning accuracy.

How have customers responded to these multifunctional technologies?

The response from our customers has been extremely favorable, particularly for the low-volume producers of large gears. Customers are excited about a single machine that can do all operations prior to surface hardening. For many of these processes, setup and response time is extremely critical. Traditionally, you had a machine on the floor for blanking, one for turning, mounting, drilling and then finally gear cutting. Machine availability is a constraint. Being able to provide multiple operations on a single machine provides several key advantages.

How has DMG/Mori Seiki's software package evolved?

Our software package for developing spiral bevel, worm or spur gears was developed in Pfronten, Germany at DMG in parallel to the work done with Sandvik's disc tool and their work with Mori Seiki. Some of this work had matured by the time we collaborated with Mori Seiki so a decision was made to pull it all together into a single portfolio. We had both been focusing on integrating operations at that time. While the ball nose solution gave us greater flexibility because it could handle worm and spiral bevel gears, the Sandvik disc tool was more productive and could offer faster cycle times for spur, helical and other gears which can be machined with it. The Sandvik disc tool takes us into higher volume applications and is generally competitive with high-speed steel tools. We wanted both packages in the portfolio because they solved different challenges for different applications.

What are the largest gears that DMG/Mori Seiki machines can currently handle?

The largest gear can be 4.2 meters in diameter, 1.2 meters long and weigh up to 20,000 kilograms (48,400 lbs). This can be done on DMG's DMU600 FD. For shaft-based gears, Mori Seiki's NT6600 can handle gears over six meters. We have five different machines that can handle gears over one meter in diameter on the DMG side. These include the DMU340, DMU210, DMU160 and DMU125. On the Mori Seiki side, several machines can handle large gears including the NT3000, NT4000 and NT5000 series. We have a whole range of machines depending on the

continued

DMG/Mori Seiki's NT4250 is capable of handling several large gear machining operations (courtesy of DMG/Mori Seiki).

length, diameter and mass of the gears that need to be cut.

What are the key markets currently for these multi-functional machines?

The most popular area has been customers who are doing contract production of gears in wind, mining and more conventional power generation applications.

They have embraced the technology more quickly than OEMs that are producing their own products.

What was DMG/Mori Seiki's experience like exhibiting at Gear Expo in Cincinnati?

Gear Expo was very valuable to us. While we've been cutting gears on our machines for years, we've never really participated in a focused event like that. We tried to exhibit some of the gear technologies at larger trade shows but it was not a productive way to target the market. Gear Expo was efficient and effective for us to talk to a customer who shared the same focus in the same market, and it's certainly something we will continue to do in the future. The attendees that dropped by our booth seemed very interested in the demonstrations. Many times they would see a demo, leave and come back with a co-worker and then they'd return again with the president of their company. The customers at Gear Expo "got" what we were trying to demonstrate regarding the integration of machine operations.

Where do you think multifunctional machining will be in five to ten years?

I think there are no constraints or obstacles to prevent us from integrating more special operations into the machines. We've seen a decline in many special machines, the radial drill press for example, the transfer lines are almost gone. I think the special purpose machines will either reinvent themselves to become multifunctional or largely disappear. This is happening later in gears because of the tight tolerances.

What new capabilities can customers expect from DMG/Mori Seiki in the near future?

Honing is one area that we are starting to incorporate into our machines. We are actually pursuing partnerships with a few gear companies in honing and grinding applications. We'll have something new to share in these areas at IMTS in September. We're also planning on providing some heat treating capabilities down the road. I'm not ready to discuss the details just yet, but it's something we're working on. We want to have a broad portfolio for all gear operations now and in the future.

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DMG/Mori Seiki University

With all the new multifunctional capabilities comes a particular learning curve for machinists. Thankfully, DMG/Mori Seiki developed a training program to provide employees, distributors and customers with education solutions that increase innovation, productivity and safety in the manufacturing environment. DMG/Mori Seiki University has a curriculum that focuses on both technical and non-technical skill development.

Founded in 2006 by DMG/Mori Seiki USA as a corporate training facility, the university supports the precision, high technology CNC machine tools, controls and software solutions manufactured and distributed by Mori Seiki and DMG. It serves the Americas with high quality, instructor-led classes and the global marketplace with third-generation online education. The company employs state-of-the-art educational tools and advanced adult learning techniques at the DMG/Mori Seiki USA headquarters located in suburban Chicago. Classes include programming and operation as well as machine maintenance on both DMG and Mori Seiki machines.

Education On Demand (EOD) is DMG/Mori Seiki University's (MSU) solution to online training. EOD offers online immersion into basic manufacturing skills and CNC operations with virtual machine tools that look and act just like the real thing, providing an interactive environment that engages students, keeps their attention and improves retention. For more information on onsite and online courses, visit *www.dmgmsuondemand.com*.

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Getting a Grip on Big-Gear Lubrication

Jack McGuinn, Senior Editor

In the wide, wide world of moving parts, the gears required for the big jobs—the *really* big jobs—often experience big problems. Proper lubrication of these gears is paramount in industrial applications such as wind turbines, kilns, sugar mills, crushers, heavy construction, offshore drilling rigs, mining and quarrying. Scuffing, extreme friction, edge-loading, micropitting, misalignment and, of course, harsh environment issues—all are potential troublemakers. This is particularly true for large, slow-running, open gear drives where high torques are transmitted.

For perspective, consider this: damaged tooth flanks (due in part to an underperforming lubricant) are the reason for about 60 percent of gear drive defects.

It therefore follows that proper lubrication of these gears is paramount—especially when one considers that many big-gear applications directly involve public safety and failure is not an option.

Nevertheless, stuff happens. And when it does, the most common lubricant-specific causes for big-gear application breakdowns include inadequate film viscosity, incorrect lubricant specified, nozzle clogging (sprayability), bearing-lubricant issues, contamination and, of course, failure to withstand harsh environment effects such as dust, salt water, heat and cold.

Conversely, these problems can be addressed, if not completely avoided, with the use of lubricants that will reduce friction, heat, wear, operating temperatures, downtime and maintenance. And, valuable environmental upgrades are part of the mix as well. Bottom line, the use of high-performance gear oils, further boosted with newly advanced additives, can prevent or stop such problems as the above-mentioned skewed tolerances, high-friction-related heat and wear, extreme pressure, etc. This is typically achieved by:

- Improving overall tribological properties of the metal surfaces
- Returning efficiency and previously wasted energy to the system for increased power
- Improving physical surface improvement, which steps up oil flow and increases oil film strength
- Improving the shear strength of the base lubricant
- The overall reduction in friction and friction-related wear
- Protecting against rust by forming a continuous film of lubricant that excludes water from gear tooth surfaces
- Resisting flaking from gears at low temperatures, thereby maintaining full protection against wear and scuffing

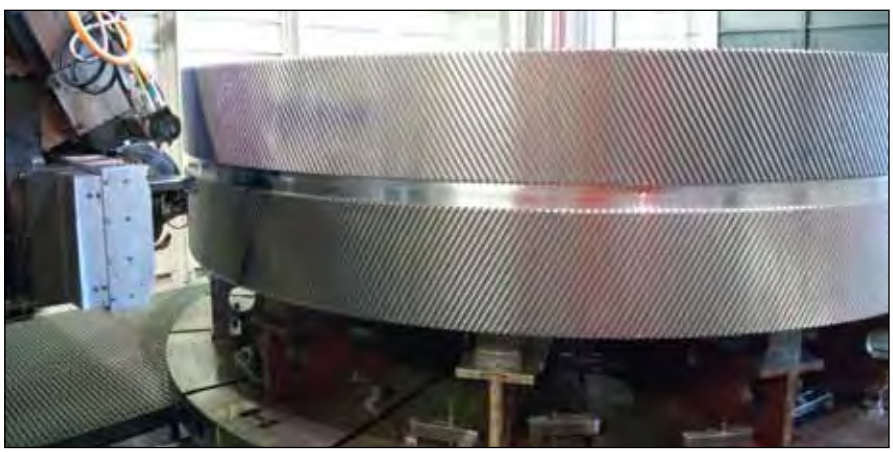
But given that many of these issues also apply to smaller gear sets, why does size matter?

And what constitutes a "big" gear? Are its dimensions etched in stone? Depends who you ask.

"Gears for mill and kiln service start at about 20 feet in diameter," says Frank C. Uherek, manager of mill products engineering and inside sales for the Rexnord Gear Group, Rexnord Industries LLC. "Big gears would be considered over 24 feet in diameter up to 46 feet. The dividing line is based on the number of manufacturers available to make gears in this size range. (Anything) much over 35, feet the number of manufactures is limited to five."

"With our research activities in wind turbine gearboxes, we con-

continued



The correct lubrication choice for big gears—like this double-helical gear from HMC—takes on added significance when public safety concerns are part of the application (courtesy HMC Inc.).

sider gears (ring gears) up to several feet in diameter (to be large)," says Dr. Aaron Greco of Argonne National Laboratory, currently on assignment with the Wind and Water Power Program/Technology Development and Testing Team for the U.S. Department of Energy in Washington, DC.

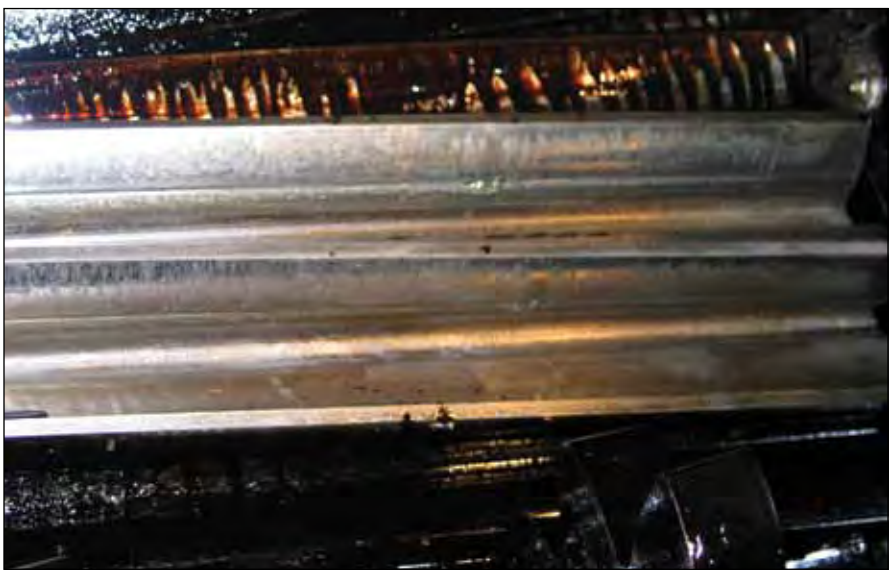
We also put the question to Rob Ferguson, a gear engineer for Indiana-based HMC, Inc, who replies, "The term 'big gear' is relative but I consider big gears (to be) over 120" in diameter."

We then asked the group to offer their own list of what they considered the primary issues in the big-gear realm relative to lubrication.

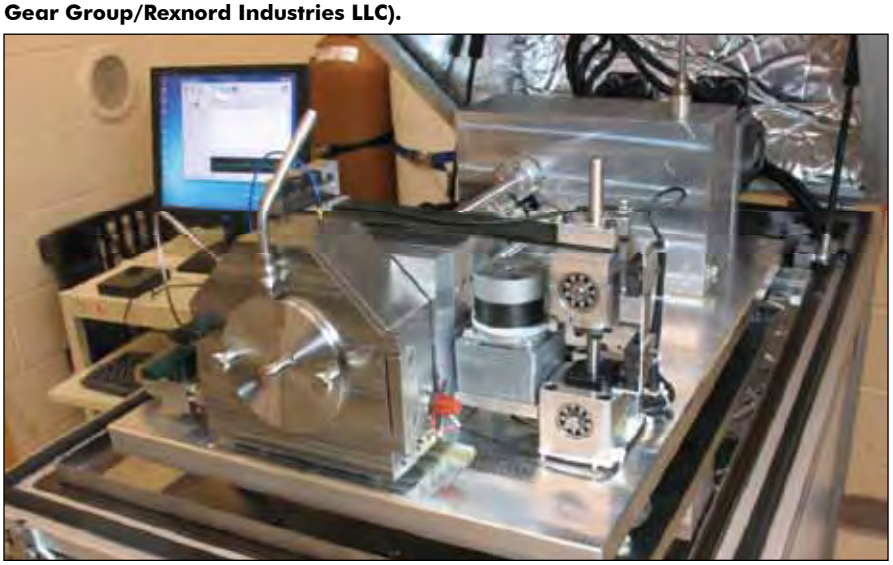
"Big gears operate at relatively low speed," says Ferguson. "At these low speeds it is very difficult to maintain an adequate oil film thickness. Many large gears also operate in outdoor environments with large temperature swings throughout the year. They are also exposed to contaminants that can be come entrapped in the lubricant and entrained in the gear mesh."

Uherek weighs in with "(What's important) is ensuring that adequate lubricant is supplied to the mesh, both in terms of viscosity and amount. Significant wear can occur due to plugged spray nozzles. In addition, the lubricant must be pump-able at low temperatures. Contamination control is also critical."

"The general difference between large-diameter gears and small is that the rotation speed is slower and torque is higher for large gears," says Greco. "These operating conditions relate to slower pitch velocity affecting the entraining velocity and higher contact pressures (especially if there is misalignment and edge loading issues). Lubricants used for these applications therefore can consider EP and wetting behavior. Some common failures observed in wind turbine gears include scuffing, micropitting and macropitting."



A kiln gear set showing distress due to insufficient viscosity (courtesy Rexnord Gear Group/Rexnord Industries LLC).



This ring-on-roller, bench-top test rig from PCS Instruments is used at Argonne National Laboratories for testing lubricants (courtesy Argonne National Laboratories).

And, Ferguson explains, "Big gears operate at relatively low speed. At these low speeds it is very difficult to maintain an adequate oil film thickness. Many large gears also operate in outdoor environments with large temperature swings throughout the year. They are also exposed to contaminants that can become entrapped in the lubricant and entrained in the gear mesh."

Identifying and qualifying a specific lubricant for big-gear applications is crucial. We asked two of our experts to explain why that's the case and how it is done.

For Uherek, "The best source of information is a manufacturer's recommendations based on ambient temperatures, speed of the gear and application (e.g., mill or kiln). If these are not available, the AGMA 9005 Industrial Gear Lubrication standard offers guidance on lubricant types and spray intervals. Another source is the AGMA 6014 Gear Power Rating for cylindrical shell and trunnion-supported equipment that has an extensive discussion in the annex covering types of lubricants and options."

And HMC's Ferguson states that "The selection of an adequate lubricant can be complex if you encounter challenging operating environments. It is important to know the operating speed, the environmental conditions—such as ambient temperature, operating temperature, duty cycle, type of enclosure if any—and how the lubricant will be applied."

One factor perhaps not readily apparent in specifying a lubricant for a big-gear application is the need—more accurately, the lack of—a test rig sufficient in size to do the job. Just how

problematic is that?

"To my knowledge there are no test rigs that can test gears at the size of wind turbines (besides full-scale dynamometers)," says Argonne's Greco. "However, the operating contact conditions of large gears can be replicated by more versatile ring-on-roller benchtop test rigs that are commercially available."

"Yes, most R&D is done on gears that are (already) in service," says HMC's Ferguson. "Most end users are not willing to experiment on their large gears due to the high cost."

"Many existing lubricant tests do not (even) involve gears," says Uherek, pointing out that "4-ball testing, or the FZG load test, use gears meshing on a ~4 inch center distance. Although gear teeth are involved, the ability to scale up the test results to 257-inch centers and the use of intermittent spray applications are limited. In many cases lubricant suppliers test on a few real-world mills as they estimate performance and balance additive packages. This type of testing is the most accurate, but comes at substantial cost. Therefore, future lubricant advances are limited."

A huge component of big-gear-related lubricants is additives; typically synthetic, they are that "something special" that greases the grease, you might say.

Of their usage and efficacy, Uherek says that "Depending on the application, the key issues (when using additives) are maintenance of high viscosity, achieving ease of application, and staying power between applications (10 to 20 minutes) for intermittent systems. As these are single-use lubricants, life enhancing, water and foam resistance become less of an issue than in an enclosed gear drive."

However, additives also lead to added cost, so their use must be weighed accordingly, vis`a vis good performance. Which begs the question: will synthetic additives completely replace their natural, mineral-based counterparts?

"The choice of mineral- or synthetic-based gear oils and the relative percentage split of each in the future will depend on many aspects," explains Felix Guerzoni, product application specialist and team leader at Houston-based Shell Global Solutions U.S. Inc. "There are no doubt significant benefits in moving to synthetic-based gear oils, and the lifetime cost benefit and return on investment can be quantified. One contributing factor could be the number and capacity of base oil manufacturing plants manufacturing API Grp I base oils, which are set up to manufacture more of the heavier viscosity grade base oil cuts required for industrial gear oils. No doubt the mix is moving towards more API Grp II and Grp III plants. The data reported recently (*Lubes 'n' Greases* magazine) suggested that in 1998, 56 percent of the North American base oil capacity was API Grp I, whereas in 2011 that number had dropped to 29 percent."

And yet, Rexnord's Uherek states, "Synthetic oils are not always the solution to lubricant issues. (While) they can offer advantages in lower-pour points and less viscosity change over broad temperature intervals, EHD film thickness needs to be closely monitored and application intervals need to be

audited when considering a lubricant change. Given moderately high contact pressures—and when slow speed sliding occurs—residual compounds such as asphaltic still solve many problems."

And while HMC's Ferguson allows that synthetic lubricants will indeed attain greater currency, he "doubts" that the traditional lubricants will be "completely replaced." There are many traditional lubricants that have proven they can do the job and introducing new, unproven lubricants will be difficult," he says.

Returning to the here-and-now, what lubricants currently exist that serve to prevent or minimize micropitting (also known as grey staining), for example, in gear teeth and scuffing wear—just to cite two all-too-prevalent gear failure causes?

"There are several active areas of R&D for gear oils that address these issues, including engineered, nanoparticle lubricant additives, new base synthetics like PFPE (perfluoropolyether)," says Greco.

But, Uherek points out, "In large-gear applications, micropitting is not common, due to the hardness difference between the pinion and gear. It is difficult to get micropitting when running a surface-hardened pinion with a through-hardened gear.

"Micropitting is more common when both members are surface-hardened, such as in enclosed drives. Scuffing can occur on slow-speed applications such as kilns; in those cases, surface finish, viscosity and tooth geometry modifications—such as tip relief—can alleviate this issue."

Yet when considering big-gear lubrication, it is the determining of the sometimes elusive and often complex balance between correct lubricant viscosity level and gear-generated heat.

And how is that done, exactly?

In a word—"carefully"—says Greco. "Too low of a viscosity can lead to micropitting and scuffing issues; conversely, too high of a viscosity can affect efficiency and cold-start conditions. The wind turbine industry has trended to higher viscosities, commonly 320."

Aside from always consulting with the OEM of the gear for their recommended lubricant type and viscosity grade for a given gear set, says Guerzoni. "The most accurate method for determination of required viscosity for gear sets involves an elastohydrodoyanmic (EHD) calculation. These calculations require a significant level of detail, including—but not limited to—gear geometry, surface roughness, operating temperature, load and speed.

"When all of the key data required to conduct a fully detailed EHD calculation is unavailable, operators can refer to the guidelines given in AGMA industrial gear lubrication standard 9005–E02. This standard provides a set of tables with suggested viscosity grades for industrial gear drives (separated by whether helical, spur, bevel gear or worm gear) and based on a minimum data set of pitch line velocity, operating temperature and the viscosity index of the oil (which in turn indicates whether a mineral or synthetic gear oil is being used). Consideration needs to be given to the lowest and peak operating temperatures. Generally speaking, for a given temperature—the lower the pitch line velocity, the higher the viscosity of the gear oil required. For a given pitch line velocity, the higher the operating temperature, the higher the viscosity of the gear oil required."

In closing, a brief—if somewhat off-topic—look at the continuing encroachment of direct drive versus gear-drive, and how it might affect lubrication issues seems relevant. Shell's Guerzoni offers this:

"Many OEM's in the wind sector are focusing on direct-drive technology—especially for offshore turbines. Major players, including Enercon and Goldwind, have direct-drive models for onshore, while OEM's including Siemens and GE are concentrating on direct-drive technology for future offshore installations. The proposed benefit is around improved reliability for the turbine and no gear oil to change on a periodic basis. Industrial gear oils are still required for yaw and pitch drives. Greases are still required for roller and pivot bearings with specific requirements demanded for those applications."

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Accelerating Validation Testing

Thomas N. Riley

Bringing new or improved products to market sooner has long been proven profitable for companies. One way to help shorten the time-to-market is to accelerate validation testing. That is, shorten the test time required to validate a new or improved product.

Fatigue testing is a common validation test that often involves long periods of time. However, the time can be shortened by an often forgotten—or unknown—concept of accumulated damage, which works especially well for mechanical components such as gears and shafts.

Accumulated damage is based on a fatigue curve for the material and Miner's rule: damage is the life already expended divided by the total life available according to the fatigue curve for the material. If one knows the accumulated damage for any test conditions, one can use an accelerated test—higher torques or forces at faster speeds—to produce the same accumulated damage, thereby completing the test in a much shorter time.

$$\sigma = b \bullet N^m \quad (1)$$

Where:
σ = Stress
N = Cycles
b = Coefficient
m = Exponent

For many mechanical components, fatigue curves define allowable forces, torques or stresses as a function of cycles. Many investigators have shown that power-function equations define fatigue properties for mechanical components, as shown in Equation 1, where stress is a function of cycles (Ref. 1).

A typical fatigue curve is often called an S-N curve in which S = Stress and N = Cycles (Fig. 1). Notice that it declines very sharply at the beginning and trails off at higher cycles. One could allow the curve to continue forever, which means there is always a fatigue limit to any material. Some, however, declare an endurance limit—either at one million cycles or at ten million cycles. This means there is infinite life at or below a specific stress level. Others change the curve at a specific number of cycles to reflect the realities found from testing. Whatever your experience, base your decision on actual test results.

The lower end of the curve is asymptotic to the vertical axis (approaching the vertical axis, but never getting there, even going on forever), which means, theoretically, there could be an infinitely high stress if the component does not experience any cycles. This is not physically possible in that to create stress,

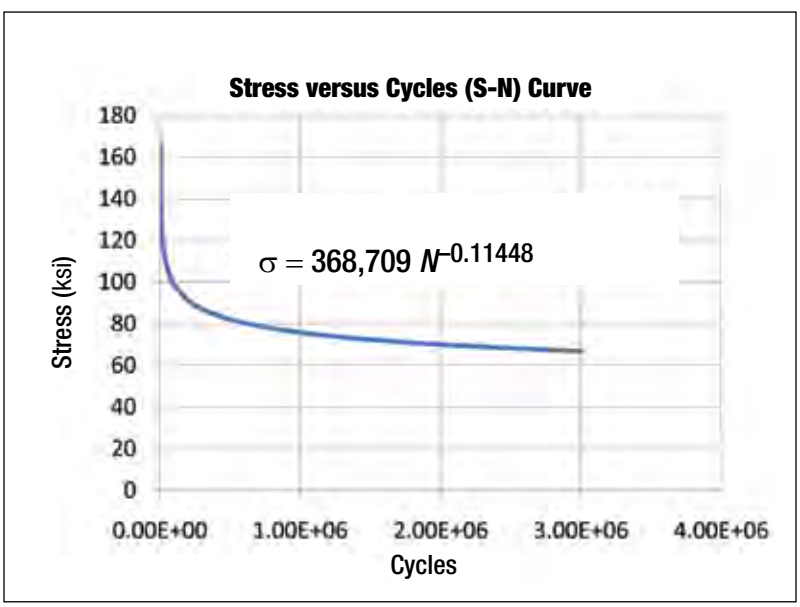

Figure 1—Typical S-N curve.

a load must be applied and at least one cycle. Material has an ultimate stress level at one cycle, but it is not infinitely high. The fatigue curve, then, is limited on the lower end to the ultimate stress. To account for low-cycle fatigue, the fatigue curve is stopped at 1,000 cycles.

It may be visually easier to interpret the curve if it is plotted on log-log paper to produce a straight line, along with the limit at 1,000 cycles (Fig. 2).

The S-N curve relates life (cycles) and stress for a specific material, heat treatment, special conditioning or any other process that influences the fatigue property. Be sure to define the fatigue curve from actual test results.

Figure 3 is an exaggerated S-N curve that shows Miner's rule (Ref. 2)—linear damage accumulation—for calculating and accumulating damage. The principle may be simple—damage is cycles used divided by cycles allowable—but it is very powerful. Of course, there are other damage-accumulation techniques that readers could use if they wish. But Miner's rule will be used in this article.

If one tested a component to the stress level and number of cycles of point P1 in Figure 3, it might take longer than desired; but one can shorten the time by testing at a higher stress.

Figure 4 illustrates the concept of accelerated testing. A second point (P2) accumulates the same amount of damage as P1, meaning that P2 must be located on a curve that runs through P1 and be parallel to the original S-N curve.

The proportion of life used (damage) is the same for the two points shown in Figure 4; it just may not visually look that way because the S-N curve (straight line) is drawn on log-log coordinates.

Perhaps an example with numbers will improve clarity. The S-N curve's equation in Figures 1 and 2 will be used for the example.

Let us suppose the duty cycle requires 200,000 cycles at a stress level of 91 ksi. To complete the test in half the time (100,000 cycles), the stress must be at 99 ksi to accumulate the same amount of damage:

$$\sigma(\text{ksi}) = 368{,}709\ (200{,}000)^{-0.11448} = 91 \text{ ksi}$$
$$\sigma(\text{ksi}) = 368{,}709\ (100{,}000)^{-0.11448} = 99 \text{ ksi} \quad (2)$$

The previous example is simple—i.e., one point. But what if the duty cycle has many points? The same procedure is followed as shown in Figure 5.

There are five stress levels in Figure 5, so there are five different numbers of cycles to accumulate for a total of 200,000 cycles. The accelerated test in Figure 5 shows that testing for 100,000 cycles at 95 ksi accumulates the same amount of damage, which means the test time is reduced by half. Using previous equations for damage, stress (S) and cycles (N) and then re-arranging them as needed, one can

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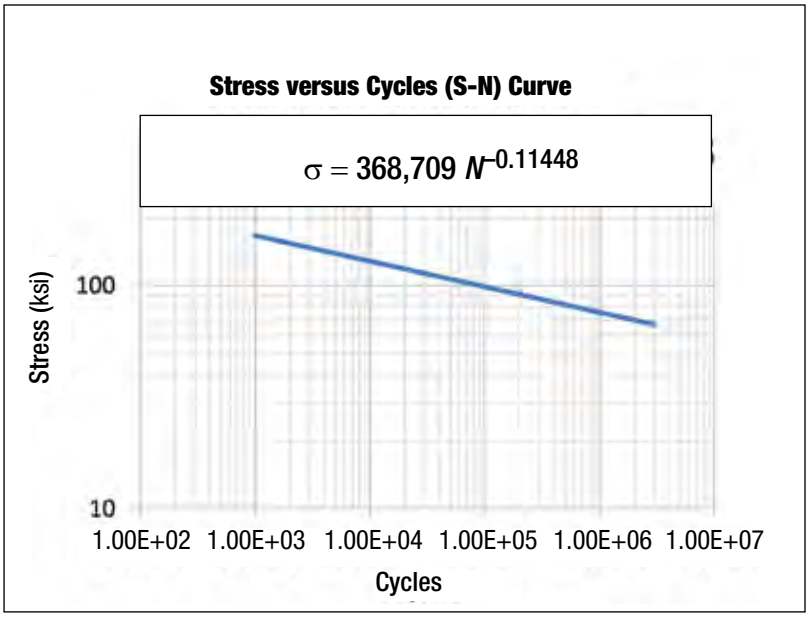

Figure 2—Typical S-N curve on log-log graph.

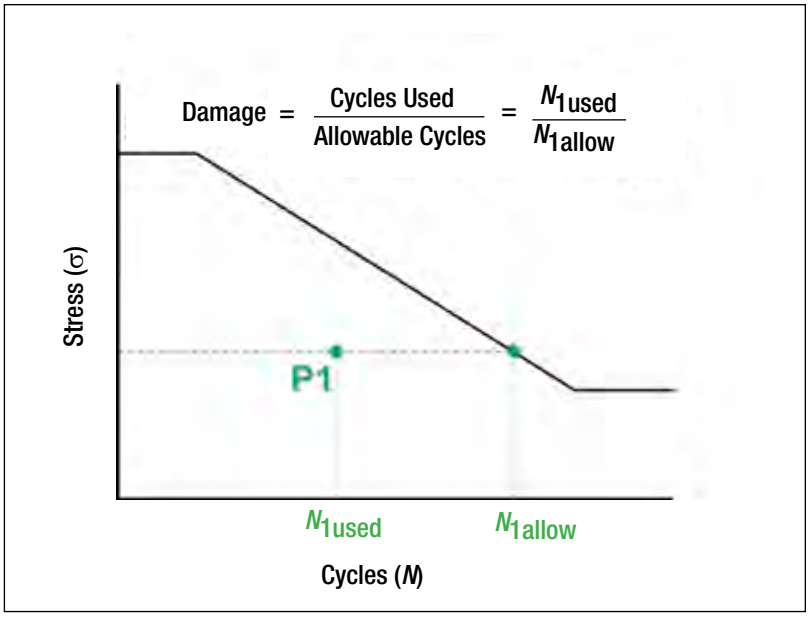

Figure 3—Exaggerated S-N curve to illustrate damage.

make the calculations shown in Figure 5.

One can use two more relationships that are shown in Figure 6. Stress is proportional to a geometry factor, and the number of cycles equals speed X time. Although torque is used in Figure 6, force could just as easily have been used. To move from one point to another on any curve one must use the curve's equation; it shows how the derivation creates a simple method to go from one point to another on the same curve, and how one may use more common duty cycle measurements—i.e., torque (or force), speed and time.

Equation 3 shows the use of torque, geometry, speed and time to replace stress and cycles (also shown in Fig. 6) within the fatigue curve equation, where:

$$\sigma = b \bullet N^m$$

$$\text{Torque} \bullet \text{Geometry Factor} = b(\text{Speed} \bullet \text{Time})^m \quad (3)$$

If one wants to accelerate a gear test, for example, then one knows that the gear tooth stress equals the tooth force from the torque X a geometry factor. That relationship is well documented in technical literature such as AGMA documents (Ref. 3).

The next step is to change each duty cycle point (torque 1, speed 1 and time 1) to the test condition (torque 2, speed 2 and time 2). The derivation to achieve that change is in Equation 4:

$$\frac{T1 \bullet J = b(S1 \bullet t1)^m}{T2 \bullet J = b(S2 \bullet t2)^m}$$

$$\frac{T1}{T2} = \left(\frac{S1 \bullet t1}{S2 \bullet t2}\right)^m$$

$$S1 \bullet t1 \bullet T1^{-\left(\frac{1}{m}\right)} = S2 \bullet t2 \bullet T2^{-\left(\frac{1}{m}\right)} \quad (4)$$

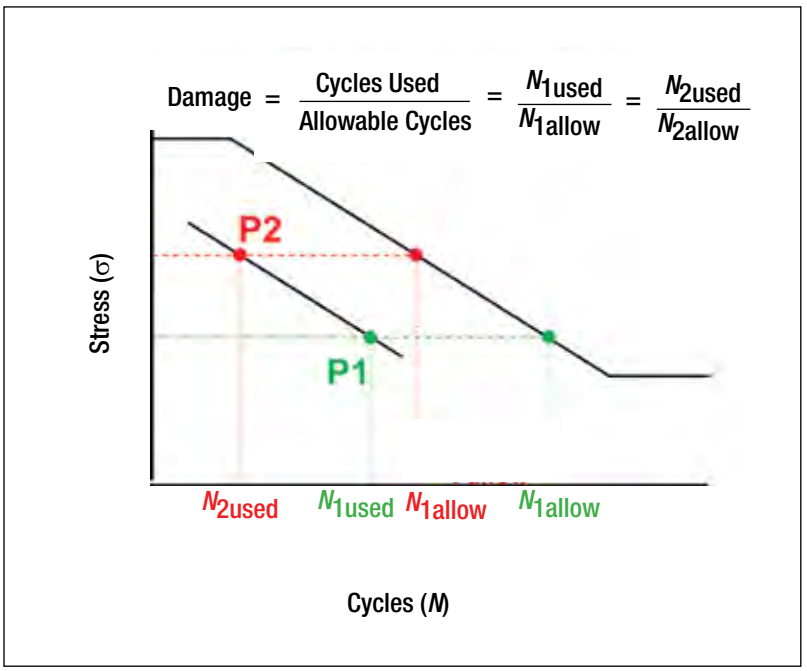

Figure 4—Exaggerated S-N curve with two points.

Duty Cycle

Cycles	Stress (ksi)	Allowable Cycles	Damage
63,251	80	626,024	0.101
56,148	85	368,641	0.152
43,456	90	223,752	0.194
31,958	95	139,526	0.229
5,187	100	89,139	0.058
200,000			0.735

Acclerated Test

Test Cycle	Damage	Allowable Cycles	Stress (ksi)
100,000	0.735	136,092	95

$$\text{Damage} = \frac{\text{Cycles}}{\text{Allowable Cycles}}$$

$$\sigma = 368{,}709\ N^{-0.11448}$$

$$N = \left(\frac{\sigma}{368{,}709}\right)^{-\frac{1}{0.11448}}$$

$$\text{Allowable Cycles} = \frac{\text{Cycles}}{\text{Total Damage}}$$

$$\sigma = 368{,}709\ (\text{Allowable Cycles})^{-0.11448}$$

Figure 5—One accelerated test point replaces complex duty cycle.

Where:
S = Speed (rpm)
t = time (hours)
T = Torque (lb-ft)
J = Geometry Factor
m = Exponent

When each duty cycle point is converted to the test condition, the test condition duplicates the same damage as entire duty cycle.

Figure 7 shows an example of a gear duty cycle converted to a gear test cycle. If the gears were tested according to the duty cycle, it would take 36,000 hours; but an accelerated test would only take 22.6 hours—a fantastic savings in test time.

Accelerated testing must be based on well-known fatigue (S-N) curves and test experience to assure that new failure modes would not be introduced. Without such knowledge and experience, one can introduce failure modes that would not appear in real applications or pass tests that are not related to the material's real fatigue life. However, properly used, accelerated testing can save a company time and money in getting products to market much sooner. And that means bringing in new revenue much sooner.

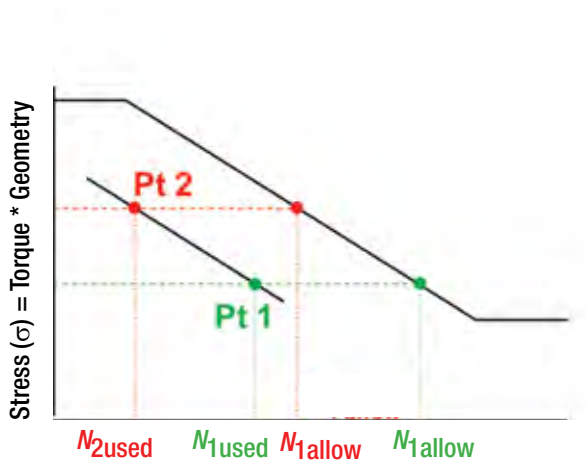

Figure 6—Moving from one point to another.

Duty Cycle

Torque (lb-ft)	Speed (rpm)	Time (hours)
2,100	2,200	5,000
2,000	1,955	6,000
1,745	1,700	8,000
1,625	1,600	10,000
2,050	2,000	7,000
		36,000

0.11448 = m

Test Conditions

Torque (lb-ft)	Speed (rpm)	Time (hours)
1850	2100	0.9
1850	2100	1.5
1850	2100	5.8
1850	2100	12.8
1850	2100	1.5
		22.6 Total Test Hours

$$\sigma = 368{,}709\ N^{-0.11448}$$

$$N = \left(\frac{\sigma}{368{,}709}\right)^{-\frac{1}{0.11448}}$$

$$S1 \cdot t1 \cdot T1^{-\left(\frac{1}{m}\right)} = S2 \cdot t2 \cdot T2^{-\left(\frac{1}{m}\right)}$$

$$t2 = \frac{S1 \cdot t1 \cdot T1^{\left(-\frac{1}{m}\right)}}{S2 \cdot t2^{\left(-\frac{1}{m}\right)}} = \frac{S1 \cdot t1}{S2 \cdot t2}\left(\frac{T1}{T2}\right)^{\left(-\frac{1}{m}\right)}$$

Figure 7—Example of duty cycle conversion to test condition.

References:

1. Shigley, J. E. and L.F. Mitchell. *Mechanical Engineering Design*, Fourth Edition, McGraw-Hill, New York, 1983, Section 7–4, "High Cycle Fatigue."

2. Juvinall, R.C. and K.M. Marshek. *Fundamentals of Machine Component Design*, Fourth Edition, John Wiley and Sons, Inc., Section 8.12 "Fatigue Life Prediction with Randomly Varying Loads."

3. ANSI/AGMA 2001–D04. *Fundamental Rating Factors and Calculations Methods for Involute Spur and Helical Gear Teeth.*

Thomas N. Riley *is chief engineer/CoE component analysis for Eaton Corporation Vehicle Group's truck components operation in Galesburg, Michigan. He has spent many years designing and testing gears, shafts, bearings, enclosures and other components for geared systems. In his career Riley has worked in several industries, including open-pit mining equipment, aerospace and transportation. He also holds several patents as well as an Engineer of the Year award from Eaton.*

Evaluation of Methods for Calculating Effects of Tip Relief on Transmission Error, Noise and Stress in Loaded Spur Gears

Dr. David Palmer and Dr. Michael Fish

Management Summary

The connection between transmission error, noise and vibration during operation has long been established. Calculation methods have been developed to describe the influence so that it is possible to evaluate the relative effect of applying a specific modification at the design stage. These calculations enable the designer to minimize the excitation from the gear pair engagement at a specific load. This paper explains the theory behind transmission error and the reasoning behind the method of applying the modifications through mapping surface profiles and determining load sharing; (the paper) can also be used to explain the results of later experimental validation of various types of tip relief in low-contact-ratio (LCR) gears—from very long to very short. The paper will also demonstrate that although the effects of modification in any specific case can be modeled with some certainty, the same modifying strategy cannot be applied universally; rather, the required operating conditions must be considered. Last, this paper illustrates that the effect of tip relief on transmission error and load sharing is not a "black art" and can be fully explained by applying existing theory.

A study of high-contact-ratio (HCR) gears is presented to demonstrate why it is often necessary to apply different amounts and extents of tip relief in such designs, and how these modifications affect load sharing and highest point of tooth loading. Specific attention will be paid to the phenomenon of extended contact where—if no modification or insufficient tip relief is applied—contact does not stop at the end of active profile and continues beyond this point as the gear rotates, resulting in contact on the tip. This effectively increases contact ratio, has implications for the tooth load and, in particular, may affect the loading position—the highest point of single-tooth contact (HPSTC)—which is relevant to both ISO and AGMA standard ratings. The paper will consider three methods commonly employed in the industry: a simple 2-D mapping procedure carried out on graph paper; a 3-D linear tooth stiffness computation method; and a 3-D finite element analysis (FEA) calculation. The paper will also demonstrate that although in some cases these methods can produce similar results—albeit with varying degrees of accuracy—further examples will be presented that demonstrate behavior which can only be detected using some of the more complex analysis methods. The commercial viability of implementing better quality models against the time constraints in the development process will be discussed and conclusions drawn.

Introduction

Transmission error (TE) occurs when the driven gear is often momentarily ahead or behind its theoretical position in respect to the constant speed position. Gear design methods assume perfect geometric conditions and alignment between components to maintain constant angular velocity, often referred to as "conjugate action." This conjugate action is usually achieved in spur gears by using involute profiles on the teeth. But due to their ability to transmit large loads, the elastic deflection of the material from which the gears are made becomes significant. These small deflections of the teeth cause transmission error (i.e., the driven gear is often momentarily ahead or behind its theoretical position) and also the possibility of extended tip contact that can lead to scuffing of the teeth and excessive noise and vibration. Other causes of transmission error are the manufacturing processes often resulting in deviations from the true involute profile,

and tooth spacing (pitch) errors. For convenience the transmission error is expressed as a linear value measured at the base radius. This eliminates the need to specify on which gear it is measured as is the case with angular measurements.

To compensate for transmission error it is a well-established practice to apply small profile corrections to the gear teeth—often termed tip/root reliefs. An amount of relief (material removed from the flank) is generally agreed upon that is enough to allow for tooth deflections expected at a given load and also errors due to manufacturing tolerances. However the extent of relief (how far down the tooth material is removed) is not so clear, and in spur gears is known to have a significant effect on gear performance.

In the past, designers tended to use empirical values from previous experience. This may not have been the optimum approach, but a lack of information regarding design standards made them cautious about change.

The theory of profile relief to allow for tooth deflections under load was first proposed by Walker (Ref. 1). The suggested amount of relief was equal to the combined tooth pair deflection under load and the suggested extent of what we now know as long relief. Harris (Ref. 2) extended work in this area and covered different types of relief. He also introduced the concept of TE using what have become known as "Harris maps." Harris suggested that the TE curves for different loads could be used to describe the static and predict the dynamic behavior of a gear pair. Gregory, Harris and Munro (Ref. 3) confirmed Harris's predictions experimentally.

Munro (Ref. 4) later explained the fundamental mechanism behind profile relief and established a sound theoretical basis for design. He examined the effects of long and short relief and allowed the extent of relief to be varied at an intermediate position to obtain a low variation of TE at the desired design load.

Mapping 2-D Tooth Profiles to Calculate Transmission Error

The deviations from the involute profile of the pinion and wheel are to be combined from the start of active profile (*SAP*) to the end of active profile (*EAP*) (Fig. 1).

If the combined deviations of all the pairs of teeth for a pair of gears in mesh are superimposed, the pattern of TE as the gears are rotated can be identified. This is achieved by spacing the tooth pair profile deviations one base pitch apart (Fig. 2).

The uppermost point on the curve from all the overlapped tooth pairs gives the transmission error at zero-load. This is similar to that obtained from the single flank tester. When the load is applied from the torque acting on the gear, the analysis of the transmission error in one full tooth length region from *SAP* to *EAP* allows us to form a model of the contact in two dimensions (Fig. 3).

Assuming constant tooth pair stiffness:

At position *a*:

Total load = (stiffness of pair 1) ($x1 + x2$)
+ (stiffness of pair 2) ($x2$)

At position *b*:

Total load = (stiffness of pair 1) ($x4$)
+ (stiffness of pair 2) ($x3 + x4$)

When a whole series of these loaded curves is plotted, we have produced the Harris map. It displays the quasi-static

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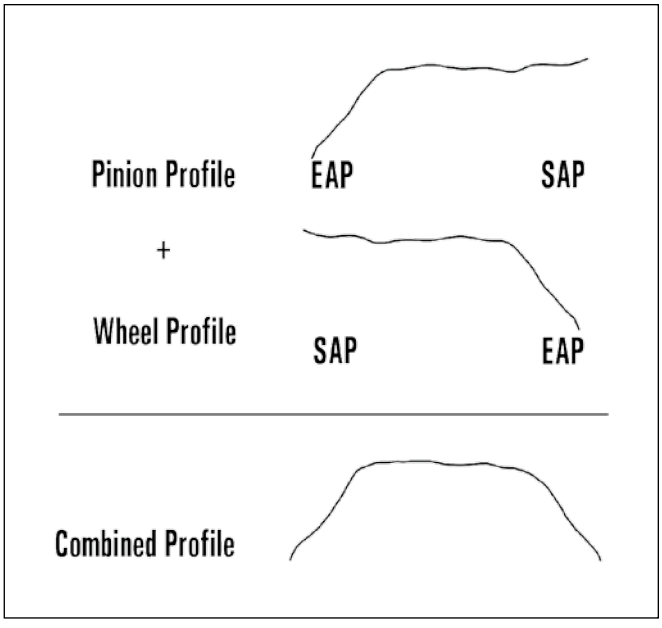

Figure 1—Combined tooth profiles.

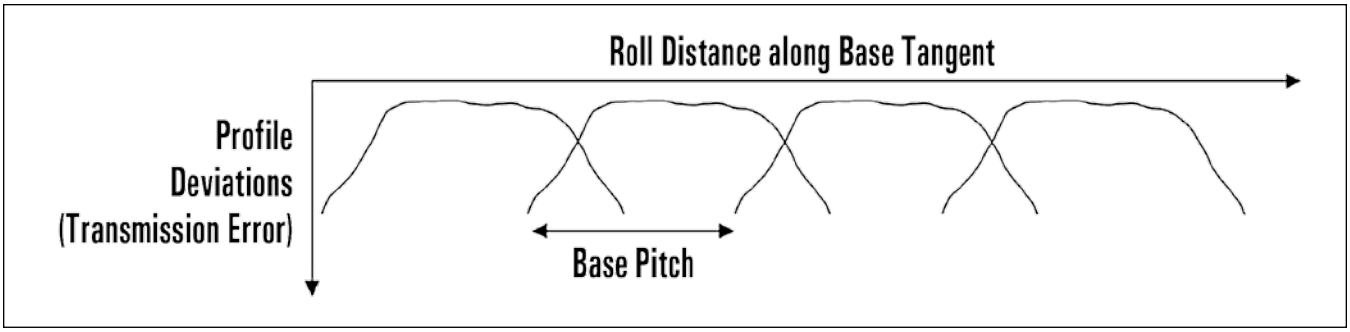

Figure 2—Tooth pair profiles offset one base pitch apart.

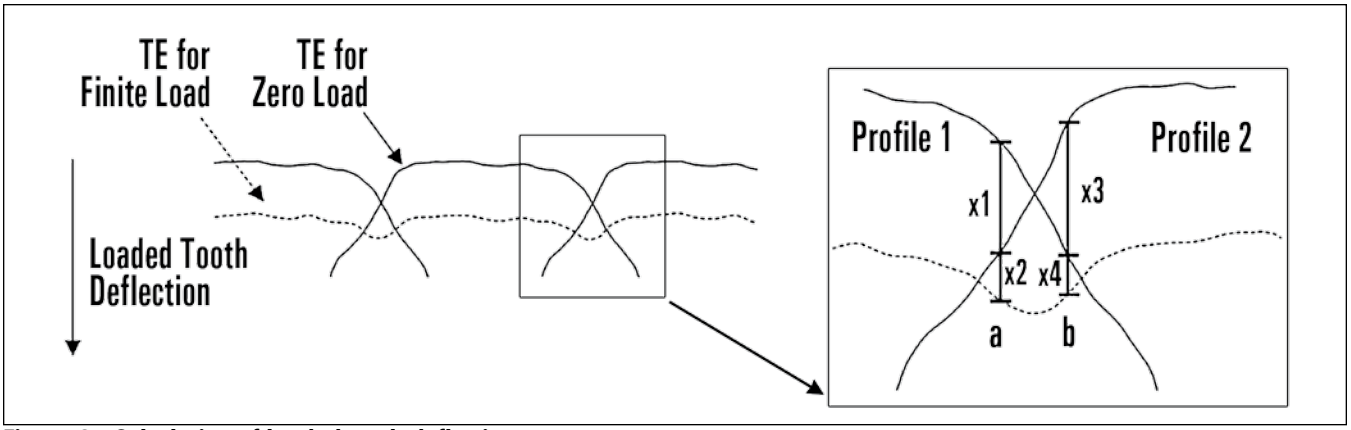

Figure 3—Calculation of loaded tooth deflection.

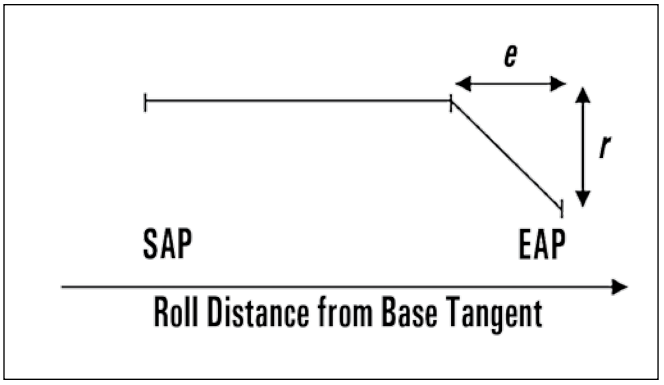

Figure 4—Calculation of amount and extent of tip relief in low-contact-ratio gears.

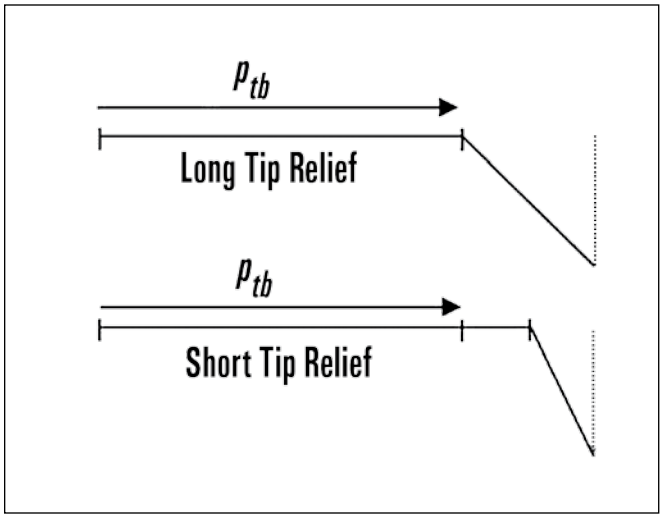

Figure 5—Extent of long and short tip relief.

transmission error for gears under a range of loads. Using this method shows the regions of single- and dual-pair contact and allows the effect of different amounts and extents of tip relief to be examined. Each curve under load shows a different deflection from the nominal zero-load position and changes in form due to changes in tooth load share during engagement. The changes in quasi-static curve form represent changes in displacement in a dynamic system that will ultimately be the source of excitation for noise and vibration in the system. A designer should look for a reduction in the amplitude of this curve form to reduce excitation.

Calculating the Amount and Extent of Tip Relief

The 2-D mapping technique was used by Munro (Ref. 4) to establish the theoretical basis for spur gear profile relief design (Fig. 4; Eqs. 1–2).

$$\text{Extent } e = \frac{\left(EAP - SAP - p_{tb}\right)}{\left(2 - \frac{P_o}{rc}\right)} \quad (1)$$

$$\text{Amount } r = \frac{P_{\max}}{c} + f_p \quad (2)$$

Where:

P_{max}	is maximum load per unit face width (N/mm)
P_o	is design load-per-unit-face width (N/mm)
SAP	is start of active profile roll distance (mm)
EAP	is end of active profile roll distance (mm)
c	is tooth pair stiffness (N/mm/µm)
f_p	is adjacent pitch error (µm)
r	is extent of profile relief from tip
p_{tb}	is transverse base pitch

Where the extent occurs at one base pitch from the start of active profile is termed "long relief," and where the extent occurs at half the remaining distance from the long position to the end of active profile is termed "short relief." The loaded transmission errors of these two types of relief have very different characteristics, as will be described in the following pages (Fig. 5).

The effect of any linear tip relief can be shown on graph paper. The examples for the case of an intermediate relief at varying loads using linear tip relief are shown in the following diagrams. What the theory allows is the adjustment of the extent of relief to obtain low variation in transmission error at a specific design load.

The charts in Figure 6 show that the amount and extent can also be adjusted to account for adjacent pitch errors.

Additional relief is applied to compensate for the pitch error and the extent of relief made slightly shorter to maintain the design load low TE, in this case Load 2.

Experimental Validation of Munro's Theoretical Basis for the Application of Tip Relief

Munro's theory of transmission error was experimentally proven during the 1990's (Ref. 5), where a series of six low-contact-ratio spur gears with the same amount of tip relief but different extents were tested (Fig. 7).

The difference in the overall TE level of the curves in the measured data in Figure 7 is due to bearing deflections not considered in the 2-D mapping.

The peak-to-peak TE and the measured sound pressure level for the long, short and intermediate tip relief cases are shown in Figure 8.

3-D Effects and Using a Simple Strip Theory to Calculate TE

Although the 2-D method produces reasonable TE predictions, there are effects from sources such as lead modifications or mesh misalignment across the tooth surface that cannot be taken into account using this method. A simple strip model can be used to approximate 3-D effects where the gear is divided into a series of strips, or narrow spur gears all acting in parallel but independent to each other. They can even be incremented rotationally to represent a helical gear (Fig. 9).

Each strip has its own stiffness, which can be a single value or vary from *SAP* to *EAP*. The example in Figure 10 shows a case of long relief where the tooth stiffness is reduced to 70% in a parabolic manner from the pitch point to the *SAP* and *EAP*. Investigations into measuring tooth stiffness have previously been undertaken (Ref. 6).

The example in Figure 11 shows that misalignment or lead modification (lead crown in this example) can change the effective tooth stiffness. This could change the optimum load level and the contact may extend to the *EAP*, even though enough tip relief was applied to prevent this in the 2-D model since the tooth will deflect more.

The strip method is reliant upon the tooth stiffness data being representative of the tooth geometry. Improvements to the model employ a tooth stiffness calculation and also link the deflections of each strip to each other across the face width.

The stiffness is made a function of height position on the tooth profile and lateral position across the tooth face (Refs. 7–8). The 2-D and improved strip methods represent a quick and relatively easy calculation, especially when converted to a computer program. But they have the limitation of being an inaccurate representation of the behavior of the gear, as there is in fact a complex relationship between the force applied and the deformation. They will give a good approximation in general operation, but may be found to be inaccurate in limiting cases or extreme geometry. This can have an impact when designing for safety-critical, specialized or high-cost applications.

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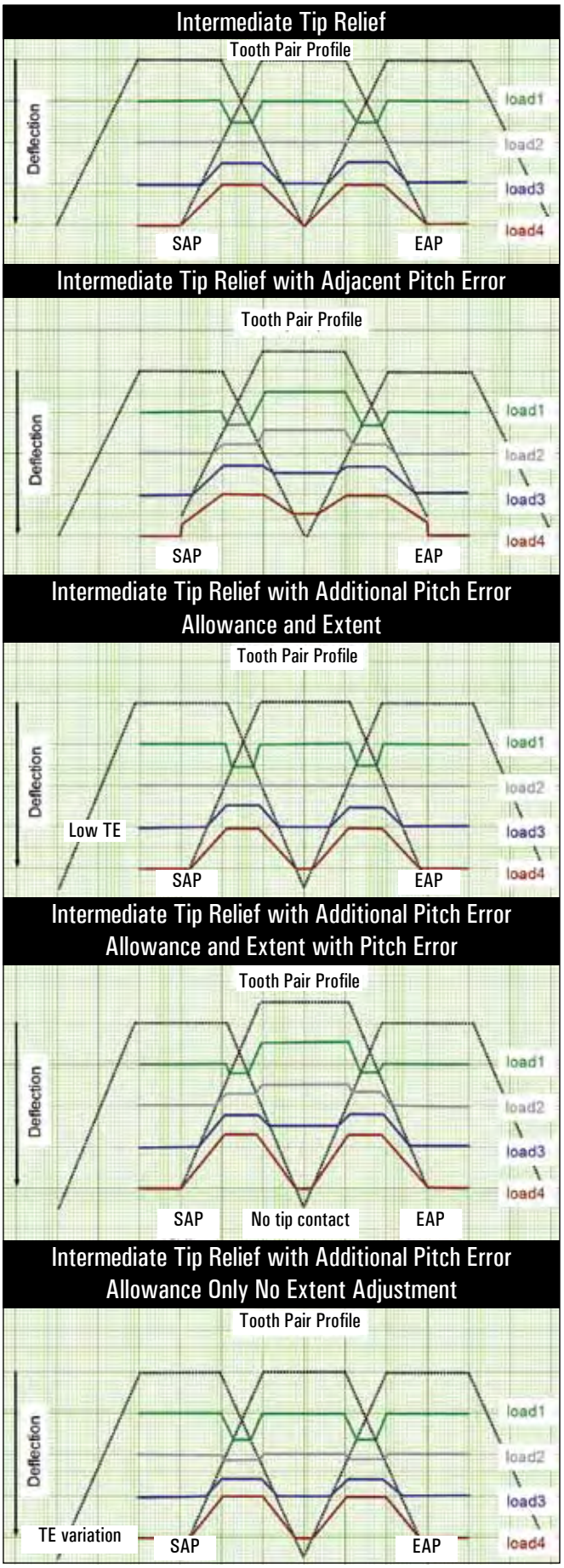

Figure 6—Mapping 2-D transmission error.

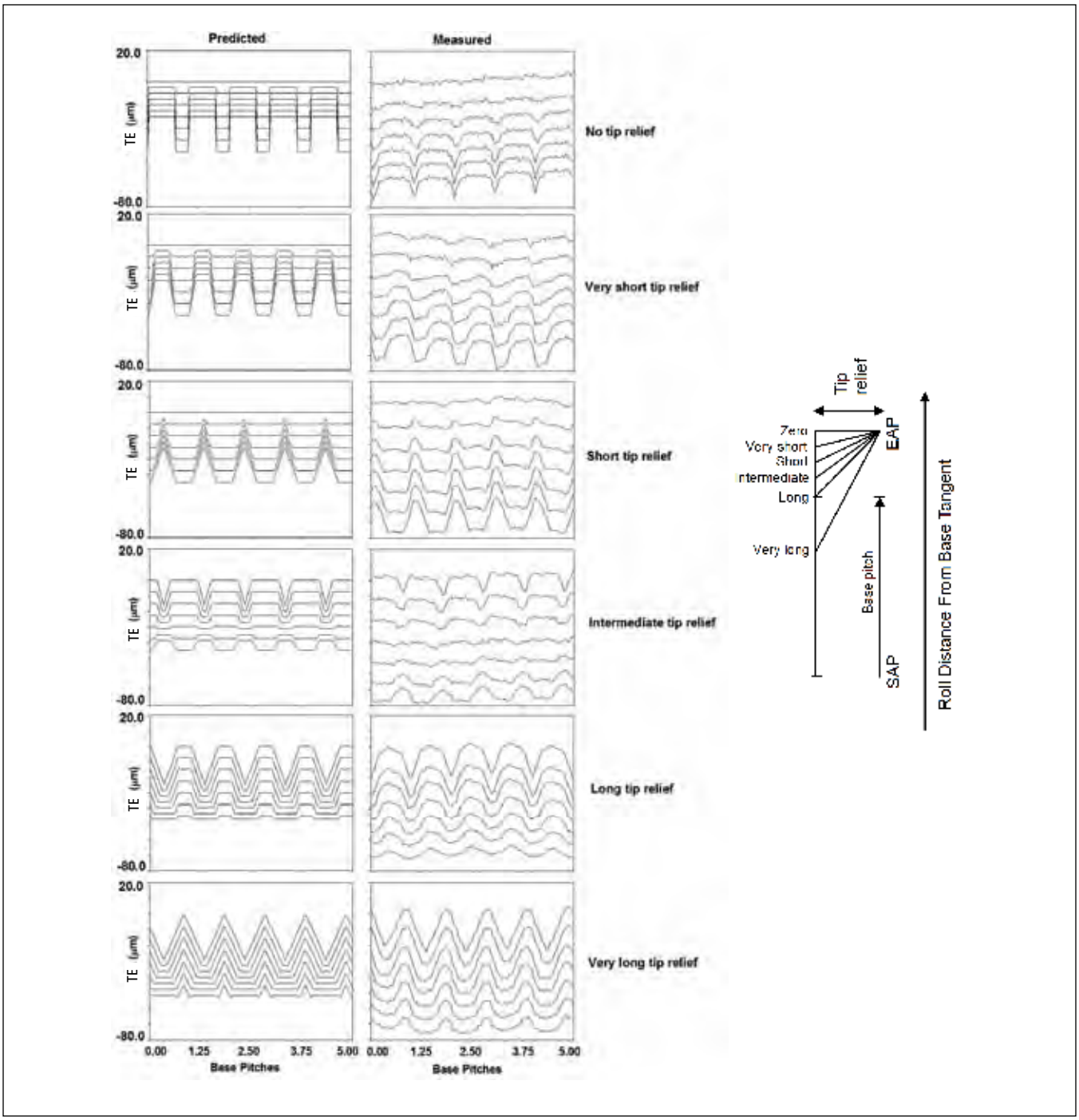

Figure 7—Measured and predicted quasi-static transmission error.

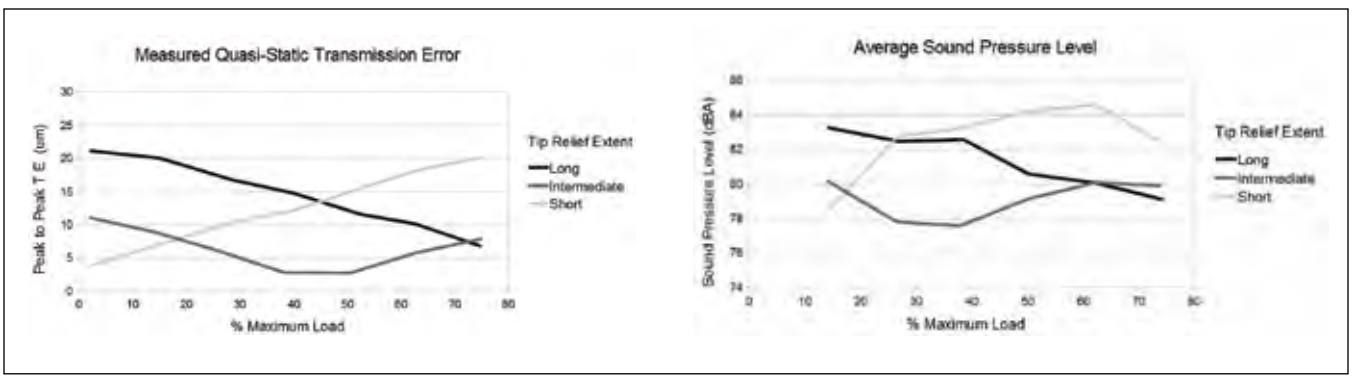

Figure 8—Measured quasi-static transmission error and sound pressure level.

More Advanced 3-D Tooth Contact Analysis Using FEA for Tooth Bending Stiffness

A finite element (FE) method to calculate tooth stiffness provides an improved level of accuracy, as it represents the relationships between all neighboring points on a surface and sub-surface, regardless of geometry. Previously an FE calculation used to be highly specialized, requiring hours—or days—to complete. Due to improvements in computer power the calculation can be reduced to minutes, thus enabling the development of a practical design tool. The rest of the examples in this paper are produced using *GATES* (*Gear Analysis for Transmission Error and Stress*) software origi-

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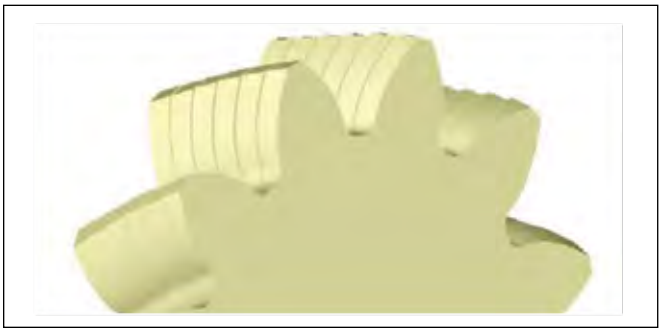

Figure 9—Division of the gear into strips.

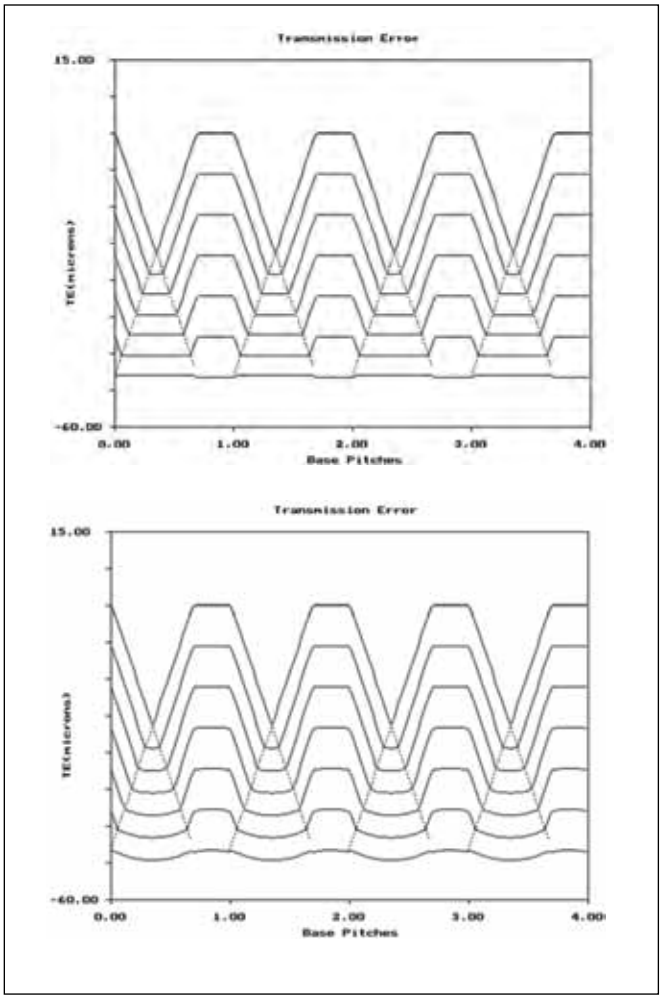

Figure 10—Long relief with variable tooth pair stiffness.

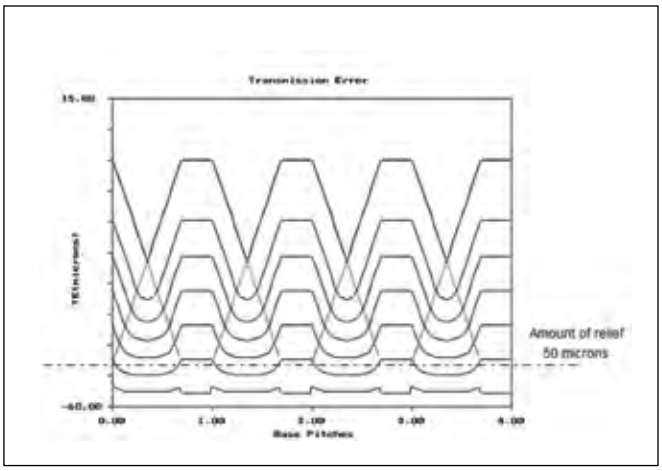

Figure 11—Long relief with lead crown calculated using the strip method.

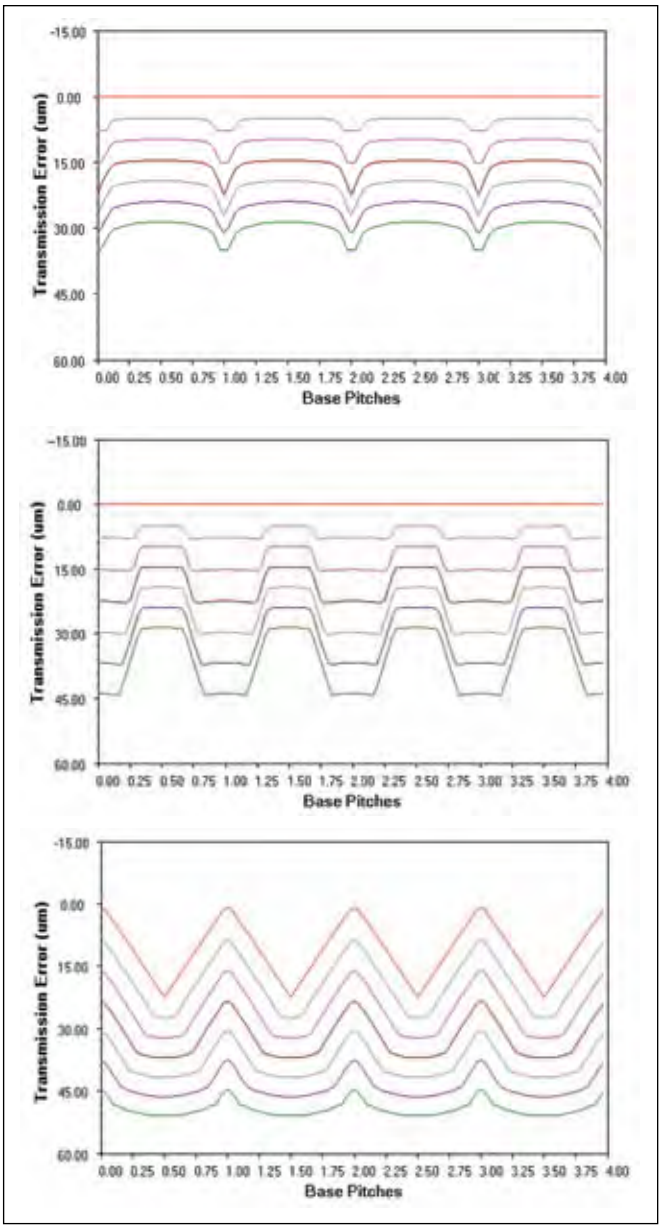

Figure 12—Transmission error calculated using *GATES* program.

nally developed at The Design Unit, Newcastle U.K. The software calculates the tooth stiffness using a 3-D FE model. It also includes effects such as extended contact at the tip of the gear if insufficient tip relief is applied. There are other programs commercially available that use advanced methods for the 3-D stiffness effects. The transmission error results are shown in Figure 12 for the zero, very short and very long tip relief case. For the zero tip relief case the results show the effect of the extended contact as a rounded effect rather than a step change in the TE. This effect will be covered later in the paper.

The *GATES* tooth contact analysis is used to review effects of tip relief in high-contact-ratio gears and their potential to produce lower transmission error levels. Some of this material is covered by Yildirim (Ref. 9), who extended Munro's theory to high-contact-ratio spur gears.

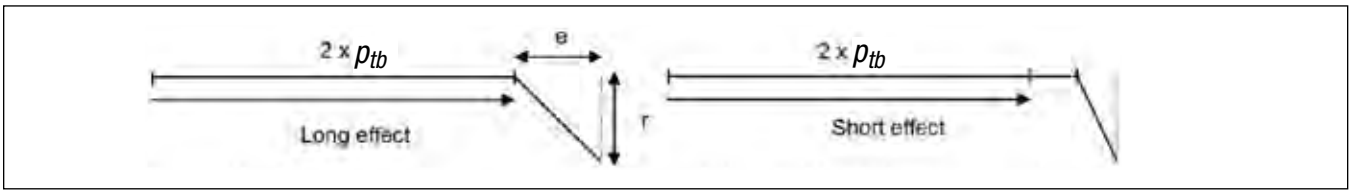

Figure 13—Calculating the amount and extent of tip relief in high-contact-ratio gears.

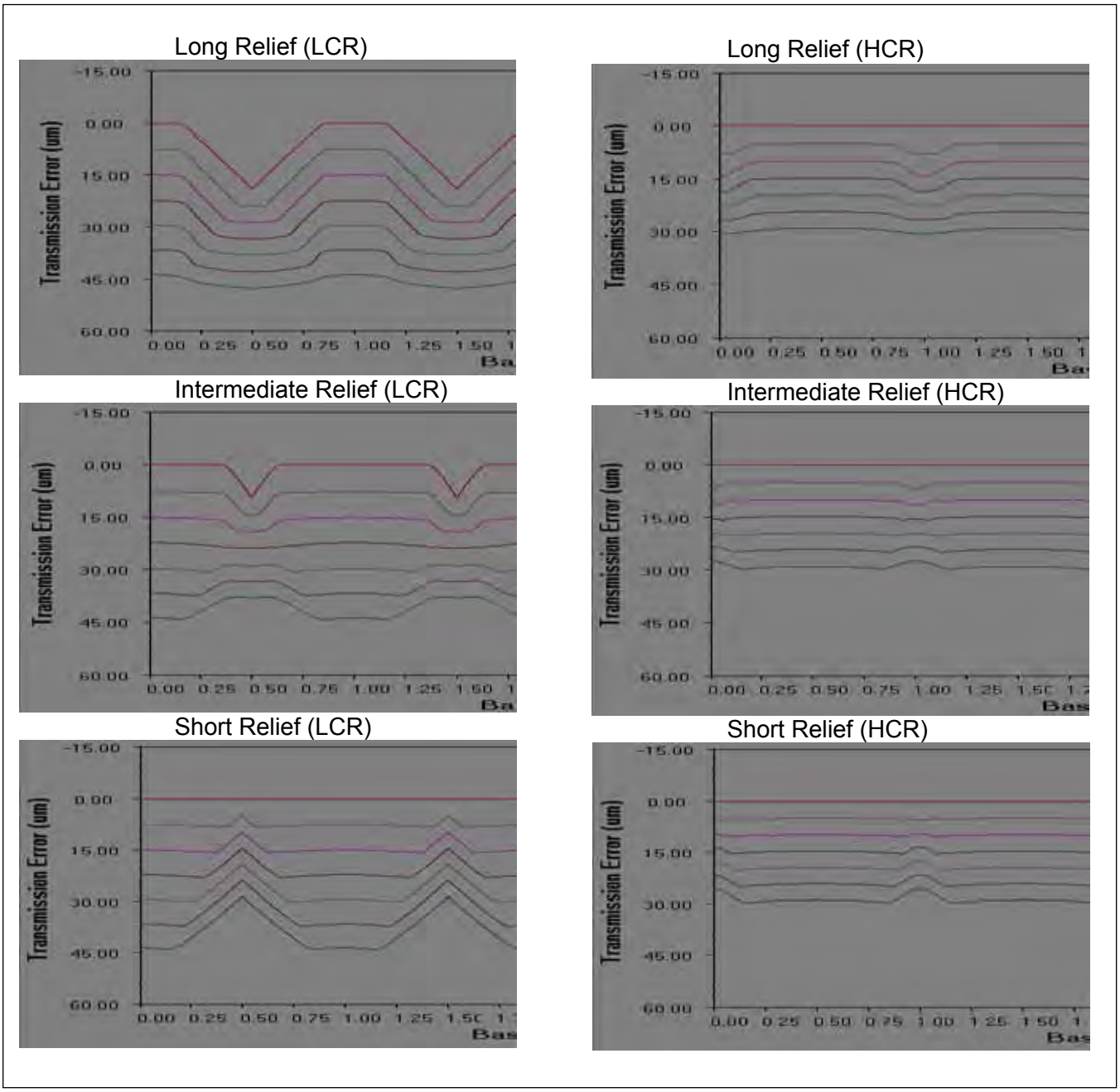

Figure 14—Long, short and intermediate relief in high-contact-ratio gears.

In high-contact-ratio gears the long and short definitions of tip relief are no longer valid, as one base pitch from the SAP would not extend further than 50% of the tooth roll length. However a similar effect to long and short tip relief can be obtained by applying the tip relief between two base pitches from the SAP for long effect and half the remaining distance for short effect (Fig. 13; Eqs. 1–2).

Tip Relief in High-Contact-Ratio Spur Gears

Note that the position two base pitches from the SAP is often called the highest point of double-tooth contact. If we also assume that there are a minimum of two tooth pairs sharing the load, then the amount of tip relief can be greatly reduced to almost 50% of that of the LCR case.

The problem with this approach is that if the contact ratio is just above 2.0, then two base pitches extend almost to the end of active profile and leave only a small distance in which to vary the extent of tip relief.

The results show that, unlike LCR gears, there are two optimum design loads where low transmission error occurs. The first is always at zero-load; the other can be designed to fall at any load between zero and maximum. The long effect has the second optimum load at maximum, the short at zero.

The three cases of tip relief are shown (Fig. 18) and compared to low-contact-ratio gears. The gear design is identical except for the outer diameter that is varied to modify the contact ratio to 2.32. In the design, adequate bottom clearance was provided to allow for this extension of the outer diameter. It is clear that correctly designed tip relief in HCR designs can produce much lower TE. The applied amount of tip relief is 50% of that of the low-contact-ratio case, as there are a minimum of two teeth pairs sharing the load (Fig. 14).

If incorrect tip relief is applied using the theory for LCR gears—i.e., too large an amount and an extent too long—the transmission error will increase and the load sharing will

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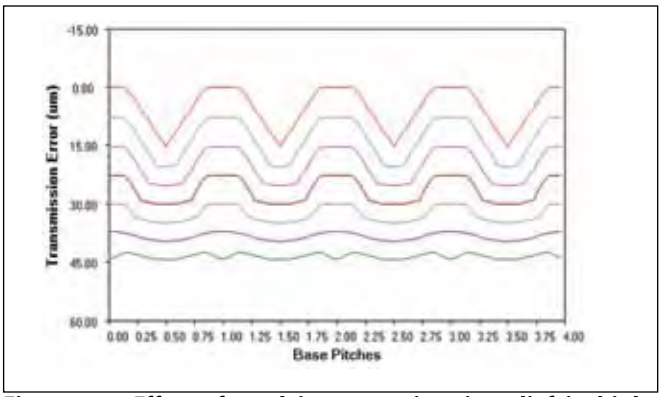

Figure 15—Effect of applying excessive tip relief in high-contact-ratio gears.

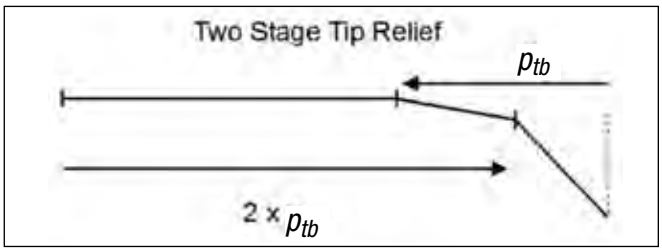

Figure 16—Two-stage tip relief extent in high-contact-ratio gears.

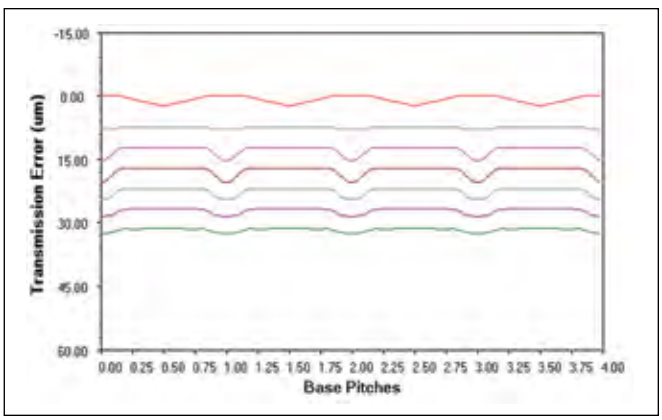

Figure 17—Transmission error for two-stage tip relief in high-contact-ratio gears.

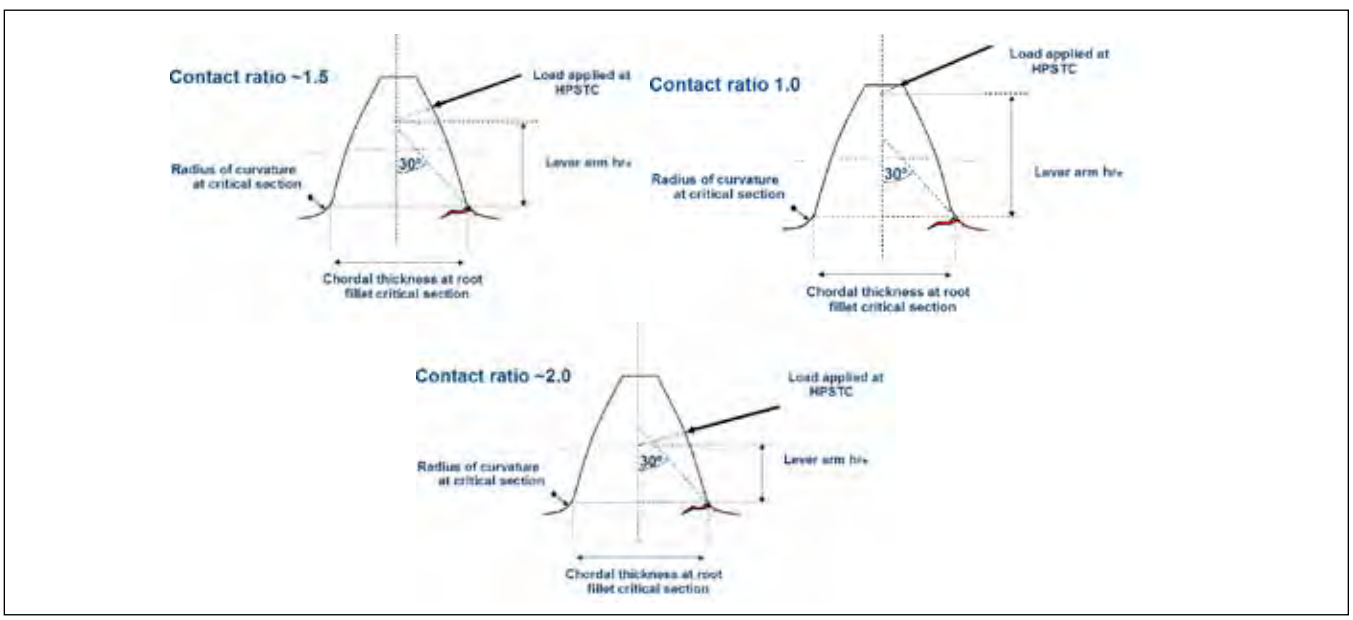

Figure 18—Effect of the contact ratio on the highest point of single-tooth contact.

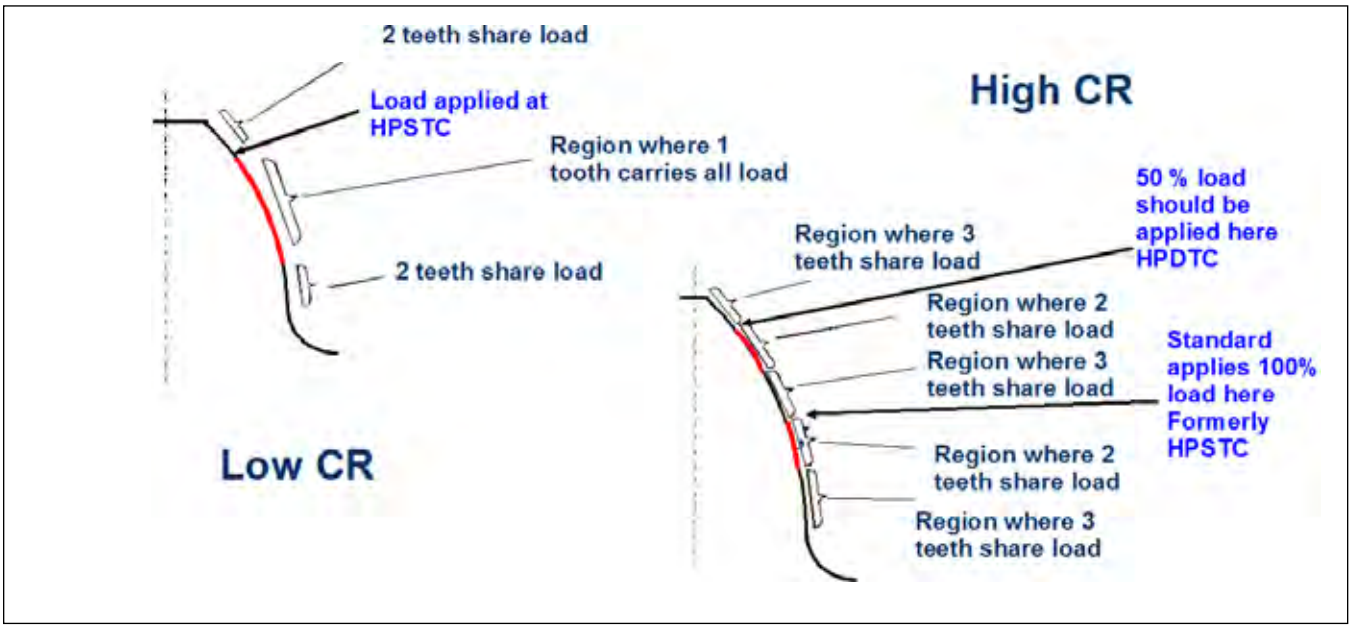

Figure 19—Regions of single-, double- and triple-tooth loading.

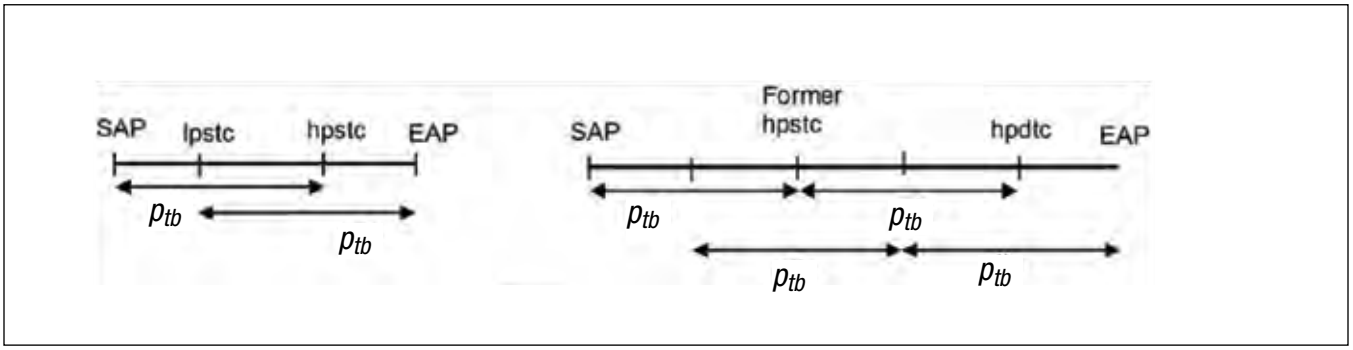

Figure 20—Highest and lowest point of double-tooth contact.

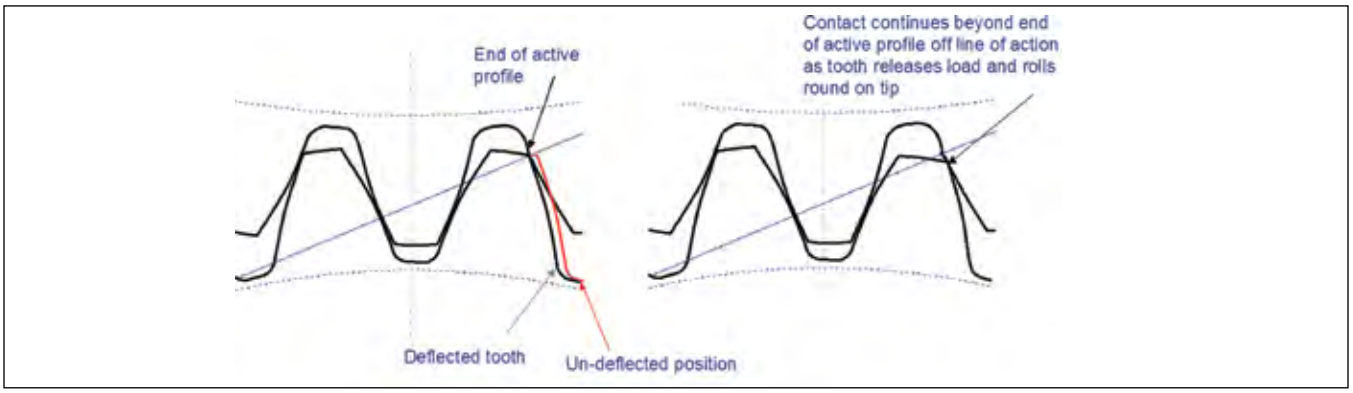

Figure 22—Measured and predicted results for extended contact.

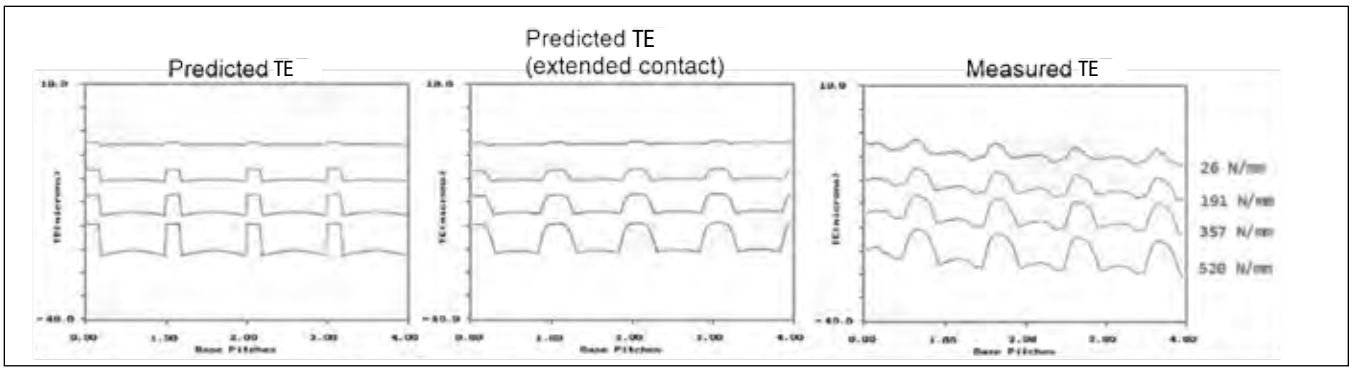

Figure 22—Measured and predicted results for extended contact.

decrease. An example is shown (Fig. 15) where the tip relief was one base pitch from the EAP.

Another type of relief that Yildirim employed was two-stage tip relief. Since the first design load for correctly applied relief always occurs at zero, a two-stage relief can be used to vary the design load from zero (Ref. 9) and can be shown using the *GATES* program (Figs. 16–17).

Tooth Bending Load and Stress and the Effect of Extended Contact

For a low-contact-ratio (LCR) spur gear, the bending stress is calculated with load applied at the highest point of single-tooth contact (HPSTC). The effect of the contact ratio is to vary the position of the HPSTC and thus lower arm height (Fig. 18).

Once the contact ratio increases above 2.0 the HPSTC passes the central part of the active region and therefore no longer exists as such. There now exists both a two- and three-pair contact region and a position termed the highest point of double-tooth contact (HPDTC) (Fig. 19).

These positions can easily be defined by one or two base pitches from the start of active profile (SAP) and end of active profile (EAP) (Fig. 20).

The ISO standard uses the same calculation of the HPSTC for loading in high-contact-ratio gears, whereas, theoretically, the HPDTC with 50% of load should be used. However, upon inspection of results using the *GATES* program, it can be shown that the effects of tooth flexibility, extended contact and tip relief impact upon whether using the HPDTC or even the HPSTC is a valid assumption.

Extended Contact and the Effect on Tooth Loading

It is not often understood that the highest stressed point on the tooth for single-tooth loading on a gear with no tip relief does not occur at the theoretical HPSTC. This is due to extended contact that occurs as the loaded tooth is restored to its original, un-deflected state at the end of active profile (Fig. 21).

Extended contact effectively increases the contact ratio, thus lowering the actual HPSTC. The measured results show

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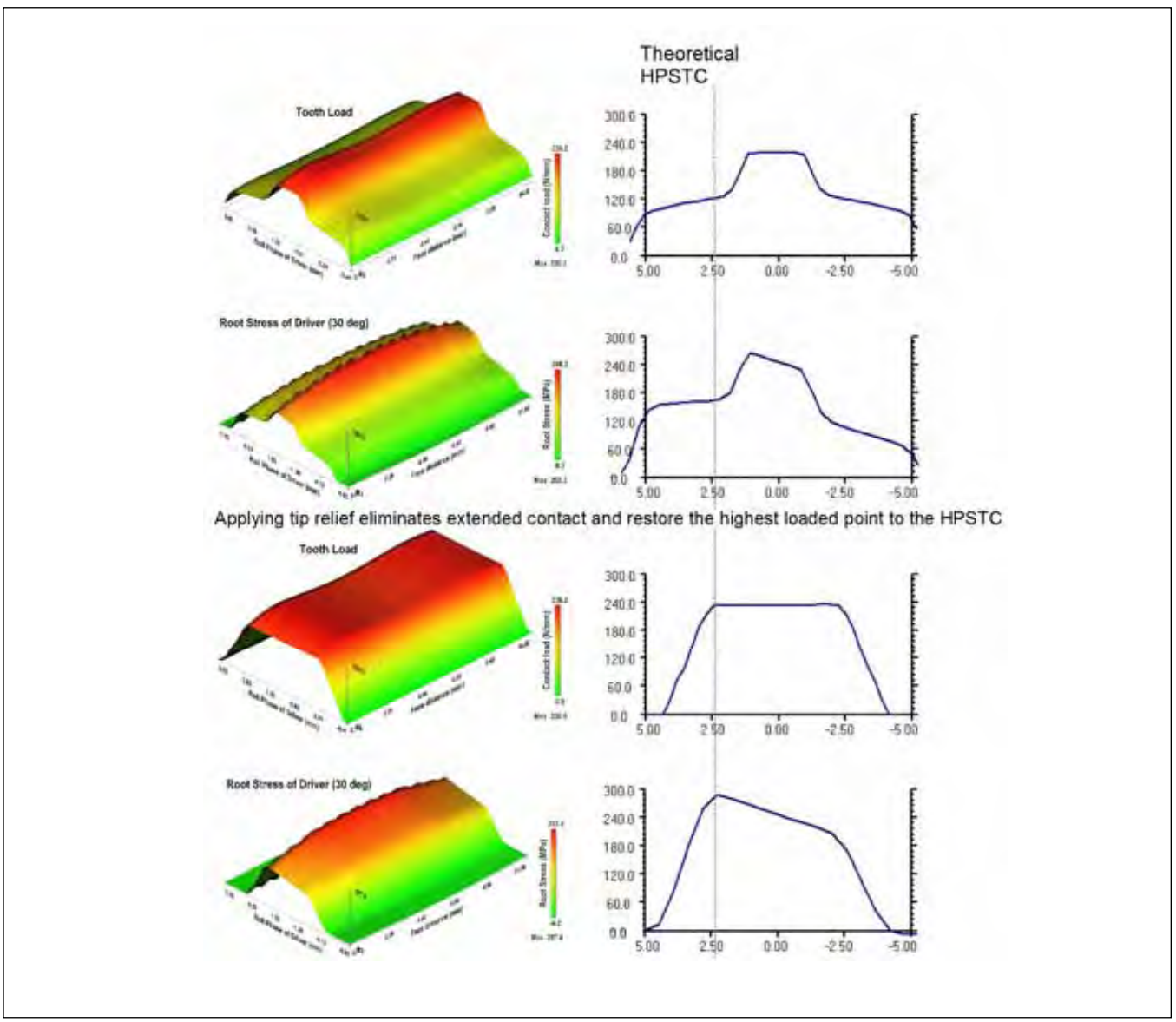

Figure 23—Effect of extended contact on highest point of tooth load.

the phenomenon of extended contact on an HCR spur gear (Ref. 6; Fig. 22).

Using the *GATES* program, the effect of this extended contact on the highest point of tooth loading can be shown; a different example is used to show this (Fig. 23).

Figure 24 shows results for tooth load (N/mm) and stress (MPa) against roll path with increasing contact ratio.

Where tip relief was applied, it was done in order to compensate for the single-tooth pair deflection. This extent is referred to as short—midway between HPSTC and tip. This is because if the extent was long HPSTC, then the tip reliefs would overlap for pinion and wheel if CR is above 2.0.

The results show that applying tip relief suitable for low-contact-ratio gears to high-contact-ratio gears reduces the load sharing and thus increases tooth load and stress. For example, for the contact ratio of 2.2 the load and stress are 236 N/mm and 274 MPa with LCR tip relief applied. However, when tip relief more suitable for HCR gears is applied (no further than HPDTC and less due to increased load sharing), the tooth load and stress are 152 N/mm and 176 MPa—or approximately 35% lower.

As mentioned, the problem with HCR tip relief is that the HPDTC approaches the tip as the contact ratio comes down to 2.0. This effectively means the extent of relief becomes

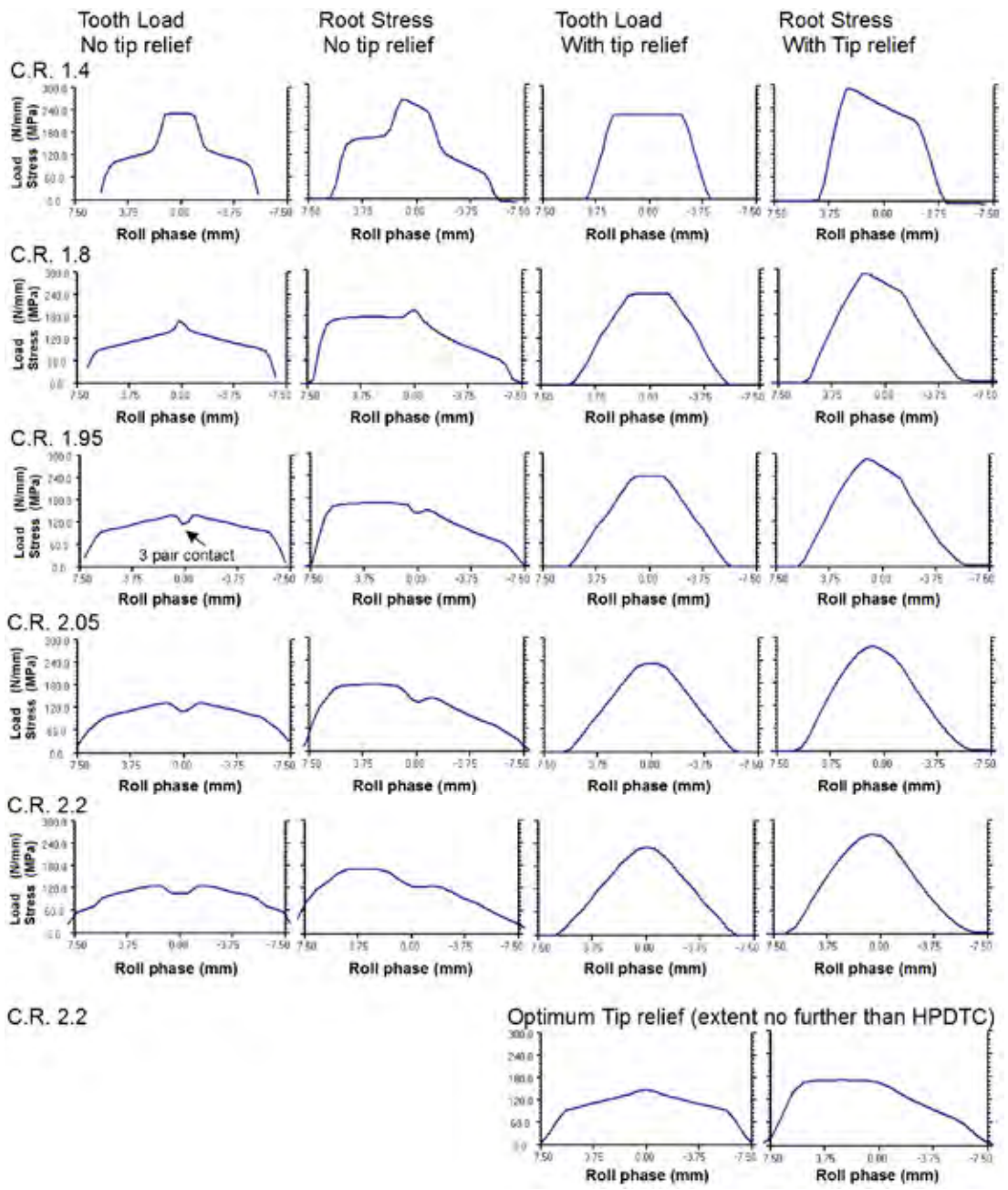

Figure 24—Effect of contact ratio on tooth load and stress.

very short, approaching zero; i.e., no tip relief. The effects of very short relief on scuffing and micropitting and the dynamic effects due to the rate of tooth loading may also be a problem. For contact ratios just below or just above 2.0 it may not be possible to apply tip relief to maintain the beneficial effects of increased load sharing.

The results also show that the highest point of tooth loading depends critically on the tip relief as the contact ratio increases. It is not sufficient to assume the high-contact-ratio gear should be loaded at the highest point of double-tooth contact.

Conclusion

This paper demonstrates that valid theories currently exist on how to apply tip relief to control the transmission error in spur gears, and have also been experimentally validated.

This paper has also described how the applied relief can induce different TE characteristics in the same gear pair, and that these will vary with load. Correct application of the relief will result in reduced excitation—the source of noise and vibration—for a specified load.

Some assumptions made by the standards and simple equations relating to load are not applicable across all designs and applications. A simple model may be created using a 2-D mapping technique to explain TE during a load cycle. Computer models are a practical design tool in modern design to facilitate this.

For high-contact-ratio gears, the effects of tooth flexibility and the ability to calculate tooth load and stress should be addressed with the use of a more sophisticated tooth contact analysis program, rather than a simple 2-D mapping technique.

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Dr. Mike Fish *obtained his Ph.D.—"Transmission Errors in Precision Worm Gears"—from Huddersfield University in 1998 under Prof. Bob Munro. The work produced software to model manufacturing and operating characteristics for more efficient production, and had industrial support from five industrial partners as well as the Department of Trade and Industry. Fish then started at Holroyd MTR—then part of the Renold Group—in 1997. From 2001 he worked for Reishauer AG and then in 2003 for KISSsoft AG, both based in Switzerland. He formed Dontyne Systems Limited in 2006 and is responsible for its general management and business development, including the development of bespoke solutions for integration of Dontyne software into other design systems, and integration with machine tools and metrology equipment for more efficient production.*

Dr. Dave Palmer *obtained his Ph.D.—"The Effect of Profile Relief in Narrow Face Width Parallel Axis Gears"—from Huddersfield University in 1998 under the supervision of Prof. Bob Munro and with industrial support from Eaton Ltd. He developed his knowledge and experience in gear and transmission design further for almost 9 years with Romax Technology Ltd. as a software designer and applications engineer. Palmer became co-director of Dontyne Systems in 2007, responsible for the development and support of software tools for the design and analysis of gear systems, known collectively as the* Gear Production Suite.

Rattle: Addressing Gear Noise in a Power Take-Off

Mikel E. Janitz

At Muncie Power, the objective of noise and vibration testing is to develop effective ways to eliminate power take-off (PTO) gear rattle, with specific emphasis on PTO products. The type of sound of largest concern in this industry is tonal. Tonal noise can be described as a distinct frequency or range of noise characterized as irritating, annoying and enduring. The testing was not concerned with nor focused on gear whine. Gear weight and size (inertia) also plays a role in vibrations and rattle, but additional testing is required to develop a full understanding of those characteristics and their relationship to rattle. Therefore inertia, gear size and weight are not discussed in this report. The noise and vibration investigated were

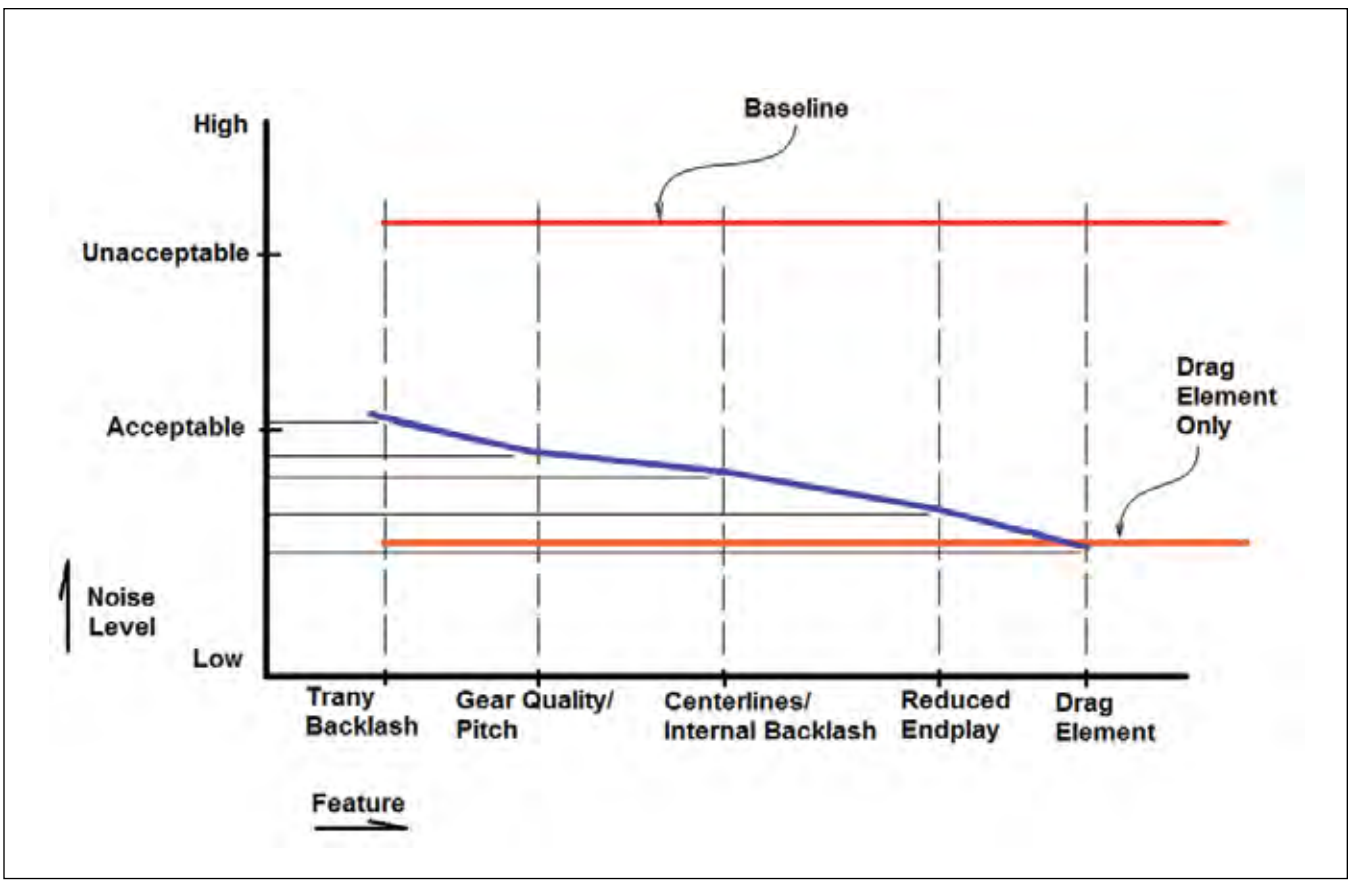

Figure 1—Baseline noise testing conducted on a diesel-powered, class-3 cab with an automatic transmission and recorded noise level.

relevant to transmission speed. The rpm range investigated for this report was as low as 600 rpm and as high as 2,100 rpm. Test data was collected using an array of sensors on our truck—coupled with our data acquisition software—and then compiled and analyzed in our test lab.

Work trucks are much quieter today, which is driving the need for auxiliary power to do the same. Gear noise, whine and rattle are of course not new but are more noticeable now than ever before. In fact, gear noise is more noticeable today as gas and diesel motors and powertrains are much quieter. Given that noise is more noticeable, the engineers conducted tests to identify and isolate particular PTO features that contribute to it. Based on a battery of tests, the engineers have identified the top contributors. The following report and graph highlights and prioritizes those contributors discovered to have the greatest impact on noise and vibration. By addressing them, noise and rattle can be significantly reduced. More importantly, this will improve customer satisfaction through product durability and reliability.

From research, testing and data analysis it was discovered that rattle is a system-dependent phenomenon that may be present or absent, depending on the power take-off and a vehicle's characteristics. This simply means that a power take-off that presents no rattle on one vehicle might rattle on a different vehicle. It is also possible for a power take-off to exhibit different levels of rattle for each side of a vehicle's transmission. Because rattle is a system-dependent phenomenon, it is extremely difficult to control it with a single solution or by using one solution in a particular manner for all PTO rattle. Therefore testing was carried out in distinct steps to better control and analyze the variables.

The first step in the testing process was to create a baseline. Baseline noise testing was conducted on a diesel-powered class 3 truck with an automatic transmission. (See Figure 1 for a depiction of the noise level recorded.) Before the gear set was mounted, meticulous measurements for external backlash, gear profile and lead, internal backlash and end-play were recorded in the QA lab by our CMM and CNC gear checker; all improvements are based on these baseline measurements. Once fully assembled, the gear set was run at idle (approx. 700 rpm), the noise level (dB) was recorded and a baseline was established. The red line in Figure 1 represents the unacceptable sound level from that test. At this point the engineering team began work on specific component features to improve or reduce noise and rattle—one step at a time.

Note that in Figure 1 the graph depicts the effect on the noise level as each feature is addressed. As one can see, the red baseline is well above the acceptable level. Why noise is unacceptable to customers and end users is due to many factors. One in particular is very subjective—i.e., the tonal quality of the noise. In general noise is annoying at best and, worst-case, irritatingly painful. Some tangible features identified by the engineers were excessive backlash between the transmission output gear and the PTO input gear; reduced gear quality; smaller gear pitch; high internal backlash between gears; gear centerlines at top of tolerance; and high tapered bearing end-play. Another feature affecting noise is drag or rotational resistance. The more drag within the system, typically, the less noise and rattle are perceived. (*Drag and its effects are discussed in more detail later in this paper.*)

It is also noted here that with all the testing conducted the graphed data indicates the features are additive. Therefore, each improved feature can reduce noise by some amount. Noise can also be reduced proportionally to the number of features improved; it is a compromise between the benefits of reduced noise versus processing cost. It was discovered one can change many component features, but the backlash between the transmission gear and the

continued

Mikel Janitz *is manager of engineering for Indiana based Muncie Power, where he is responsible for the company's test facility and product development. A graduate of Oklahoma State University with a B.S. in engineering and a Master's in engineering management, Janitz has authored numerous papers and holds five patents.*

PTO gear set must be addressed first or the other steps have minimal impact. But the design and control of backlash has its limitations. Backlash is controlled at installation and by gasket selection by the mechanic. Care must be taken to properly mount and install the gear set and torque the fasteners to achieve optimal noise levels. This is in the control of the installer at this point. For the battery of tests this was closely controlled to ensure the reliability of the data. Industry standard ranges from .006" to .012". Intuitively, the lower the backlash setting, the better the noise quality, and that is a very important relationship to manage.

After establishing the appropriate backlash between transmission gear and PTO gear the next feature worked on was gear quality. All the gears in the PTO were addressed. Improving gear quality can be costly; for example—near-net forgings, shaping vs. hobbing vs. grinding, etc. It is important to understand the relationship of manufacturing cost vs. reduced noise benefits. Testing results demonstrated that higher gear quality and gear pitch produced a detectable reduction of noise. The reduction was not only measurable but detectible to the human ear. For example, a change in 1 dB is nearly undetectable to the human ear, but a change of 3 dB is detectable to the average person and almost anyone can hear a change of 5 dB. Thus the tonal quality improved as well. Note gear quality went from a baseline as low as AGMA 6 up to AGMA 10. Gear quality was therefore the second-highest contributor in reducing noise (Fig. 1).

The next step to reduce noise focused on internal backlash and gear centerline control. These are combined since they are so closely related. The engineers determined this is a cost-effective means to reduce noise. Accurate CNC equipment, programming and tooling must be used in manufacturing to hold and repeat tight centerline tolerances. Testing indicated it is necessary to control internal backlash before moving to the next step. From a design standpoint it is important to specify and control internal backlash but the results show this had little effect on reducing rattle and noise detectible to the human ear. Hence, minimal positive impact to the end user. This was an important finding in the test. Testing proved this had the smallest impact on reducing noticeable noise of all the features investigated.

Rattle and noise creates sound waves we feel and, therefore, hear. The waves of sound come from vibration between the gear, shaft and bearing set. If the bearing set is loose (for example excessive end play >.003) the vibrations are more pronounced and the noise is noticeably louder and more annoying. Rattle like that is a huge customer dissatisfaction issue. If the end-play is reduced the noise is reduced proportionally, testing indicates. The baseline end-play was excessive, consequently the noise was unacceptable. When the end-play was reduced by 25% the noise was noticeably reduced as well. However, end-play could not be completely eliminated given the current design; therefore, rattle cannot be completely eliminated. If it were a case in which the bearings could overheat and burn up, then you have a completely different issue to contend with. Bearings need to be sized properly, lubricated appropriately and allowed to react throughout their temperature range. End-play was last on the list of features to address for this set of testing and reporting. There are other component issues effecting vibration and rattle; for example—gear size, inertia, weight, material and geometry, to name a few. These features were not addressed at this time as it would require significant time with physical testing, computer simulation and 3-D modeling to go down that path.

The last feature studied was drag or rotational resistance. This phenomenon was studied to better understand the effect of drag on noise and vibration in a gear train. As Figure 1 shows, the orange line represents the baseline gear set with the addition of drag only; this is drag above and beyond parasitic drag. Parasitic drag is friction or interference due to normal fits and tolerances. This type of drag element is measurable and specifically designed into the PTO (a drag element in and of itself). A drag element by itself will reduce noise if the drag force is significant. For example, a rotational resistance of 10 to 15 in-lbs. is sufficient to have a noticeable effect on noise. A lesser drag element in series with other features discussed will reduce noise as well. The downside of introducing a drag element is the inefficiency it creates; it creates heat and requires power (uses fuel) to overcome resistance forces. The graph also indicates noise was at an acceptable level with only a significant drag element, without other features improved. The question then becomes whether the inefficiencies can be tolerated or whether the operating costs justify the reduction in noise. Drag can come in many forms; for example, tight bearings, excessive hydraulic fluid levels, friction between clutch plates and shaft loads. Other designed parts can be introduced to create drag as well. Drag was last on the list to test because of the negative aspects associated. The graph indicates that noise can be reduced to acceptable levels without drag, but it also shows noise can be reduced by doing nothing other than adding drag.

There are many issues affecting noise and methods to reduce vibration. Some not discussed or tested here are gear size, mass and symmetry; others are geometry, material composition, forged vs. bar, heat-treating, shotpeening, scissor gears and the like. Noise and rattle are important customer concerns today. Gear manufacturers and users of power take-offs are working together to balance noise, rattle and efficiency—as well as cost and value. By utilizing modern tools such as coordinate measuring machines, gear checker, CNC machining centers and data acquisition software, engineers can better control the features and continually work to reduce tonal noise.

Cutting Teeth?

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Verisurf

EXPANDS OPERATIONS

Verisurf expanded into a new corporate headquarters located in Anaheim, California (courtesy of Verisurf Software).

Verisurf Software, Inc. a supplier of advanced 3-D measurement solutions to manufacturers worldwide recently announced record annual revenue growth in 2011 and expansion into new a corporate headquarters with metrology training center. Verisurf's consistent growth is due to increasing implementation of Verisurf 3-D measurement solutions in manufacturing companies ranging from small machine shops to large aerospace companies and their global supply chains. "I am proud of our dedicated employees and loyal resellers who are responsible for Verisurf's best month, quarter and year ever," states Ernie Husted, president and CEO. "I am very encouraged by our record number of new customers which points to increasing demand for our advanced 3-D measurement solutions."

Verisurf's consistent revenue growth has enabled the company to add employees and expand into its new corporate headquarters. The new facility is just down the street from their current Anaheim, California location and accommodates the software development team, technical support, application engineering, sales, marketing and distribution warehouse.

A major element of the new facility is the metrology training center with extensive laboratory space, tractor trailer access and a five ton overhead lift for moving large scale measurement artifacts.

"Adoption of Verisurf as a standard metrology platform for manufacturing is growing and our customers are asking us for trained workers to fill good jobs in tool building, inspection and metrology," said Ernie Husted. "Our metrology training center will provide skilled workers to manufacturers seeking to improve productivity and quality."

Renishaw

APPOINTS REGIONAL SALES MANAGER

Sheila Schermerhorn

Renishaw announces the appointment of Sheila Schermerhorn as regional sales manager for the Southwest region, covering Texas and Louisiana. Schermerhorn provides applications engineering solutions for Renishaw's machine tool, calibration, CMM and styli products. She has been with Renishaw for more than 11 years, and most recently served as regional sales manager for in the Mid-Atlantic region. A graduate of Alfred State College in New York, Schermerhorn holds a degree in mechanical engineering. Her professional experience includes CNC machining, mechanical and electrical design, and applications/manufacturing engineering.

Martin Kapp

ELECTED CECIMO PRESIDENT

The CECIMO Fall General Assembly which met in November 2011 in Zurich elected Martin Kapp as new president of CECIMO for a period of two years. He has been entrusted the responsibility of leading the European Association which represents 33 percent of the world machine tool production. Kapp succeeds Michael Hauser, CEO of Tornos A.S. and chairman of the SWISSMEM's Machine Tools and Manufacturing Technology Group.

After his election Kapp stated: "We need to focus on how to boost the competitiveness of the European machine tool industry in facing the challenges of globalization, the fight against climate change, environmental protection, the importance of market surveillance and enforement, the specific needs of SMEs and the lack of a skilled technical labor force. We need to encourage a research and innovation strategy driven by the present and future needs of the market."

Kapp continued, "Manufacturing is the core of the economy, which creates real economic and societal value. The machine tool industry offers full poential to reboot our economy and to create jobs."

IMS: Gear

INVESTS IN VIGINIA BEACH EXPANSION

Virginia Governor Bob McDonnell and Mayor William D. Sessoms, Jr. recently announced that IMS:GEAR Virginia Inc., one of the largest manufacturers of gear assemblies for the North American automotive market, will invest $35.5 million and create up to 80 new jobs in an expansion of its Virginia Beach operations. The new jobs will pay an average annual wage of $48,000. Virginia Beach successfully competed against a location in Georgia for the project.

According to McDonnell, "IMS:GEAR Virginia has thrived in Virginia Beach since its establishment there in 2000. This significant investment will allow for a larger facility and an additional manufacturing line to support a growing customer base of Tier 1 automotive suppliers throughout North America. The company continues to be a strong corporate partner to the commonwealth and a key component of the automotive industry niche that is present in Virginia."

IMS:GEAR Virginia Inc. is a subsidiary of IMS:GEAR GmbH, headquartered in Donaueschingen, Germany, with United States headquarters in Gainesville, Georgia. The company first opened its Virginia Beach facility in 2000 for the manufacture of metal and plastic gear assemblies used in automatic automotive seats. Sessoms visited the German headquarters earlier this year to help finalize the project.

"IMS:GEAR had a very attractive opportunity to take this expansion out of Virginia, but because of the quality of our local workforce and the overall positive business environment that exists in Virginia Beach, the city was able to provide a viable option for them. Of course, the help of Governor McDonnell and his team was critical to keeping these jobs in Virginia," Sessoms says.

"IMS:GEAR is proud to call Virginia Beach home of the production facility for horizontal drive mechanism for car seats," said Guenter Weissenseel, president of IMS:GEAR Virginia Inc. "We have been producing parts here for the last 11 years with the support of the people, city and the state of Virginia. We are looking forward to growing as a company to provide work and prosperity to the local community. The positions we are creating are for self-motivated, energetic people with background in operating, maintaining and building of automated high-volume production equipment.

American Wera

REPRESENTS MAE

American Wera is now representing MAE in the North American market (courtesy of American Wera).

An agreement was recently reached by American Wera, Inc. and MAE Götzen GmbH of Erkrath, Germany for representation of the MAE line of straightening presses, wheel set presses and hydraulic presses in the North American market, comprising Canada, Mexico and the United States. For MAE, American Wera will supply equipment, application engineering, onsite commissioning, training and all after-sale service, operating from its headquarters in Ann Arbor, Michigan and sales and service center in Queretaro, Mexico. The company's existing network of sales representatives will handle this new line, under the direction of product manager for MAE, Joseph Kemple.

MAE offers a broad line of manual, semi-automatic and automatic straightening equipment for the automotive, heavy equipment, steel, rail and oil country tubular goods markets on round, profiled and complex shaped workpieces in lengths up to 100 feet. MAE machines possess the high accuracy and repeatability necessary for extremely tight straightening tolerances on such large workpieces. Depending upon the workpiece, the type of machine may be electromechanical or hydraulic. Scott Knoy, vice president of sales for American Wera, states, "We believe the MAE line will complement our existing equipment, making us a greater value adder to current customers, plus it will open new markets where our expertise can be helpful to a variety of end product manufacturers."

Mitutoyo

ANNOUNCES NEW PRESIDENT

Shigeyuki Sasaki

Shigeyuki Sasaki has been appointed the new president at Mitutoyo America Corporation, headquartered in Aurora, Illinois. Sasaki has served numerous roles within Mitutoyo Corporation for the last 35 years including new product development and quality control departments in Utsunomiya, Japan; manager of purchasing and planning in Mitutoyo Germany; general manager in Mitutoyo South America; and recently vice president and executive vice president of Mitutoyo America Corporation. He will remain as an active member of Mitutoyo Corporation's board of directors.

"To retain the leadership role in the metrology market, Mitutoyo America Corporation is committed to continue providing high tech, durable products which meet our customers' demands. We are excited to move forward to the 'next level' under the guidance of Mr. Sasaki, whose leadership success has been a result of taking a hands-on, bottom building and cross-functional communication approach," states John Westhaus, executive vice president of Mitutoyo America Corporation.

Sasaki succeeds Mikio Yamashita, who served as president since 2006. Yamashita will return to Mitutoyo headquarters in Kawasaki-shi, Kanagawa, Japan at the end of the year, but will always be fondly remembered at Mitutoyo America for his insightful wisdom, compassionate nature and enthusiastic personality. He will continue his career with the corporation where he previously served as president of Mitutoyo Canada, vice president of Mitutoyo Netherlands, logistics manager of Mitutoyo Germany and sales manager of Mitutoyo Netherlands.

Westhaus, formerly vice president of capital equipment sales, will assume Sasaki's role of executive vice president. Westhaus has held many positions within Mitutoyo throughout his 28 years of service with the company.

CORRECTION

The Addendum feature in the November-December issue of *Gear Technology* contained some erroneous information regarding the Pratt & Whitney PurePower Geared Turbofan engine. To clarify:

Pratt & Whitney's PurePower Geared Turbofan engine has been selected as exclusive power for the Bombardier CSeries aircraft and Mitsubishi Regional Jet. It will also power the Airbus A320neo aircraft, as well as the Irkut MC-21 narrow-body aircraft. Pratt & Whitney has received orders, including options, for more than 2,000 PurePower Geared Turbofan engines from 26 airline and lessor customers.

The PurePower engine is not an option on the Boeing 787 Dreamliner program, as previously reported. *Gear Technology* regrets the error.

NEWS

Kistler

OPENS NEW TECHNICAL CENTER

Kistler, a worldwide supplier of precision sensors, systems and instrumentation for engine, chassis and vehicle development, as well as vehicle component manufacturing systems, has announced the successful completion of its new North American Technical Center, a 20,000-square-foot sales, training and application support facility, located at 30280 Hudson Drive in Novi, Michigan. The Kistler North American Technical Center offers Detroit-area customers fully dedicated on-site technical product sales, service and applications engineering expertise, as well as A2LA accredited calibration services for automotive testing, crash test, vehicle dynamics, manufacturing assembly joining and in-laboratory test requirements. For more information, visit *www.kistler.com*.

G&N Rubicon Gear

REVAMPS BRANDING INITIATIVE

G&N Rubicon Gear, a contract manufacturer og high precision gears, shafts and assemblies, has revamped its branding and introduced a new communication program and website. The branding update reflects the company's renewed focus as a provider of high performance motion control and power transmission components and subsystems. In response to customer feedback and changing industry dynamics, the company will now market its products under the name Rubicon Gear, dropping the prefix "G&N." The company is also introducing a new logo, along with a bold blue-grey design scheme that emphasizes the company's new theme: "The Power of Precision."

"The abbreviated version of our name has become synonymous with expertise in advanced gear technology," says Ryan Edwards, president of Rubicon Gear. "Since many customers referred to us by this name anyway, we have modified our brand image accordingly. We also have updated and expanded our website and product literature to reflect the full scope of our services to customers."

For more information, visit *www.rubicon-gear.com*.

March 7–8—Lean Transformation Summit. Jacksonville, Florida. The Lean Enterprise Institute (LEI) summit raises consciousness, generates enthusiasm and explores new frontiers in lean thinking. Attendees will learn from leading lean practitioners and colleagues who have faced the same challenges. They'll also enjoy the industry's best networking to build (or continue to build) their own network of lean thinkers. Summits are two-day events designed for mid- to upper-level managers, with a focus on sustaining the lean journey, and insights into innovative ways to enhance your lean journey. LEI present a series of summits and conferences globally throughout the year to teach actual applications, not just concepts, in plain language with the case studies, worksheets, formulas, and methodologies needed for implementing lean into your business. For more information, visit *www.lean.org*.

March 8–11—The MFG Meeting (Manufacturing For Growth). Hyatt Regency Grand Cypress, Orlando, Florida. The MFG Meeting brings together a broad spectrum of manufacturing business owners and top industry executives for a four-day forum on how manufacturers can work together to restore manufacturing to its rightful place as an engine that drives the U.S. economy. Jointly produced by four major industry trade groups, the Association for Manufacturing Technology (AMT), American Machine Tool Distributors Association (AMTDA), National Tooling and Manufacturing Association (NTMA) and the Precision Metalforming Association (PMA), this event tackles the issues that affect the entire realm of manufacturing and provides a forum for a conversation that can't be found at any event presented from a single sector's perspective. Visit *www.themfgmeeting.com* for registration details and to watch highlights from the 2011 event.

March 13–15—Composites Manufacturing 2012. The Composites Manufacturing conference and exhibition provides knowledge on composite applications, processes and best practices. This three-day program features a combination of education, networking, exhibits, exclusive tours, industry keynotes and in-depth manufacturing insight. Manufacturing engineers and management from the aerospace, medical, wind energy, transportation, recreational, consumer products and green manufacturing will come together to discover new ways to stay relevant and competitive. This dynamic event continues to evolve, grow and improve to provide an array of different learning and networking opportunities. Developed by a team of SME professionals who work hand-in-hand with an industry advisory board, this team has its finger on the pulse of composites manufacturing and understands what attendees need to succeed. For more information, visit *www.sme.org*.

March 13–16—Gear Dynamics and Gear Noise Short Course 2012. 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 on Day 4 are intended to foster interactive problem-solving discussions on a variety of topics. For more information, visit *www.gearlab.org* or contact Jonny Harianto at *harianto.1@osu.edu*.

March 27–29—Westec 2012. Los Angeles Convention Center, Los Angeles. Westec returns in 2012 redefined with a renewed commitment to local manufacturing. The manufacturing event includes keynote presentations from industry leaders in aerospace/defense, renewable energy and the manufacturing economy. The show also consists of technical sessions on topics that include small parts machining, high-speed alloy machining, milling, drilling, cutting advanced carbon fiber, carbon laminates and advances in additive manufacturing. Attendees view emerging technologies and emerging equipment applications and many other topics with an emphasis on using technology to innovate. Westec offers a place to network, form relationships and build partnerships, putting an emphasis new developments, integration, lean methods, and how to manufacture with composites, titanium, or other advanced materials. For more information, visit *www.westeconline.com*.

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the Art of Involutes

The Forest City Gear booth at Gear Expo featured a wide variety of gears utilized in medical equipment, Indy cars, fishing reels, even the recently launched Mars Rover. Scattered among Forest City's products in Cincinnati were some unique gear sculptures created by an artist that finds more inspiration from the pages of industrial magazines than art galleries. Salem Barker incorporates gears and machinery into his art simply because industry has always been a part of who he is and where he came from.

"I've always had a boyish fascination with heavy industry, and being mechanically inclined I took immediate aptitude to machining and machine tool building. These trades eventually led me around the world as an onsite machinist. After years of projects on nuclear submarines, steel mills, mining machinery, power plants, there are only two pages in my passport that have any room for more stamps."

As a teenager, he learned the fundamentals of geometry, metrology and machine tool construction while working at a small machine tool reconditioning shop. The shop specialized in older generation gear hobbers. He credits this experience with taking his love for both art and industry in an entirely new direction.

"As with all my sculptures, whether gear-like or not, I begin by removing stock until a desirable overall external mass is achieved. Open space in sculpture can be just as powerful as solid mass. My intent is to create non-frontal sculptures that can be viewed on all sides. I always look for lines while sculpting. Lines define the action of each piece, and are a signature to the fluidity of my work."

It's rare to find a sculptor showing his work at a gear exhibition, but Barker believes the venue is a perfect fit. "It's a lot easier for my work to catch an interested eye when standing alone rather than in the midst of competition. People get over-stimulated at art shows and sculptural exhibitions. I like the concept of placing non-functional art in the midst of market-driven industrial machinery."

No matter the direction his art takes him, Barker believes industry does not get the attention it deserves in today's society.

"Back when my grandfather was in school, it was taught that mining, manufacturing and agriculture were the foundation of all economic commerce. No matter how you break it down, those three things are still at the basis of any country's sustenance, wealth generation and sovereignty. Today's schools just teach (or drug) children to be easily managed citizens. Most have discontinued their shop classes and sold or scrapped the school's wood and metal working machinery. Students are literally being taught that industrialization is bad for the earth.

The job of an artist is to communicate—with beauty. I try to harmonize industry and nature with my gear-themed sculptures, bringing attention to the usefulness of man's creations as well as the Creator's."

A gallery of Barker's work can be found online at *www.salembarker.com*.

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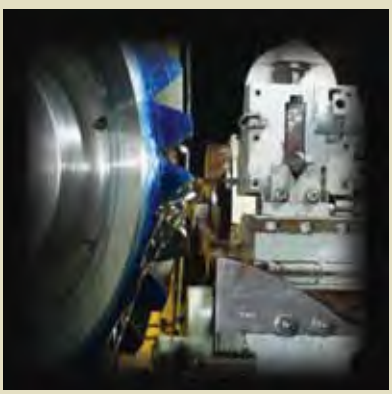

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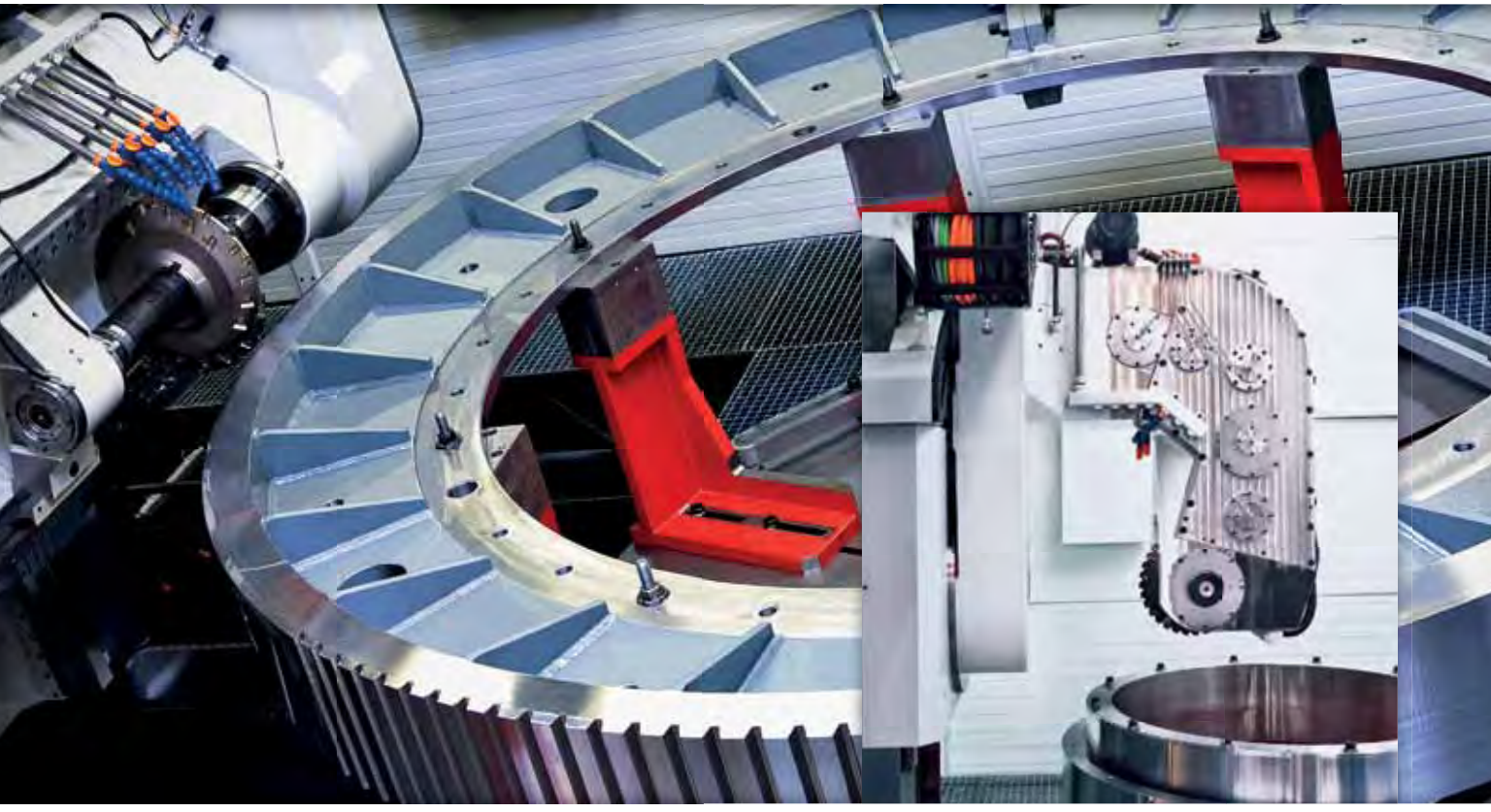

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