GEAR TECHNOLOGY®

March/April 2010

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The Journal of Gear Manufacturing

Feature Articles

- Why Vacuum Carburizing?
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Technical Articles

- Innovations in Gear Hobbing
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- Fatigue Lifetime of High-Heat, Polyamide Gears

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- Addendum: Old Friends and Gear Machine Memories

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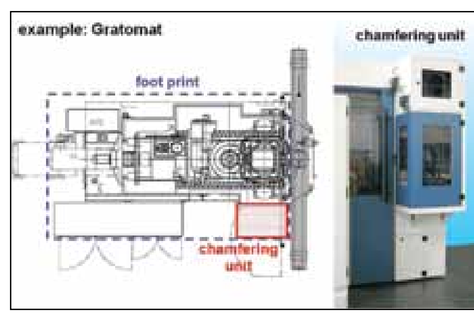

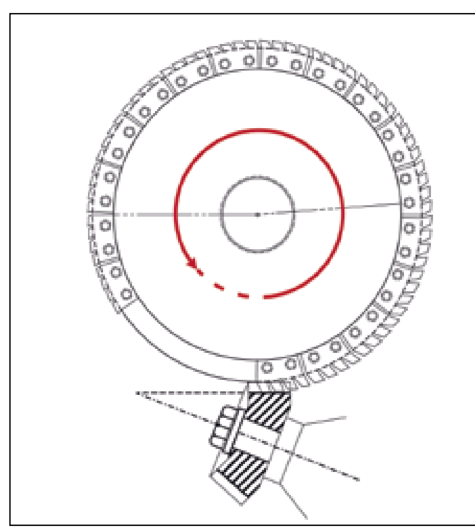

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GEAR TECHNOLOGY

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BPA WORLDWIDE™

HEY, BROTHER, CAN YOU SPARE SOME TIME?

A movement has begun that should be important to all Americans, especially those of us with a close connection to manufacturing. The movement centers around the book *A Nation on Borrowed Time*, written by Joe Arvin of Arrow Gear and Scott Newton of Apex Media Solutions.

The book's main premise is that most of America's economic troubles can be traced to one root cause: the loss of wealth resulting from decades of foreign trade deficits. More importantly, the book focuses on our country's declining capability to create new wealth through manufacturing. The book is extremely well-written, easy to follow and unbiased in presenting the facts about how we got into the mess we're in (see our full review of the book on page 10).

More importantly, the book offers suggestions about how our nation can get its economy back on track—suggestions that center around providing an environment that encourages growth and investment in U.S. manufacturing.

I know I'm preaching to the choir in talking to you about this subject, but I applaud Joe Arvin for his efforts and agree that policies to encourage the creation of wealth must be discussed by the decision-makers in Washington and supported at the grass-roots level. Joe has done far more than complain about the situation. He's gone through an extraordinary effort to inform and motivate Americans about something that frightens him and should be of concern to all of us.

A myriad of worthy causes vie for the attention of our lawmakers. Jobs growth, new energy, health care reform, Medicare/Medicaid, social security, debt reduction and many other important economic issues sit right under the noses of those lawmakers. But we need to make sure they're aware of the bigger picture—the fact that without the creation of wealth, we'll never have the environment or means necessary to tackle any of these important problems. The man with his pockets turned inside out doesn't worry about the big picture. He's too busy trying to get by, day-by-day. Unfortunately, that's how our government usually operates.

But this big picture is too big to ignore.

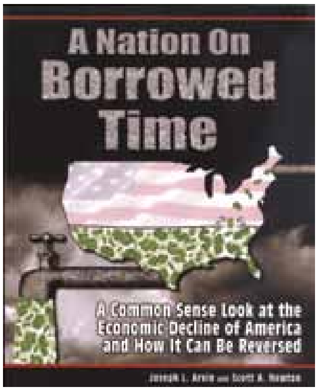
The reality is, there are only three ways to create wealth: You can rip it out of the ground; you can grow it; or you can manufacture it. Once upon a time, the U.S. manufacturing industry created enormous wealth—and kept that wealth here in America. If we can find a way to restore that wealth-building engine, we'll create an environment where tackling some of those other problems won't be nearly as difficult. We'll have the resources to solve more problems without borrowing more money from the rest of the world.

Fortunately for us, the book lays out some suggestions, not just for our lawmakers, but also for the rest of us who want to get involved. In addition to the book, the authors have launched a website, *www.anationonborrowed-time.com*, to serve as the focal point for their movement. At the website, you can order the book, join their mailing list and find suggestions about what you can do to take this movement to the next level. You can also watch videotaped interviews of me and others talking about some of these issues in more detail.

The authors' purpose isn't to sell books. Their mission is to raise awareness and create a grass-roots campaign to spread that awareness. I encourage you to participate in that campaign by visiting their website and learning more about it. If you like what you see, order the book, read it and act on it. The future of our nation—including you, your children and generations to come—depends on it.

Michael Goldstein,
Publisher & Editor-in-Chief

P.S. I've recently come across another very good book, *The American Machine Tool Industry*, by Albert B. Albrecht. This book deals with the decline of that industry, but it also touches on the impact of the decline of U.S. manufacturing on the welfare of our nation. Although this book is much narrower in scope, it would be of interest to those, like me, who've spent a lifetime in the machine tool industry. For more information on ordering the book, contact the author via e-mail at *albertalbrecht@verizon.net*.



By Joseph L. Arvin and
Scott A. Newton

www.anationonborrowedtime.com

107 pp. APEX Media Solutions.

BOOK REVIEW

Are We Going the Way of the Mayans and Romans?

By Jack McGuinn, Senior Editor

A recent USA Today front-page story—"The New Ghost Towns"—talks about the growing number of small towns across the country that, due to job losses in manufacturing, are becoming virtual ghost towns, with one 21st Century difference—most of the people still live there. The common thread running through these towns' plight is the same—major manufacturing company offshores jobs and eventually closes the facility, throwing most of the citizens out of work. But unlike in earlier downtimes, there is no option of "moving to where the jobs are," because there are practically no jobs—certainly not in manufacturing.

This is mentioned merely to make the point that there really are no new revelations in "A Nation on Borrowed Time," by Joseph L. Arvin, president of Arrow Gear Company and Scott A. Newton, president of APEX Media Solutions.

But this is must reading.

The authors devote three of the five chapters to highlighting the ongoing deterioration of the American industrial base and the economic and social ills that accompany it. They document how, beginning in the 1970s, the out-sourcing of skilled manufacturing jobs to rebuilding countries like Japan or developing countries such as China was the Trojan Horse that began the long, sustained attack on the American middle class workforce that continues today.

That offshoring of good jobs, as the authors stress, has led to a severe depletion of national wealth, which impacts workers (pay), businesses (profits) and government (tax base). Put another way, by exporting what were once family-supporting, community-sustaining jobs—jobs that paid mortgages and taxes, bought automobiles, put kids through school, etc.—we are in fact exporting the nation's wealth in the bargain while enriching others'.

A highlight of this book is that the information is presented in a very concise, straightforward and, yes, heartfelt manner.

Given Arvin's background, a major goal of his efforts here is to determine the "root cause" and "corrective action" of this economic/societal malaise. Arvin calls out fellow manufacturers regarding their own culpability: "American-owned manufacturing has done very well, American-based manufacturing is now a shell of what it once was."

The authors also point out how—due to job loss—the shrinking tax base, especially at local levels, is seriously impacting education funding for even the most basic needs.

All of this, according to Arvin and Newton, is just one set of examples of how we have, seemingly willfully, depleted our collective wealth in the enrichment of our trading "partners." And the technology transfers that have been going on for decades since the post-WWII Marshall Plan and continue to this day—like the training of Chinese CNC operators, for instance, is yet another example.

So, as Chapter Four asks, "What Can be Done?" In a nutshell—the answer is the power of manufacturing, high-end manufacturing, and all the value added benefits that flow from it.

Another problem for the American economy and well-being is apathy.

"Conveying this message and reaching those who agree with its content is only a first step," say the authors. "If these concepts go no further than the pages of this publication, these proposals for corrective actions will have no chance of being implemented."

Just how this industrialist renaissance will occur remains in doubt. The authors mention the usual things U.S. manufacturers' seek—meaningful federal and local tax breaks, incentives, monetary reforms and a truly fair playing field for international trade.

Last—and perhaps of most importance—is education. In this era of inflated student grades belied by declining math and science scores, declining numbers of engineering students and very little leadership from the usual suspects—the U.S. Congress—it is hard to imagine improvement anytime soon.

The greatest praise to be directed toward the authors of this book is respectful gratitude for their taking the time to write it. The impending, decades-in-the-making train wreck that is the gutting of the middle class and all that entails is happening in plain sight. And like the weather, we all talk about it as if nothing can be done, as if it were an approaching mammoth meteor. *A Nation on Borrowed Time* proves otherwise.

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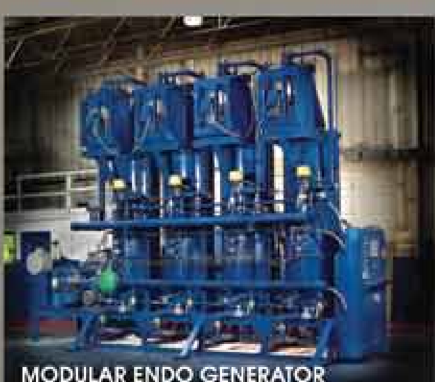

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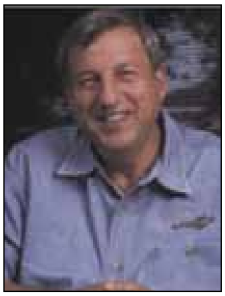

Crowning:

A CHEAP FIX FOR NOISE REDUCTION AND MISALIGNMENT PROBLEMS

Fred Young, CEO Forest City Gear, Roscoe, Illinois

Noisy gear trains have been a common problem for gear designers for a long time. With the demands for smaller gearboxes transmitting more power at higher rpm and incumbent demands for greater efficiency, gear engineers are always searching for new ways to reduce vibration and limit noise, without increasing costs.

Some popular solutions to the noisy gear problem include enlarging the pinion to reduce undercut, using Phenolic, Delrin or other noise-absorbing products, where possible, or changing to a helical gear train. Other methods include tightening specifications to ensure greater gear quality or redesigning the acoustical absorption characteristics of the gearbox. Occasionally, experimentation with gear ratios can limit harmonic frequency amplification, which otherwise can cause a gearbox to amplify noise like a finely tuned stereo system. Modifications may be made to minimize heat treatment distortion or possibly eliminate the need for heat treatment entirely.

Particular attention must also be paid to gear geometry to ensure maximum contact.

Another approach to the gear noise problem that yields good results is crowning or barreling of the teeth. This technique involves changing the chordal thickness of the tooth along its axis. This modification eliminates end bearing by offering a contact bearing in the center of the gear.

A second benefit of the crowning approach to gear cutting is the minimization of misalignment problems. Crowning can also reduce lead problems in the gears themselves, which causes the gears to wear unevenly and bind because of eccentricities and position errors.

Obviously, a gear with a center contact is less affected by discrepant manufacturing or design; furthermore, one can reduce the backlash requirements and allow the gears to wear in rather than wear out.

Shaving is a secondary gear finishing operation done after rough hobbing or shaping to create the desired crown. Crown shaving has long been a popular method, especially in manufacturing coarse-pitch gears. Two variations of the crown shaving method will produce a gear to compensate for off-lead or misalignment conditions.

One approach produces a crown by rocking the table during the reciprocation of work and cutter. The degree of crown is readily changed by this method. The other approach is plunge feeding, which requires dressing the shaving cutter to the desired crown. Generally, it is faster to plunge feed, but the technique can subject the cutter to greater wear. Shaving improves the quality of profile and reduces error in the gear tooth through the cutting and burnishing action of the cutters.

The crown form can be produced on gear teeth in several other ways. One method is to shape the gear by use of a crown cam in the shaper back-off mechanism. The proper radius of the gear is calculated by using the amount of crown on the flank and the pressure angle of the gear. Unfortunately, the blocks, while not complex, tend to be expensive.

The advent of the latest generation of gear equipment has made two methods of crowning while hobbing popular. Both methods produce crowns by increasing and decreasing the center distance of cutter to workpiece. The first method utilizes physical copying of a template by a hydrocopying or mechanical following device. This allows taper hobbing or even the creation of sinusoidal wave forms, if desired. More recently, the second method, CNC hobbing, has become commonplace.

Depending on software limitations, CNC allows cutting gears in almost any desired form. A disadvantage to this approach is the high cost of the equipment, though the payback has decreased considerably in recent years.

New CNC shapers can cut a crown gear or spline without the need for buying a special crowning cam. On our Gleason Pfauter P 300 ES, for example, we can crown by cutting a slight right and left hand helix angle along the face width of the part. This leaves the root diameter straight. We also have a Bourn & Koch Fellows MS 450 with a U-axis for controlling the back-off. It can be programmed to move the cutter spindle in and out during the stroking cycle to crown the tooth by cutting deeper at the ends of the face width and more shallow at the high point of the crown.

Users of heavily loaded gears have been using crowning for quite some time. Another area ripe for the use of crowning is in the manufacture of hydraulic wobble motors. Here, the application is strictly for misalignment problems rather than for noise reduction. An allied area involves heavily loaded pinions used in actuators for aircraft control surfaces. Generally speaking, it is more advantageous to crown the pinion because it makes more revolutions per minute and may generate more noise. In this case, it is of paramount importance to compensate for load deflection. Unfortunately, few companies in the United States have been applying this technology to commercial fine-pitch gearing. However, the few manufacturers who have tried it are most pleased with the results. Some users have reported a five to 10 times reduction in noise, accompanied by less vibration, wear and power draw.

Prime candidates for use of the crowning technique are the small fractional horsepower motor manufacturers or anyone dealing with spur or helical pinions that are susceptible to noise or misalignment. American manufacturers would be wise to take advantage of the availability of this kind of technology.

Exploration of crowning as a solution to noise and misalignment problems can produce a real competitive advantage for gear manufacturers and users alike.

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Razorform Inserts

KEEP VALUE IN ONE SPOT

The ability to cut an entire part on a single machine has long eluded efforts to minimize downtime, but recent technological developments are beginning to catch up. One such advancement is Razorform Tool's indexable inserted broach tool for CNC lathes with locking spindle.

Razorform Tools carbide inserts remain in the machine turret during indexing, resulting in longer tool life while reducing downtime.

The tool provides two cutting edges per insert, so the tool body remains in the machine turret during indexing, allowing operators to skip the 10 to 15 minute-plus step of re-zeroing the tool. John L. Gardner, president of Razorform Tools, describes the process they've trademarked "The Future of Broaching."

"The angle of the pocket and the insert allow the cutting edge to jut up and make the cut, directing the vector of force down into the center of the tool body."

The combination of the tool, the design of the insert, and the insert pocket produce a stable cut with less chatter, so the insert provides longer life. Another advantage of the Razorform tools is the 4140 steel shanks, which "don't allow 'flexing' of the tool holder during the cut," Gardner says. "A solid carbide tool is so hard it is brittle. So brittle, in fact, we've heard of solid carbide tools just breaking in the middle of the cut from the stress."

The TiN-coated, double-sided micro-grain carbide inserts last longer than the typical carbide or high speed steel inserts brazed into the tip of a tool body. Gardner says this is an inferior method because "The high heat of brazing greatly weakens carbide, often times causing it to crumble during cutting, necessitating tool change-out, which means hours of machine downtime."

A third, traditional alternative is the time consuming method of transferring parts to an old style broaching machine, which typically uses high speed steel inserts that don't last as long as carbide. Razorform inserts provide a nontraditional method of broaching that allows manufacturers to perform more operations on a part on one machine. "The key value is keeping it all in one spot," Gardner says.

Very few competitors exist in this market, according to Gardner, and those that do, while broaching in the same fashion, use small slivers of carbide that do not support the cutting force like the brawny Razorform inserts. Razorform customers, he adds, that have switched from a competitor's version report that their cutting edge is thinner and prone to breaking. In fact, the average Razorform Tools client cuts four to five times more keyways per cutting edge with Razorform tools than with the main competition.

Baldor Electric first tested the technology out in January 2006. "It worked great, and we did a lot of testing there to make sure it was holding up," Gardner says.

Many of Razorform's customers are small job shops, so it's not known which ones of them have tried cutting gears, although, at IMTS 2008, the interest from gear companies was evident. One gear company began ordering Razorform tools after the show and another started testing them and reported positive results. Due to this exposure, multiple companies are now using Razorform tools to cut gears more efficiently and cost effectively using their CNC machines.

Currently the tools are available in nine standard sizes ranging from 0.127 (for a 1/8 inch keyway) to a 0.502 (for a 1/2 inch keyway), but the company hopes to expand this product offering in the future as it grows. Another future plan for development is to offer EDM spline cutting. This is an application that didn't occur to Razorform when the tool was designed, but several customers have reported using them in this application.

"They'll take our product and EDM a spline tooth onto our insert and use that on our tool to cut splines on their CNC lathe," Gardner explains. "However, we don't offer the final product on that. The client has to EDM the cutter themselves.

EDM is definitely the next step for us in the future."

A marketing budget is something else it is planning on in the near future, but for now, keep an eye out

continued

for Razorform Tools at trade shows such as the Pacific Design and Manufacturing Show, Westec, Eastec, IMTS 2010 and PMTS 2011.

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BMW

SETS SAIL WITH FOREST CITY GEAR AND ARROW GEAR PRODUCTS

The BMW Oracle Racing trimaran employed gears from Forest City Gear and Arrow Gear in the engine and winch system.

Forest City Gear supplied crown gears and splines of special high-strength, lightweight and corrosion-resistant titanium for use in the engine and winch system of the new BMW Oracle Racing trimaran (originally a multi-hulled boat first used by the Polynesians 4,000 years ago). Arrow Gear supplied the bevel gears for the gearboxes.

The winches on a racing yacht are critical items of equipment. Speed, reliability and weight are important factors when determining which winch packages will be installed on a racing yacht.

Made from Ti-6-4, a popular alloy often found in aerospace applications, this material is extremely durable and was determined ideal for this project by the Alpha Engineering Consulting designers, customer of Forest City Gear. The process used to manufacture these gears and their corresponding spline components was hobbing and shaping, respectively. The crown radius was the point of main concern, owing to the extreme stress and motion present when such gears are in use.

As Jon Williams, a member of BMW Oracle Racing's shore team explained, "During the build-up to the previous America's Cup in Valencia, Spain, we undertook development of our own transmission components for the winch systems on our yachts. After careful study, we had determined this was a critical area for improving our performance on the water." BMW Oracle Racing was looking to reduce mass and increase mechanical efficiency of the gear and spline assembly. A prototype project proved successful and the team undertook a complete redesign of the gearboxes for their USA87 and USA98 yachts. These new gearboxes were manufactured in New Zealand and used by BMW Oracle Racing in the America's Cup.

The current edition of the America's Cup sees different rules than previous Cup programs. Under these rules, all equipment for the yachts must be constructed in the country the team represents. In the case of BMW Oracle Racing, which races under the flag of the Golden Gate Yacht Club of San Francisco, all equipment must be made in the United States.

Williams says, "The construction of our trimaran was a formidable project and it was clear we needed to utilize a group of vendors with specialist skill and expertise. Our project called for a fairly wide selection of gears, splines and driveshaft components, some of which were non-standard sizes. The two vendors we selected to produce these components were Arrow Gear and Forest City Gear."

For Forest City Gear, Jared Lyford and Tom Christenson ran the project. The gearbox casings and other associated parts were manufactured by RB Enterprises of Everett, WA. For Arrow Gear, Joe Arvin ran the project to deliver the bevel gears. Final assembly of the gearboxes and their installation occurred at BMW Oracle Racing's structural R&D facility in Anacortes, WA.

At the conclusion of five weeks of intensive testing on the waters off Seattle and San Diego, the gearboxes were removed for inspection. The gears were only showing the first signs of polishing on flanks.

Williams concludes, "Arrow Gear and Forest City Gear have provided the team with a quality product. We would use them again."

continued

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Bevel Gear Cutter

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The Phoenix 280C Bevel Gear Cutting Machine from Gleason reduces cycle times by up to 35 percent for bevel gears and pinions up to 280 mm in diameter.

A high-speed automatic loader minimizes workpiece changeover to five seconds for gears and seven seconds for pinions. The machine is appropriate for automotive manufacturers looking to cut workpiece costs on the highest volumes and for job shops that need more flexibility to change parts quickly.

An on-machine inspection device reduces non-productive cycle times. The time needed to remove and inspect parts in a quality lab following a cutter change or when preparing a new part or family of parts is taken out of the equation.

Chamfer/deburr time has also been reduced with an auxiliary chamfering spindle that deburrs a gear in parallel to the one being cut, as opposed to the operation being performed in sequence after cutting.

The 280C operates more reliably in production environments where dry machining is performed. The machine's column is cast from an advanced polymer composite material that provides high thermal stability and damping, which is appropriate for high volume, dry cutting conditions. Hot, dry chips are contained away from the cutting zone.

With guarding that improves access to service areas and new features such as a servo door system with robust rails, the 280C is more reliable in comparison to machines with pneumatic door systems. Other new features include a tool-less hydraulic cutter spindle clamping design to do away with the time and effort needed to change the cutter system. Arbor changeover is faster with quick-change workholding that is removed from the front of the machine instead of from the back without special tools or fasteners.

Software for the 280C is new. Used with either Fanuc 30i or Siemens 840D CNC, the software system provides less experienced operators with the know-how to optimize setup, programming and machine operation. Diagnostics screens help debug problems, and the 280C is network-ready, so Gleason can help with problem-solving in remote diagnostics for installations worldwide.

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DTR

OFFERS HOBS FOR CUTTING WIND TURBINE AND HEAVY INDUSTRIAL GEARS

DTR Corporation recently announced its full line of high-performance, large, coarse-pitch hobs for cutting wind turbine and heavy industrial gears. According to the company's press release, these hobs are precision-made with the latest in coatings and high speed steels (Grade M-2, M-35, ASP2030 or ASP2060, etc.) and ground forms up to AGMA AA quality. Hob sizes range from 5 (5.0 DP) to 32 (0.8 DP) module and OD up to 340 mm (13.0 inches).

DTR manufactures a complete line of hobs including involute, worm, chain sprocket, timing pulley, serration, spline or special tooth shape and shaper cutters for auto, aerospace, wind, mining, construction and other industrial gear cutting applications. The company exports to the United States, Europe, Japan, China, India and other East Asian countries.

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Robotic Shot Peener

CHANGES TOOLS

A robotic shot peening system from Guyson Corp. changes blast heads to automatically perform multiple peening operations without manual adjustments. A single robotic shot peener can perform various metallurgical shot peening processes that would otherwise require two or more automated blast machines.

The tool-changing blast machine features a slotted rack inside the shot peening chamber, so blasting tools are stored by the nozzle manipulator when not in use. The assorted tools required are determined by the range of components being shot peened and the peening process specifications. These may include straight nozzles of different bore sizes, a lance with an angled nozzle for ID peening, a rotary lance tool for small ID peening or a blasting tool that provides a different size of peening shot.

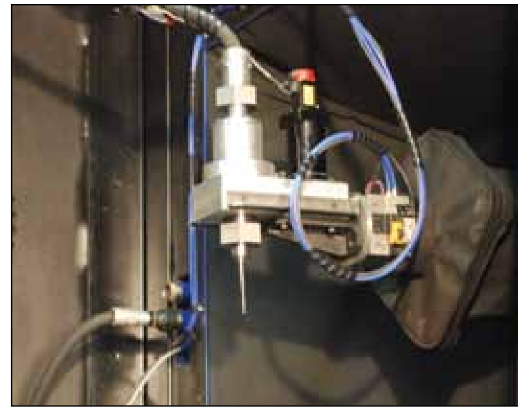
One wall of the 78 by 78-inch peening cabinet has a large opening with a customized protective suit for the articulated six-axis robotic arm. A laminated fabric seals the rubber-lined blast chamber, which is fabricated from a one half-inch thick continuously welded steel plate. This feature isolates the robot from the harsh shot peening environment while accommodating the full range of motion of the robotic nozzle manipulator.

The robotic machine is equipped with a 3,000-pound capacity, 65-inch

continued

diameter turntable driven by a servomotor and controlled as a seventh axis of robotic motion. The rotary lance peening nozzle also has a servomotor drive, and the nozzle's rotation is programmed through the robot controller as an eighth axis.

In order to comply with strict aerospace shot peening specifications, the nozzle manipulator is capable of repeatedly following the contours of complex-shaped components while constantly and accurately maintaining the correct stand-off distance, nozzle angle and surface speed required for the precisely controlled, cold-working



metal treatment process.

Interested customers are invited to submit sample components for free lab testing and application engineering evaluation at Guyson's factory in New York.

For more information:
Guyson Corporation
13 Grande Blvd.
Saratoga Springs, NY 12866
Phone: (518) 587-7894
www.guyson.com

Rex-Cut Abrasive Wheels

OFFERED IN VARYING GRITS

The universal Type 27 unitized abrasive wheels are for grinding, blending and polishing stainless steel, mild steel and aluminum. The Rex-Cut Megabrite T27 Unitized Wheels are all purpose and come in coarse, medium and fine grits for light grinding, blending and polishing applications. They are suited for edge breaking, light deburring, weld surface preparation, scale removal, rust removal, flash removal, blemish removal and paint preparation.

The wheels are available in 4.5 and five inch diameters with and without hubs. According to the company's press release, they are smooth-running, quiet and provide good operator control and wheel life.

For more information:

Rex-Cut Products, Inc.
960 Airport Road
P.O. Box 2109
Fall River, MA 02722
bobc@rexcut.com
www.rexcut.com

Furnace Temperature Uniformity

BENEFITS FROM IN-DOOR HEATING

The Number 921 electrically-heated, 2,000 degrees Fahrenheit, heavy-duty box furnace from Grieve Corporation is currently in use for various heat treatments at a customer's facility. Workspace dimensions measure 24 inches wide by 48 inches deep and 24 inches high. Nickel chrome wire coils are installed with 34 kw of power, which is supported by vacuum-formed ceramic fiber to provide heat to the workload. An in-door heating element provides more temperature uniformity.

The 921 unit features seven-inch-thick insulated walls with five inches of 2,300 degrees Fahrenheit ceramic fiber and two inches of 1,700 degrees Fahrenheit fiber. The six and a half

continued

floor insulation has four and a half inches of 2,300 degrees Fahrenheit firebrick and two inches of 1,900 degrees Fahrenheit block insulation. The furnace has a 3/16-inch steel plate reinforced shell and a half an inch steel front plate construction.

A motor-operated vertical lift door is a feature along with a digital programming temperature controller and manual reset excess temperature controller with separate contactors for efficiency and safety.

For more information:
The Grieve Corporation
500 Hart Road
Round Lake, IL 60073
Phone: (847) 546-8225
Fax: (847) 546-9201
sales@grievecorp.com
www.grievecorp.com

CoroMill 490

OFFERS 10 MM DEPTH

The Sandvik CoroMill490 is a milling cutter that can shoulder mill, face mill, edge, contour, slice, slot in all materials, and the latest version of it can take up to 10 mm depth of cut.

The 13 mm insert is designed for larger depths of cut and engagements up to 10 mm. The new insert size is

included as part of an expanded program of cutter bodies in diameter range 40 to 250 mm and in grades and geometries for steel and cast iron machining.

For more information:

Sandvik Coromant USA
1702 Nevins Road
Fairlawn, NJ 07410
Phone: (201) 794-5000
Fax: (201) 794-5257
www.coromant.sandvik.com/us

25 Bar Furnace

A VIABLE ALTERNATIVE TO OIL QUENCH

Seco/Warwick introduced a 25 Bar Single Chamber Vacuum Furnace as a process alternative to vacuum furnaces using an oil quench. The 25 Bar HPQ provides the same hardness properties as an oil quench, and when it is equipped with optional PreNit and FineCarb advanced LPC vacuum carburizing technology, the furnace can reduce cycle time by up to 50 percent in certain applications.

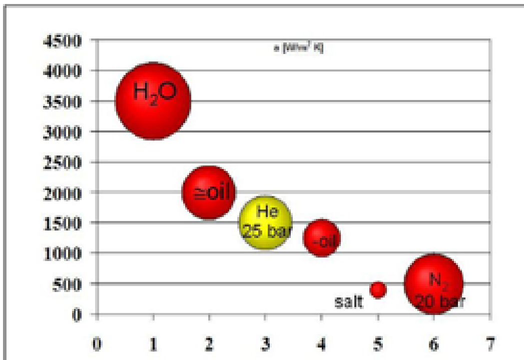
Using helium as a quench medium, the 25 Bar furnace lowers distortion and renders parts washing unnecessary. Loads are both heated and quenched in the same chamber with the single chamber furnace. Many of the problems associated with oil quenching are minimized with the 25 Bar HPQ including the disposal of spent quench fluids, the requirement for a washer to clean parts and post heat treating machining needed to compensate for part distortion in oil.

Helium is used as a process atmosphere to maximize cooling. Recycling

continued

systems are available to recover and reuse the helium, which tends to be higher cost than other process gases; however, there are many choices for supply systems, and helium follows the same installation guidelines as nitrogen.

Seco/Warwick is offering free trials for a limited time at its R&D facility, so companies interested in the process can obtain a full metallurgical report for their samples without any risk. Customers that decide to invest in the new technology will receive extra field support to assure proper installation and efficient operation.



Comparison chart of the thermal properties of a variety of common quench mediums.

For more information:

Seco/Warwick
P.O. Box 908
Meadville, PA 16335
www.secowarwick.com

Small Rotary Table

HANDLES THIN CYLINDRICAL WORKPIECES

Grob Systems has developed a small rotary table for its G-350 five-axis machine, so it is now capable of producing precise, thin, cylindrical workpieces. The machine upgrade targets tool manufacturers that make boring bars with complex insert seats and turbine manufacturers making blades.

The five-axis machine's two rotating axes work for both primary industries; although, blade machining requires a high level of dynamics because of abrupt reversing points at the blade transition from one 3-D surface to another.

The machine is capable of workpieces with a diameter of 250 mm. The table's rigid backbone has 375 mm between the table surface and the tip of the support for clamping both sides. Fixtures corresponding to the workpiece can be designed for the rotary table for radial clamping.

Up to four hydraulic couplings are included on the table for hydraulic clamping and unclamping. A hydraulic flow meter (at 120 bar/1,740 bar) adjusts the stroke necessary to clamp different parts.

"Volumetric accuracies are what make this Grob option so outstanding for thin cylindrical parts," says Bob Ruelle, Grob Systems account director for standard machining centers. "A large table top would be problematic for small, thin and complex workpieces clamped at the ends, which need the entire surface machined.

"Longer tools with a greater projection would be necessary and the risk of collision would be increased," Ruelle says. "For this reason, we developed the small table, put it into testing and discovered its usefulness for more than just machining cutting tools and turbine blades. It can be used to develop parts for optical electronics, medical technology, tool and mold making, essentially to produce electrodes."

continued

For more information:
Grob Systems Inc.
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Bluffton, OH 45817
Phone: (419) 358-9015
Fax: (419) 369-3331
info@us.grobgroup.com
www.grobgroup.com

Water-Soluble Coolants

INCREASE SUMP LIFE

The Rustlick PowerCool MaxLife and PowerCool MaxLife CF coolants are water-soluble oils with new additives that formulate to provide maximum biostability and performance for heavy-duty cutting and grinding applications. The technology employed, from ITW Rocol North America, increases sump life, decreases overall fluid use and high performance.

The PowerCool MaxLife coolants are safe for all metals, including ferrous/non-ferrous metals, aluminum, brass, bronze and copper. They can be used for a range of low- to heavy-duty applications including machining, cutting, grinding and milling.

The coolants come in chlorinated and chlorine free versions. The Rustlick PowerCool MaxLife contains chlorinated EP additives, and PowerCool MaxLife CF contains non-chlorinated EP additives and is recommended for use on titanium. Both products are available in five or 55 gallon containers.

For more information:
ITW Rocol North America
3624 West Lake Avenue
Glenview, IL 60026
Phone: (847) 657-5343
Fax: (800) 952-5823
www.rocolnorthamerica.com

Mobile Induction Heater

TREATS METAL PARTS

Digimac is a compact, transportable induction heating system from GH Induction Group. It is capable of outputs up to 25 kW and 20 kHz.

The system includes the generator with digital interface for control and a handheld transformer and coil. The MPC control provides power regulation, alarms and cooling water flow data. There is an optional semi-automatic mode with energy control available. Temperature feedback can help control the heating cycle, and pre-programmed heating cycles can be stored in memory. Digimac is used for various industrial applications including heat straightening metal parts, welding cooling pipes, paint and varnish cleaning and sealing.

For more information:
GH Induction Group
1840 Roslyn Rd.
Grosse Point Woods, MI 48236
Phone: (313) 432-1602
gheusa@comcast.net
www.ghe-usa.com

Vacuum carburizing offers shorter cycle times and better quality control compared to traditional heat treat methods (courtesy of Ipsen).

Why Vacuum Carburizing?

HEAT TREAT ALTERNATIVE OFFERS ADVANTAGES OVER CONVENTIONAL METHODS

Matthew Jaster, Associate Editor

While a majority of heat treating in the gear industry is done using conventional atmospheric carburizing methods, vacuum carburizing continues to gain market share due to its reduced process time and more environmentally-friendly technology. In 2010, the focus of vacuum carburizing—also known as low pressure carburizing (LPC)—is the minimization of heat treat distortions, improvement of furnace equipment and the development of high temperature and low temperature techniques. Many companies are increasing the pressure levels of gas quenching and providing multiple quench media within a single furnace or multi-cell system.

"According to different sources, LPC is currently between 10–15 percent of the carburizing market," says

continued

Rafal Walczak, vacuum furnaces team leader, Seco/Warwick Corp. "Compared with data from 10 years ago when LPC was 1–3 percent of the market, we can see much progress. This growth will continue at the same rate in the future driven by the latest material developments in vacuum carburizing."

"Future growth will reach roughly 30 to 40 percent in the next five to 10 years based on a variety of reasons," says Bill St. Thomas, sales manager at Ipsen. "Rising energy costs, shorter cycle times and better quality control will make electrically heated vacuum furnaces far more attractive than gas fired furnaces. New steel grades are being developed for a variety of industrial markets as well."

Vacuum carburizing is particularly useful for gear applications because parts carburized in vacuum furnaces and quenched in inert gas have fewer deformations compared to traditional technology.

"High velocity, directional flow of quenching gas creates a uniform cooling environment for all parts located through the furnace chamber," Walczak says. "A series of tests with gears, followed by measuring their geometry, showed that there is a trend in deformations after vacuum treatment and high pressure gas quenching (HPGQ). Both direction and level of deformations are repeatable. This allows gear designers to adjust the primary shape in a way which results in minimal tooth deformations after the heat treat process."

For the heat treat of large gears, Walczak says Seco/Warwick supplies double chamber furnaces with oil quenching. "With LPC, such equipment allows for the application of vacuum carburizing technology to steel grades with lower hardenability as well as parts with thick sections, which cannot be positively quenched under gas."

William Gornicki, vice president of sales and marketing at ALD-Holcroft, says vacuum carburizing has gained a significant market share for the new generation of transmissions such as dual clutch (DCT) and six- and eight-speed automated transmissions.

AISI 9310 bevel gear set up for low pressure vacuum carburizing (courtesy of Solar Atmospheres).

"Also, some gear components are assembled directly after heat treat because no hard finishing is needed after vacuum carburizing. There's no intergranular oxidation, no washing after heat treat," Gornicki says. "It's the integration of heat treatment into the manufacturing line."

"Shorter cycle times and far less machining are needed with vacuum," St. Thomas says. "Small gears, dense loads and blind holes are processed with ease versus conventional methods."

The ability to process other higher alloyed materials will allow the gear industry to branch out into more exotic steels that may result in superior mechanical properties, according to Trevor Jones, project engineer at Solar Atmospheres, Inc. Jones adds that there are also advantages to root-to-pitch case depth ratio.

"The root-to-pitch case depth ratio obtained in vacuum carburizing is over 90 percent where conventional carburizing methods is under 70."

Of course these companies don't expect customers to just take their word on each feature or capability in vacuum carburizing. Most market players offer free testing to anyone considering this form of heat treating and will educate customers on the vacuum process and recommend the optimum heat treat to fit specific needs.

"It's a challenge to get the word out to potential customers on the benefits of this process and encourage them to switch from their current conventional carburizing methods," Jones says. "Older specifications often dictate the use of conventional methods and will not allow for vacuum carburizing unless authorized by a qualified engineer."

What might help the cause is the continued push for green technology in manufacturing. Green heat treating is plausible in vacuum carburizing and an easy sell regarding the environmental impact this method has over other forms of heat treating.

"Vacuum carburizing doesn't emit any harmful gases, and most of the furnaces we install have a closed water system to cool the furnace, thus saving clean water," St.

Thomas says.

Jones says from an industry standpoint, vacuum furnaces generally have a smaller carbon footprint on the environment over atmospheric furnaces. "There is a fair amount of antiquated equipment in our industry that consumes more energy than is required because of out-dated control systems."

And the green benefits in heat treating directly correspond with cost benefits, Gornicki adds.

ALD-Holcroft, in fact, is taking new steps to further widen the ecological benefits of its vacuum carburizing systems. "Our new generation furnace systems include energy saving options such as automated start-up and automated shut down procedures. Our furnaces are also equipped with a smart electrical power management system, which avoids unnecessary consumption peaks."

R&D efforts at ALD-Holcroft to minimize heat distortion will lead to lower cycle times, and the development of high temperature vacuum carburizing will lead to lower energy consumption.

ALD-Holcroft furnaces are equipped with energy saving options to promote green manufacturing (courtesy of ALD-Holcroft).

"Both LPC and HPGQ are environmentally friendly technologies," Walczak says. "In the case of FineCarb (*Ed's note: See product spotlight on page 34 for more information*), more than 90 percent of the gas emitted to the atmosphere is hydrogen. Nitrogen and helium used for quenching are also inert gases, which do not pollute our planet."

One area that Solar continues to focus on is the use of electricity. "We're constantly reminding our technicians to turn off equipment if it's not being used. Items such as shop fans, excessive hold times on furnace bake-outs and leaving the diffusion pump on when it is not needed are all items that waste electricity," Jones says. "Our electric bill is by far our most expensive utility due to the fact that all our furnaces are heated via electric graphite heating elements. We have no gas-fired furnaces nor [do we] utilize combustion to heat our customers' parts."

With all of the capabilities in vacuum carburizing, why exactly is the market share so low compared to other heat treating methods?

Price has always been one issue. The initial capital investment costs are much higher in vacuum carburizing than atmospheric carburizing.

"Rather than purchasing a new vacuum carburizing furnace, some heat treaters would prefer to keep their current equipment online," Jones says.

"The biggest challenge, in reference to the gear industry, is overcapacity and the financial situation many gear producers are facing, especially in the North American market," Gornicki says. "High temperature vacuum carburizing is also a challenge. It requires new fine grain stabilized steels to avoid unwanted grain growth during heat treat. However, the availability of these new micro-alloyed steel grades is difficult, especially for gear companies with globally distributed manufacturing sites," Gornicki says.

Another challenge is to comply with CQI-9 regulations without creating unnecessary costs while operating the equipment, Gornicki adds. "CQI-9 was issued by the Automotive Industry Action Group (AIAG), in March 2006, as a specification evaluation for the automotive industry.

"ALD-Holcroft is working on several committees to define practical CQI-9 regulations for vacuum carburizing," Gornicki says.

"Current specifications need revising to allow vacuum carburizing to advance in the industry," Jones says. "The progression in technology of HPGQ has evolved over the last several years to adequately quench certain steels. Outdated drawings, however, will not allow gas quenching because the drawing or specification dictates liquid quenching."

While challenges exist, major markets, including aerospace, automotive, agricultural, wind, mining and commercial

continued

heat treating, are using vacuum carburizing today and see potential growth in the future. It's an area that will continue to attract attention as more technology unfolds, either as the preferred method or as a complement to atmospheric furnaces.

"Most companies that require heat treating are considering equipment for in-house processing mainly due to high cost of transportation and turnaround time," St. Thomas says. "Vacuum carburizing has many benefits that should be considered in the future."

Product Spotlight

Here's a few of the vacuum carburizing systems currently on the market. For more information on vacuum carburizing, heat treating equipment and services, visit *www.geartechnology.com*.

FineCarb–Seco/Warwick

For almost 10 years, Seco/Warwick has been supplying its FineCarb technology to vacuum systems. This consists of a mixture of gases where the carbon carrier is ethylene and acetylene mixed with hydrogen and ammonia at a specified volume ratio, protected by the patent.

The FineCarb method eliminates negative effects while preserving all qualities that are typical of the particular carbon carriers. This way even, well-formed carburized layers are obtained on all surfaces of workpieces treated, including deep non-through holes, inner and outer gears, preserving a clean surface of the workpieces in question. In addition, the whole process is being accomplished successfully with low industrial gas consumption.

"The need to accelerate the surface layer saturation with carbon was the motivation to continue to develop LPC technology. In spite of the high cost of machinery, the technology became competitive with gas processes due to the speed and repeatability of the cycle. The LPC of steel using FineCarb technology provides carburizing cycles with a shorter cycle time than gas carburizing, with full control and repeatability of the processes," Walczak says.

Additionally, the company provides a simulation software tool called *SimVac*, which determines the carburizing process limits according to specified carbon case parameters. "Results can be printed and attached to the batch report, and the created recipe can be easily transferred. The software has a built in database of steel grades according to different international standards."

ModulTherm 2.0–ALD-Holcroft

ModulTherm is a highly flexible and fully automated concept in vacuum thermal processing technology. It combines three basics into one linked multi-chamber vacuum furnace system: heat treatment, quenching and material handling. The quenching and hot vacuum transfer chambers are integrated into a rail-mounted shuttle module that can service two to 12 or more independent treatment chambers. This modular design makes it easy to adapt the system to meet particular production requirements with direct integration.

ModulTherm has several features and options including high equipment availability, larger volume treatment chambers, 2,200 pound gross load capacity on original system, 7,000 lbs capacity on the new large size, convective heating to reduce cycle times, identical "time-to-quench" for every load and reversible quenching gas flow that improves uniformity and reduces distortion and dynamic quenching. In addition to thermal processing equipment, ALD-Holcroft provides all parts storage and retrieval systems, load transfer automation and computer controls for integration.

Processes include vacuum carburizing, carbonitriding, neutral hardening, normalizing, annealing, spheroidize annealing, stress relieving, vacuum brazing, high purity copper annealing and sintering. ModulTherm has been utilized for drive and axle components, transmission components, shafts, fasteners, precision machine components, castings and forgings, brake lines, hose fittings and tools. The company has developed dozens of configurations compatible with production used by manufacturing and heat treating facilities in the United States, Canada and Mexico.

LPC–Solar Atmospheres

Solar Atmospheres offers "Low Torr Range Vacuum Carburizing" (also known as LPC) for optimum case hardening. The benefits are wear resistant part surfaces with case depth uniformity, maximum case integrity, minimal distortion and clean parts. Solar carburizes in a single chamber with a newly developed *in situ*, gas pressure quenching system. The advantages include reduction in part distortion and precise temperature control, optimal case depths with acetylene gas mixtures. Single chamber carburizing means less part handling for cost effective processing. Metallurgically, this method prevents surface intergranular oxidation (IGO) and decarburization. The avoidance of IGO provides high case integrity for improved wear life compared to traditional carburizing. Additionally, the presence or absence of carbides can be controlled according to specification requirements. The process also produces compressive residual stress for improved fatigue life.

Advantages of this method include, minimal distortion, efficient part handling for improved quality and turnaround, furnaces ranging from lab sizes to six feet long, shorter cycle times for reduced costs, uniform case depth including improved gear root to pitch ratios, automation of specific cycles to insure repeatability, customized cycle development for specific applications and the ability to efficiently carburize blind holes. Because of furnace and processing capability, Solar offers specific cycle development for a range of alloys. New cycles are being developed for new materials and new applications, including powdered metal parts.

Super TurboTreater and TurboTreater–Ipsen

The Ipsen Super TurboTreater is a HPGQ vacuum furnace designed for larger load capacities for the processing of dies, tools and parts with complicated geometries. It's effective for larger, heavier loads with features including multi-directional cooling and isothermal hold functionality, a reliable water-cooled motor to improve hardening performance for heavy loads, convection-assisted heating combined with trademarked Flapper Nozzle technology that reduces cycle time and improves temperature uniformity during heat up and quench speed to allow heat treatment that exceeds the latest GM die block heat treatment specifications.

The Flapper Nozzle, a cooling gas injection port, is simple and reliable. It requires no complex linkage or actuation mechanism. This design reduces heat loss from the hot zone while improving temperature uniformity during heating. Convection heating has been demonstrated to dramatically reduce cycle time, especially for large cross sections or dense loads. These technologies decrease energy consumption, saving both time and money in addition to reducing maintenance worries and expenses.

For hardening, tempering, brazing, sintering, annealing (and AvaC and SolNit) high speed steels, titanium or the latest super alloys, Ipsen delivers fast cycle times and improved workload results with TurboTreater. Features include Ipsen's patented gas quenching system, a compact cooling system design and three zones of heating with Digital Trim control ensure temperature uniformity throughout the hot zone.

For more information:

ALD-Holcroft Vacuum Technologies, Inc.
49630 Pontiac Trail
Wixom, MI 48393
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Fax: (248) 668-2145
www.ald-holcroft.com

Ipsen, Inc.
984 Ipsen Rd.
Cherry Valley, IL 61016
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www.ipsenusa.com

Seco/Warwick Corporation
180 Mercer Street
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Solar Atmospheres, Inc.
1969 Clearview Rd.
Souderton, PA 18964
Phone: (800) 347-3236
Fax: (215) 723-6460
www.solaratm.com


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678910
ORDER'S UP.

Hybrid Economy, NASCAR Performance

VMT TECHNOLOGIES DESIGNS POSITIVELY ENGAGED, INFINITELY VARIABLE TRANSMISSION

Matthew Jaster, Associate Editor

Gary Lee invented the Universal Transmission design.

To better understand the concept behind VMT Technologies Universal Transmission, you have to start in the snow—the light, champagne-powdery kind typically found in Utah. Gary Lee, inventor of the Universal Transmission design, was having trouble getting his snowmobile through it.

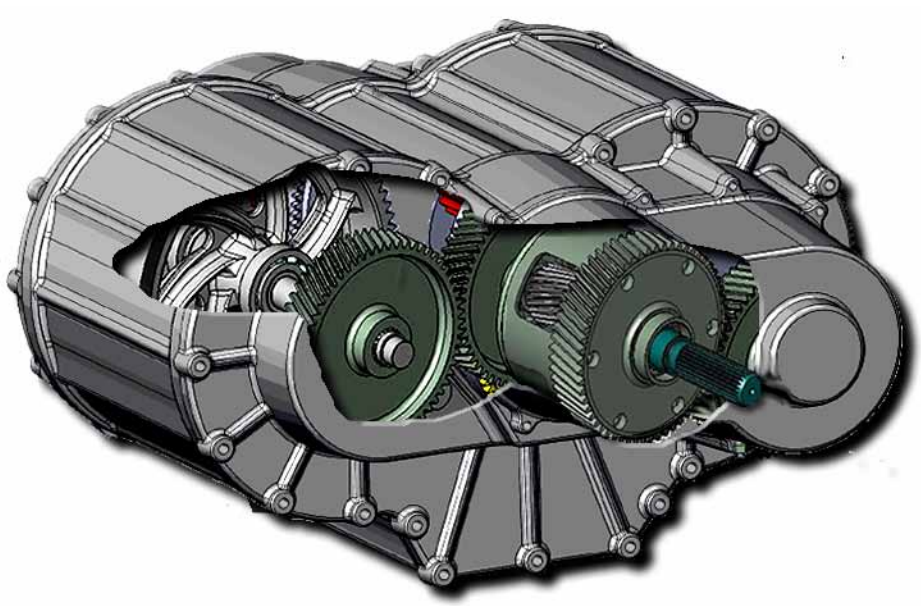
"We were pushing snow instead of getting on top of it," Lee says. "The heat generated would cause the rubber belt in the transmission to fall apart. I was burning a belt every time I went out on a snowmobile trip. I figured there had to be a better way where the friction is positively displaced."

Lee began tinkering with the transmission on his snowmobile and realized there were things that could be done to improve the design. This thought process eventually led to the creation of the company, VMT (Vernier Moon Torque) Technologies and a design concept for a positively engaged, infinitely variable transmission.

Today, VMT claims the transmission prototype can improve vehicle gas mileage up to 30 percent or more and can also improve the way electric/hybrid vehicles operate. With the assistance of CEO Richard Wilson, Mark Stoddard, chief marketing and business development officer and Steve Sutherland, chief operating officer, Lee began discussing the new transmission concept with OEMs. Discussions involved an alternative to standard transmission design.

"It's an infinitely variable transmission, requiring no clutch or torque converter, and it's constantly engaged. It doesn't use friction to change gears.

continued



VMT Technologies has designed a concept for a positively engaged, infinitely variable transmission (courtesy of VMT).

It can replace the expensive motor controller and turn low-torque hybrids to high-torque hybrids," Lee says. "Friction is not a friend to efficiency or performance."

The Universal Transmission uses an engaged drive chain instead of a friction belt. This allows a friction-free chain-to-sheave relationship as the torque flows through the gear/chain engagement. There are other distinct properties that make the design unique to the transmission market including:

- Metal gears always remain engaged, giving drivers maximum performance;
- It never disconnects the engine from the load like standard or automatic transmissions current ly do;
- The fuel savings alone is enough to dramatically reduce pollutants, reduce effects from fossil fuels and encourage energy independence;
- The transmission not only makes electric and hybrid cars a reality in passenger vehicles, but large trucks as well.

"The efficiency of the transmission

Lee explains the transmission technology during a recent presentation (courtesy Stuart Johnson, Deseret News).

Lee discusses the advantages of the Universal Transmission to senior engineers at a major transmission manufacturer in Korea (courtesy of VMT).

can also allow you to reduce the size of the engine, which improves gas mileage," says Mike Agrelius, sales director at VMT. "In electric and hybrid vehicles, the Universal Transmission could replace the expensive controller, making electric hybrids more competitive in the automotive market."

"Electric cars are still in their infancy," adds Sutherland. "Having an infinitely variable transmission that performs right out of neutral can significantly cut costs. The price tag of an electric car can double due to the battery pack and controller alone."

VMT sees a market much broader than that of continuously variable transmissions (CVTs), since their transmission can work in trucks and heavy equipment as well as small vehicles. VMT believes with the Universal Transmission there is room to improve on this design.

"CVTs are friction-based and have limited torque application. It's appealing because there are more gear increments and better gas mileage. We know that at the very minimum, the Universal Transmission will match anything they've been able to do with the CVTs," Sutherland says.

In order to meet the many challenges of the Universal Transmission design, VMT worked with Brigham Young University for three years. Mechanical engineering students as well as teachers were instrumental in helping to research and understand the problems that had to be overcome to develop what has become this transmission concept.

"The work done at BYU allowed Gary to use it as a springboard, and we've been on the fast track ever since," Sutherland says.

More than 15 mechanical engineers, including four distinguished professors of mechanical engineering, consider the Universal Transmission breakthrough technology. While transmission companies have spent billions on new technology efforts, Lee's knowledge of gears and his determination as an inventor were pivotal in providing the right foundation for the Universal Transmission concept.

VMT is aggressively seeking various opinions and feedback from the likes of Allison Transmission, Borg Warner, Honda, Subaru, Hyundai and Kia on the concept. One company, in particular, considers the Universal Transmission "leap frog technology."

"We've been especially pleased with all the interest and intrigue we've seen since November," Sutherland says. "It's an exciting opportunity for us to be able to incorporate Gary's vision and provide engineering consulting in the future."

"Hybrid economy with NASCAR performance," Lee says. "This is probably the best description we can give for the work we're putting together."

While the country continues to explore fuel efficiency in the automotive market, there's no denying the fact that many Americans still enjoy larger vehicles.

"Americans love big, powerful

continued

Lee and Will Decker, senior engineer, discuss the Universal Transmission at the white board (courtesy of VMT).

automobiles. We're excited about the possibility that an infinitely variable transmission could make an electric Ford F-150 a reality and offer a significant energy savings to the electric, hybrid or conventional versions," Sutherland says.

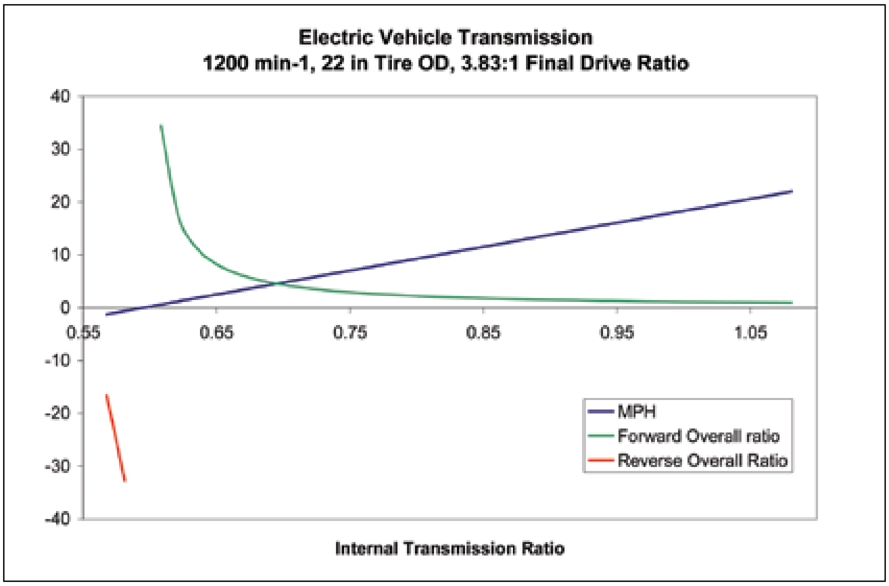
At the company's website (*www.moongears.com*), the Universal Transmission development process is detailed along with a series of questions and answers that describe the benefits versus a standard gearbox, automatic transmission or CVT.

The company also goes into great detail on the advantages of the Universal Transmission in the semi-truck market. About 50 percent of all oil for vehicles is consumed by trucks. If the Universal Transmission is utilized in a semi truck, fuel usage could rise from 5 mpg to perhaps a high of 6.5 mpg just from keeping the engine running in its "sweet spot" and never having to shift. Every time you shift, you disconnect the engine from the load, and you lose momentum or inertia. Going uphill requires dramatic uses of fuel just to recapture that momentum at every gear. Fuel will be saved because there is no clutch and the transmission is constantly engaged. Save fuel in trucks and you make a far stronger impact than saving fuel in cars. With an improvement of 5 mpg to 6.5 mpg in the big rigs, and more in smaller trucks, some of which could have electric or hybrid motors, there could be a 15 to 25 percent reduction of the fuel consumed in U.S. vehicles—just in trucks.

Currently, the licensing company is continuing to get the message out via press conferences, press releases, technical papers, peer review groups and professional journals. VMT has a fully working 3-D CAD prototype of the design and is looking for strategic partners to create a functional, in-vehicle prototype. The transmission design can be applied to heavy trucks, agricultural and heavy duty equipment, maritime, automobiles (including electric, hybrid and light trucks) and military vehicles.

It's been a whirlwind of activity for the Provo, Utah-based organization as it continues to spread the word on the transmission technology. The VMT staff includes many employees from a variety of career fields that simply felt Lee was onto something as he tinkered with snowmobile transmissions in the Utah snow.

"We all came into this from different backgrounds," Agrelius says. "We're just a matter of months from securing a strategic partner. People in the industry see the value and the possibilities of this technology, and they want to get a head start on their competition."



This table shows the output of the transmission as it steps through its range of discrete ratios (courtesy of VMT).

For more information:

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New Developments in Gear Hobbing

Dr. Oliver Winkel

Management Summary

Several innovations have been introduced to the gear manufacturing industry in recent years. In the case of gear hobbing—the dry cutting technology and the ability to do it with powder-metallurgical HSS—might be two of the most impressive ones. And the technology is still moving forward. The aim of this article is to present recent developments in the field of gear hobbing in conjunction with the latest improvements regarding tool materials, process technology and process integration.

Introduction

A couple of newer developments have been introduced regarding gear hobbing; i.e., the innovations in the substrate materials and coating systems have led to an increase of productivity by higher cutting speeds and longer tool life.

But we all know that higher performance leads to higher prices for the tools, so the impact on the tool investment as well as the resulting cost-per-piece have to be examined.

Another perspective to improve productivity is to shorten the process chain. Here, the process integration via chamfering and deburring on the hobbing machine is discussed. Beyond conventional chamfering methods like the Gratomat principle or rotary deburring, a new process using specially designed chamfering cutters will be presented.

Finally, the chance for cost savings by process substitution is discussed, focusing on examples for finish hobbing. To overcome shaving as the traditional soft-finishing method, new tool concepts are presented that aim to increase the process performance regarding tool life and workpiece quality. Of equal importance, the ability to eliminate or control the natural twist of finish hobbing might lead to new applications.

Modern Tool Design

Machine tools have also improved considerably in the last decades, but their major impact on hobbing technology was related to tool development. If we examine those past improvements, the focus was, on the one hand, on the substrate materials and, on the other hand, on the coating systems (Fig. 1). Together, both developments led to much higher cutting speeds and/or longer tool life. Even processes like dry hobbing became a reality.

Coming from the conventional HSS substrates (e.g., EMo5Co5 or M35) with TiN coating, the use of carbide hobs seemed to be critical to dry hobbing applications. But after initial success, problems with the process's reliability regarding tool life of the reconditioned carbide hobs (e.g., due to cobalt leaching during stripping) stopped the trend. Then, the introduction of the more heat-resistant TiAlN coatings—in combination with higher alloyed and more homogeneous PM-HSS substrates—brought the dry cutting back on track. Today, dry cutting with PM-HSS, as well as carbide, is a given. And since the AlCrN-based coatings have recently been introduced successfully in the gear hobbing market, speed and feed could be increased even more in many applications.

Besides their more homogeneous structure, the main advantage of the powder metallurgical HSS substrates is the ability to contain greater amounts of alloys. As shown

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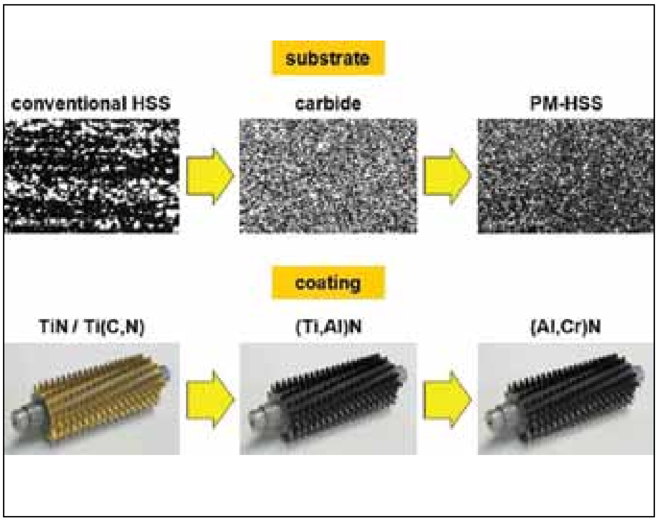

Figure 1—Tool improvements in the past.

in Figure 2, the remaining content of iron was reduced from about 70% for a standard substrate (e.g., ASP2030, S590 or Rex45) to a minimum of 55–60% for the so-called “bridge materials” (e.g., ASP2080, S290 or Rex 121). Those extremely alloyed substrates are more similar to carbide material then PM-HSS, which affords the advantage of higher wear resistance but, conversely, the disadvantage of excessive re-sharpening. Therefore, medium-alloyed substrates like ASP2052, S390 or Rex 76 are a good compromise for high-performance hobbing applications.

Regarding the different coating systems, Figure 3 shows a comparison of their most important characteristics (Ref. 1). While the higher hardness of the TiCN coating compared to the TiN coating showed potential to improve the tool performance in wet cutting, the low red hardness (maximum service temperature) of both coatings was not really sufficient for dry hobbing applications. Here the TiAlN, and especially the new AlCrN coatings, have proven their performance ability. With maximum service temperatures of 900–1,100°C, in combination with their thermal isolating effect to the substrate material, a new level of dry cutting could be reached.

Higher performance means higher pricing (Fig. 4). As a rule of thumb, on PM-HSS hobs a TiAlN coating costs about 20% more than a TiN coating. An AlCrN coating will cost an additional 30% compared to a TiAlN coating—or about 55% more than a TiN coating. For carbide hobs, the coating prices are typically about 20% higher than for PM-HSS tools.

Due to the typically lower tool costs, PM-HSS is actually the preferred substrate material for hobs, especially in the smaller modules (e.g., automotive and truck industry). Characteristic of PM-HSS is its reliable wear behavior in a widespread range of applications. Carbide offers advantages, especially in the area of finishing and cutting of high-strength workpiece materials (R_m > 900 N/mm^2), due to its high wear resistance. For low- to medium-strength material (R_m = 500–700 N/mm^2), typical cutting data are given in Figure 5. While PM-HSS normally allows higher chip thickness (higher feed rate), carbide offers higher cutting speeds.

The final decision for the best choice of substrate should be based on a detailed analysis of the cost per piece (Fig. 6). It is assumed that using PM-HSS leads to lower tool costs (in this case, 16%). Carbide tools offer lower machining times (22%) and thus lower machining costs. In the present example, both advantages almost negate each other concerning cost per piece. This clearly demonstrates that the decision regarding the right substrate should always be made on an application-by-application basis. If no significant advantages are present for carbide, PM-HSS is actually favored in most applications due to its more reliable performance and lower investment costs.

But the example also points out a couple of other aspects. Since the process is running on an older machine, the automation is quite slow. Therefore, the idle times (loading and

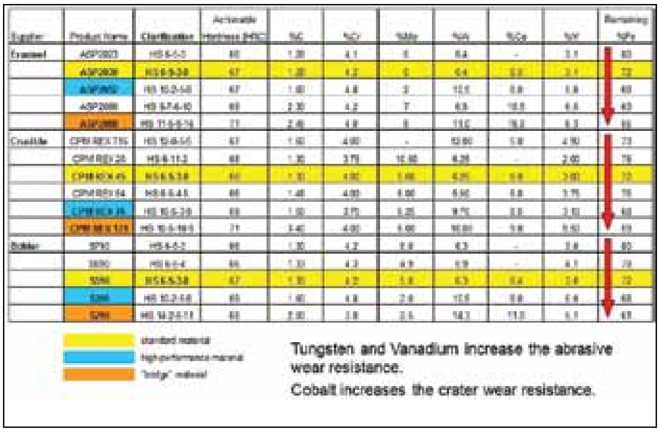

Figure 2—PM-HSS materials.

Product Name	Coating Material	Microhardness (HV)	Friction Coefficient against Steel (dry)	Internal Stress (GPa)	Max. Service Temperature (°C)	Coating Color	Coating Structure
BALINIT® A	TiN	2300	0.4	-2.5	600	gold-yellow	Monolayer
BALINIT® ALCRONA	AlCrN	3200 !	0.35	-3	1100 !	blue-grey	Monolayer
BALINIT® B	TiCN	3000	0.4	-4.0	400	blue-grey	Multi-layer, gradient
BALINIT® C	WC/C	1000 / 2000	0.10-0.20	-1.0	300	black-grey	Lamellar
BALINIT® D	CrN	1750	0.5	-1.5 / -2.0	700	silver-grey	Monolayer
BALINIT® DIAMOND	polycrystalline	8000 - 10000	0.15-0.20		600	light-grey	Monolayer
BALINIT® FUTURA NANO	TiAlN	3300 !	0.30-0.35	-1.3 / -1.5 !	900 !	violet-grey	Nano-structured
BALINIT® FUTURA TOP	TiAlN	3300 !	0.25 !	-1.3 / -1.5 !	900 !	violet-grey	Nano-structured
BALINIT® G	TiCN + TiN	3000	0.4	-4.0	400	gold-yellow	Multi-layer, gradient
BALINIT® HARDLUBE	TiAlN + WC/C	3000	0.15-0.20 !	-1.7 / -2.0	800	dark-grey	Multi-layer, lamellar
BALINIT® TRITON	DLC (a-C-H)	2500	0.1-0.2		350	black-grey	Monolayer
BALINIT® X.CEED	TiAlN	3300 !	0.4	-3.0 / -3.5	900 !	blue-grey	Monolayer
BALINIT® X.TREME	TiAlN	3500 !	0.4	-4.0	800	violet-grey	Monolayer

Source: Balzers ! : positive influence on dry hobbing

Figure 3—Properties of modern coating systems.

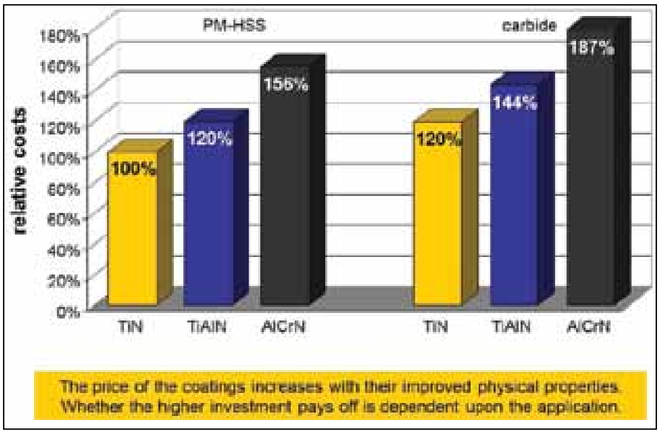

Figure 4—Costs for different coatings.

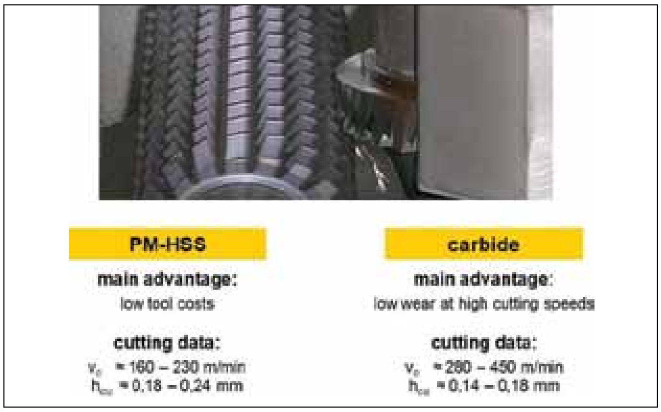

Figure 5—PM-HSS versus carbide.

unloading of the workpiece, etc.) are about 40% of the cycle time. The rule is that the higher the cutting data (speeds and feeds), and the lower the hobbing time, the faster the automation should be. Another interesting point is that although the tool costs of about 35% are quite high, the portion for the tool investment of about 10% is very low. The conclusion is that the price for a new tool should not be the primary criterion because it has a very small impact on the total costs. Indeed, the message is exactly the opposite: If the higher price for substrate material or coating is connected to a higher performance ability of the tool, this investment pays off in many cases. This is especially the case if the higher tool performance is used to increase the cutting data, which leads to minimized machining costs.

Chamfering and Deburring Methods

Besides the generating of the gear teeth itself, secondary operations have to be carried out as well. A very important one is the elimination of the burrs that are caused by the cutting process. Additionally, a chamfering of the sharp edges is requested in many applications. Since the difference between deburring and chamfering is important and often mixed, the most important aspects are pointed out in Figure 7.

Deburring is necessary to protect the worker against injuries during manual handling of the workpieces. In subsequent processes, burrs on the face sides can affect the gear quality if the faces are used for locating or clamping. Finally, remaining burrs on the finished part can cause higher noise emission or wear in the gearbox.

Chamfering is often applied to avoid nicks during workpiece transportation. In addition, the sharp edges lead to over-carburization, which causes embrittlement and can lead to edge chipping. This will lead to higher wear in the gearbox. Other aspects might be the support of the assembly process and the improvement of tool life during the hard finishing process (especially for gear honing).

There are two typical chamfering processes that differ from each other in flexibility and needed chamfering time. The first one is the Gratomat process (Fig. 8), where chamfers along the tooth are created with milling cutters. The tools are pressed on the workpiece faces under pre-load and at a specific setting angle. The applied milling cutters are made of carbide for a higher tool life. High-speed spindles are creating the necessary cutting speed. The process is very flexible regarding the workpiece geometry and relatively insensitive towards the workpiece strength. If an according chamfering unit is integrated in the hobbing machine and there is a sufficient cycle time for hobbing, the chamfering can be done parallel to the primary processing time. In this case, no additional cycle time for chamfering is needed.

Figure 9 shows one possibility for the integration of such a chamfering unit—while using a 4-station ring loader, the 90° position can be used for the chamfering, thus eliminating the need for additional floor space. As a result, the footprint of the machine stays constant while an additional operation

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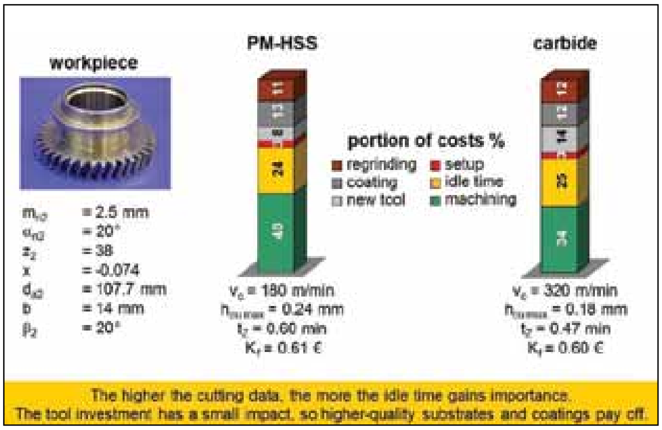

Figure 6—Cost calculation example.

Figure 7—Why chamfering and deburring.

Figure 8—Gratomat.

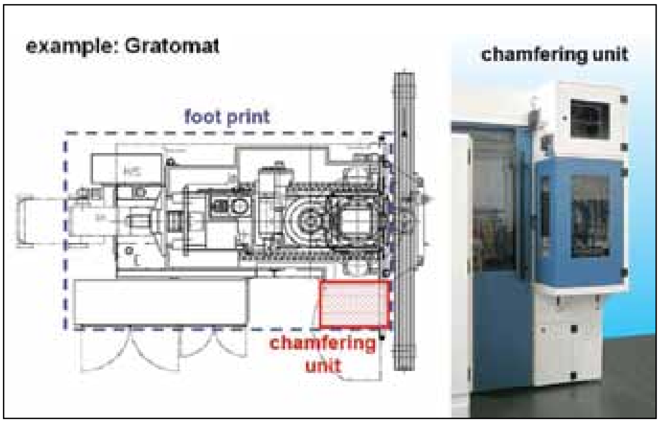

Figure 9—Floor space of integrated unit.

Figure 10—Rotary deburring.

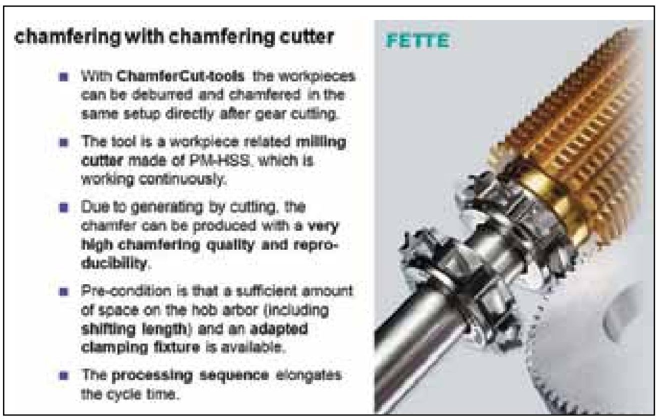

Figure 11—ChamferCut.

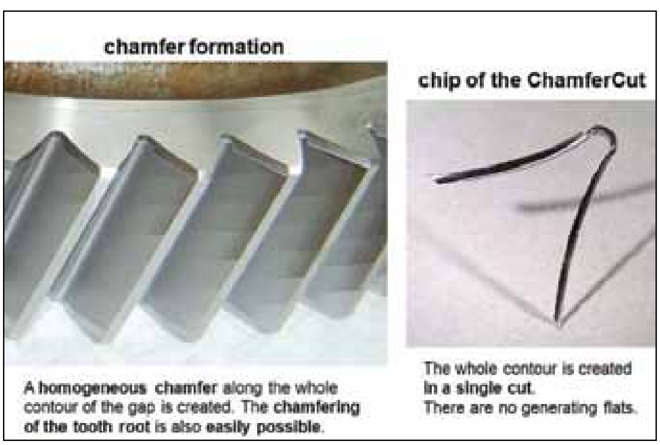

Figure 12—Chamfering quality and chips.

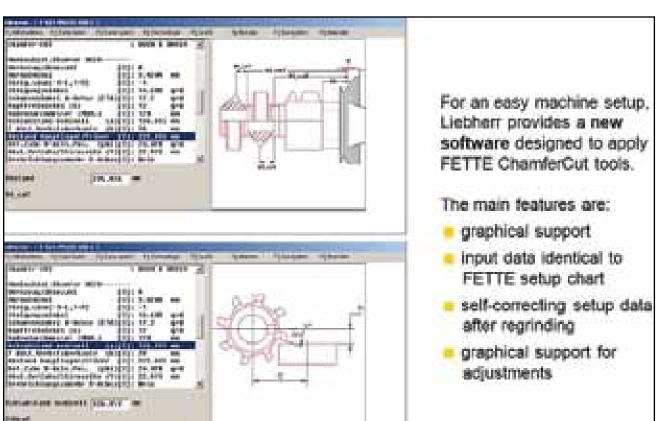

Figure 13—User interface.

is integrated.

The same principle can be used to apply a chamfering unit for rotary deburring tools. While the Gratomat principle is quite flexible regarding the workpiece geometries to be machined due to the use of standard milling cutters, the chamfering itself takes some time. Here, the rotary deburring has its benefits in the extremely short chamfering times due to the applied special tools (Fig. 10).

With rotary deburring, the chamfering is done by cold forming. The chamfer is created by a specially designed tool that rolls under pressure with the gear. The deformed material on the face side is sheared off by deburring disks. Deformed material in the gear flanks can be flattened by burnishing wheels, which are integrated in the rotary deburring tools.

Those tools can therefore be quite complex, since they consist of several gears. The typical substrate material is PM-HSS.

As mentioned, the process allows very short chamfering times, which can be just a couple of seconds. Thus, chamfering is typically done parallel to the primary processing time—even at very short cycle times. The economic limits are set by the low-flexibility and high-strength workpiece materials.

An alternative to the conventional chamfering methods requiring additional chamfering units is the ChamferCut technology (Fig. 11; Refs. 3–4). By adding additional chamfering cutters (the so-called ChamferCut tools) to the hob, the chamfering can be done on a standard hobbing machine in the same setup, directly after gear cutting. Due to the specific tool design, the chamfering process is working continuously. Its function and restrictions are discussed in the following.

All tools for gear hobbing and chamfering are mounted on one arbor. After the gear has been cut, the ChamferCuts come into play. The first ChamferCut creates a uniform chamfer at the top of the gear. The second ChamferCut is then responsible for the deburring and chamfering of the bottom side. The result is a chamfered gear that needs no additional machining.

To get an impression of the chamfering quality, Figure 12 shows an example. Due to the fact that each ChamferCut is specifically designed for a single workpiece geometry and the chamfering itself is done by cutting, it creates a very uniform and homogeneous chamfer along the whole tooth gap. Even the chamfering of the tooth root area is easily performed. Unlike the hobbing process, the chamfer is not formed by several enveloping cuts. Rather, the whole chamfering contour is created in a single cut and is therefore not a generating process.

Crucial to the feasibility of this technology for industrial applications is a suitable software support for the operator, which means the quality and usability of the according machine software. Therefore, a custom software package has been developed using the same data and graphics as the setup sheets provided by the tool supplier to simplify the programming and adjustments (Fig. 13). Afterward, the software calculates and dictates the necessary axis movements.

When a tool is worn out, it can be easily re-sharpened on the rake face—identical to hob sharpening. The necessary adjustment of the setup data after re-sharpening of the ChamferCuts is done by the software, based on the actual outside diameter.

The ChamferCut technology is applicable to both small- and large-module gears (Fig. 14). Here the pre-grind form milling is followed by a chamfering of the bottom side of the gear. Since rotary deburring of this module 16 gear is not possible and the Gratomat principle would require an additional machine, the ChamferCut offers the chance to remove the heavy, ICI-created burr on the bottom side in the same setup.

But it has to be mentioned that there are also some preconditions when applying this chamfering process. Primarily, a sufficient amount of space on the hob arbor, in combination with an according shifting length, is required. Furthermore, the clamping fixture has to be adapted because the ChamferCut is working at a lower center distance than the according hob. Finally, the ChamferCut tools should not have interference with the workpiece contour.

Summing up:

- A major drawback might be that the chamfering process always increases the cycle time.
- Of significant benefit are the reduced investment costs, compared to the chamfering units and the short setup times.

Finish Hobbing

Although hard finishing (like honing or grinding) remains strong in the gear market, the cost efficiency of soft finishing (like shaving) is still unbeaten. Where applicable, finish hobbing offers the shortest possible process chain (Fig. 15).

Since shaving is still the most-applied soft finishing process, finishing hobbing has made great strides with the improved accuracy of modern hobbing machines in combination with high-quality tools (quality AAA or better). Therefore, the quality gap between finish hobbing and shaving continues to narrow.

If both processes are compared directly (Fig. 16), shaving has proven to be a very economical and established process—especially in mass production. Additionally, the achievable profile accuracy before hardening is very high. On the other hand, shaving will always be a wet cutting process and in fact appears to be close to its technological limits. Here, finish hobbing shows some potential: in particular, the ability for dry cutting and the introduction of new tool concepts have potential for the future.

Even the former drawback of the process-related twist might be possible to overcome.

Figure 17 shows an example of a state-of-the-art finish

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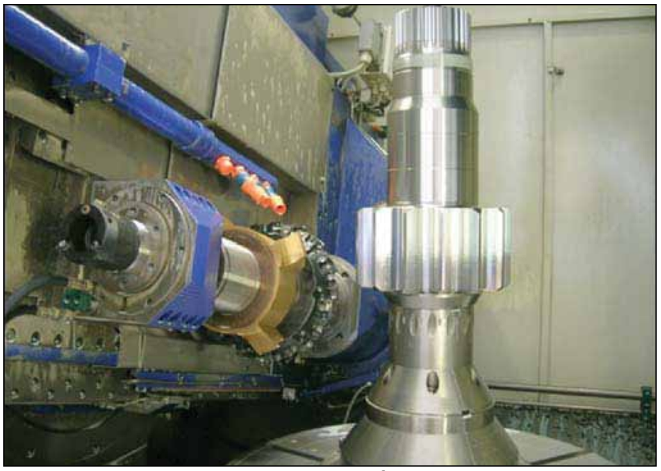

Figure 14—Gear milling and chamfering.

Figure 15—Finish hobbing.

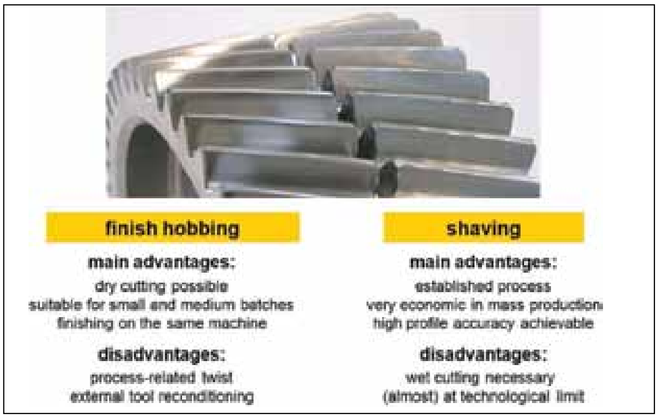

Figure 16—Finish hobbing versus shaving.

Crank Shaft Gear

module	mm	2.557
number of teeth		45
helix angle	degree	23
tip diameter	mm	134.10
workpiece width	mm	30.0

machine	LC 300	
tool		
type of tool		carbide
outside diameter	mm	80
number of gashes		17
number of starts		1
length	mm	200
technology		
number of cuts		2
coolant		dry
cutting speed	m/min	260 / 800
feed	mm/WR	5.1 / 1.0
infeed for 2nd cut	mm	0.1
no. of clamped pcs.		1
automation		KKB
times		
machining time	min.	1.48
idle time	min.	0.22
cycle time	min.	1.70

Figure 17—Machining example III (technology).

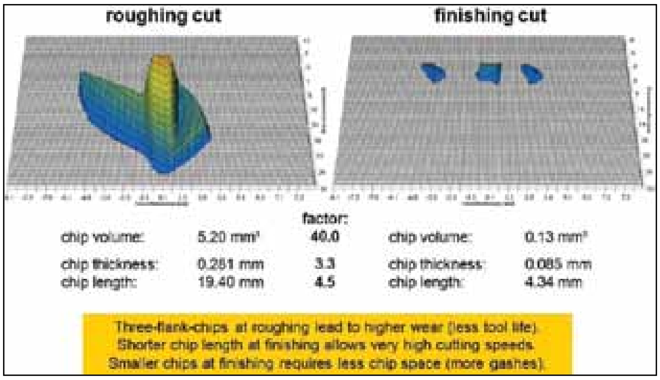

Figure 18—Chip geometry for first and second cut.

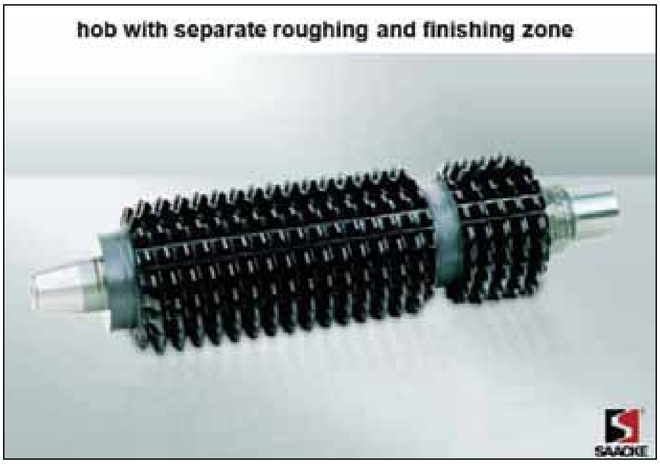

Figure 19—Carbide tandem hob.

Speed Gear

module	mm	2.77
number of teeth		40
helix angle	degree	25.28
tip diameter	mm	126.1
workpiece width	mm	15.5

machine		LC 130
tool		
type of tool		carbide
outside diameter	mm	70
number of gashes		19
number of starts		2 / 1
length	mm	134 / 40
technology		
number of cuts		2
coolant		dry
cutting speed	m/min	400 / 750
feed	mm/WR	2.2 / 0.8
infeed for 2nd cut	mm	0.15
no. of clamped pcs.		1
automation		KSR
times		
machining time	min.	0.23 / 0.40
idle time	min.	0.14
cycle time	min.	0.77

Figure 20—Machining example IV (technology).

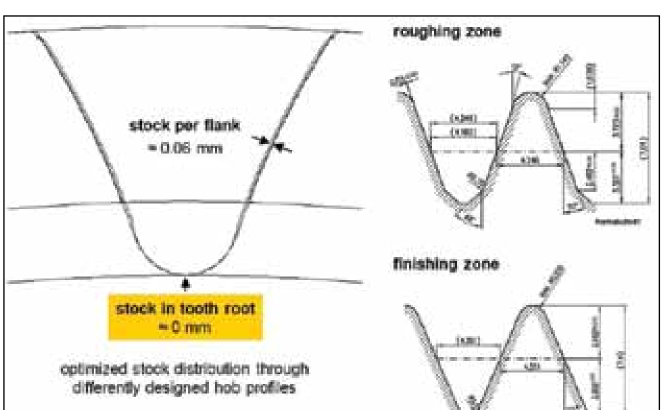

Figure 21—Stock distribution (example IV).

hobbing operation. The former wet shaving and hobbing processes were replaced by dry finish hobbing in two cuts. Due to their high wear resistance, carbide tools are well suited for this application and the higher applicable cutting speeds in the second cut lead to significantly shorter cycle times. Significantly, the direct drive technology in hobbing machines provides the necessary spindle revolutions for the highest cutting speeds. Typically, the achievable workpiece quality is in the area of DIN 6–7.

In such conventional finish hobbing processes, the first and the second cut are made with the same hob at the same shifting position. The drawback here is that there is always a compromise regarding the tool design to match the needs of both cuts. As shown in Figure 18, the chip geometries for the first and second cut are totally different, and therefore the optimum technology differs significantly. For example, the chip volume in the first cut is much higher, so more space in the gashes is needed. The chip thickness and the chip length are smaller in the second cut, allowing the use of harder substrate materials at higher cutting speeds.

A first step in the direction of a separate optimization for both cuts is shown in Figure 19. In this case, the hob was split in two areas—a longer roughing and a shorter finishing zone. The separation of roughing and finishing zone offers numerous new possibilities for process optimization. For example, the tool life of the finishing zone is very high because the influence of the roughing cut on the wear behavior is eliminated and the amount of material removed is minimized. The roughing zone also shows increased tool life since the wear no longer has an impact on the workpiece quality and there is no additional wear caused by the second cut in this area. Therefore, the total number of machined parts per sharpening increases, although the tooth length is shorter.

Additionally, both parts of the hob can be optimized independently of each other concerning the specific needs of each cut (e.g., different number of starts). This can shorten the cutting times; examples are shown in Figures 20 and 21.

For the roughing cut, a two-start hob is used to achieve the highest material removal rates. For the finishing cut, a single-start hob was chosen to get the best-possible workpiece quality. Furthermore, the hob profiles are different in both sections, so that the finishing hob is only cutting on the flanks and eliminating the feed scallops from the first cut.

As such, the theoretical stock in the tooth root is zero. The pressure angle of the roughing hob was decreased to increase the tip radius for better tool life.

The achieved quality is documented in Figure 22. Typically, the profile limits the quality level. Since the hob quality has the most impact on the resulting profile accuracy, there is actually maximum potential for quality improvements. In this case, a very good overall quality was achieved.

Since the feed scallops have been limited to one micron by a small feed rate, they cannot really be seen in the quality measurement chart. Nevertheless, the scallops—as well as the generating flats—can be seen clearly visual due to the bright shining surface after dry hobbing (Fig. 23). But since these deviations are in a submicron range, they can no longer be identified subsequent to heat treatment. In this case, a surface quality of R_z = 2 µm (R_a = 0.35 µm) was achieved after finish hobbing. This supports the contention that the use of high-quality tools and hobbing machines, in combination with a suitable cutting technology, can close the gap or even exceed the quality level of shaving in several applications.

By using modern CNC controls, the possibilities for tool optimization are even greater. Figure 24 shows a very complex tool system that can be applied for finish hobbing (Ref. 3). This tool system boasts not only roughing and finishing hobs—it also contains two chamfering cutters (ChamferCut). This tool concept combines advantages of finish hobbing with the possibility for process integration (chamfering). Instead of three separate working processes on different machines—hobbing, deburring and shaving—all operations are done in one setup and on the same machine. To assure optimum workpiece quality, the finishing hob is manufactured as a shank-type hob where additional tools can be added to its arbor. These tools are the ChamferCuts and roughing hobs, which are fixed by a hydraulic screw. Since each tool is separate, even different substrate materials or different number of gashes are applicable.

Despite all discussed opportunities for process optimization, one drawback of finish hobbing versus shaving remains—i.e., the natural twist of the tooth flanks if a helical gear is hobbed with lead crowning. If only the "cross" of profile and lead in the middle of the gear flank is checked, the existing twist cannot be identified (Fig. 25). Only the topological measurement of lead and profile in three different positions (top, middle and bottom for profile and tip; pitch and TIF diameter for lead) will show the real topography of the tooth flanks (Fig. 26). Here, the twist is the continuous profile or lead change along the workpiece width or tooth height. Although the profile and lead quality in the middle section is very much within DIN 7 tolerances, the created twist of about 16 mm leads to an exceeding of the given tolerance. Usually, the twist errors are much bigger than the deviations caused by feed scallops or generating flats.

Therefore, this twist is not accepted in many applications—for noise or wear reasons—and should be avoided. In the past, this was only possible by shaving. But based on a technology patented for generating grinding (Ref. 3), the transfer to hobbing was made in coordination with the tool supplier (Refs. 3, 5–6). The principle is to change the profile angle of the teeth on the finishing hob along its length (Fig. 27). The hob is then shifted diagonally during the finishing cut over the whole length. Due to the continuous profile change along the hob, teeth always come into contact with the workpiece and have the necessary correction to compensate for local profile error, which might cause the twist. In

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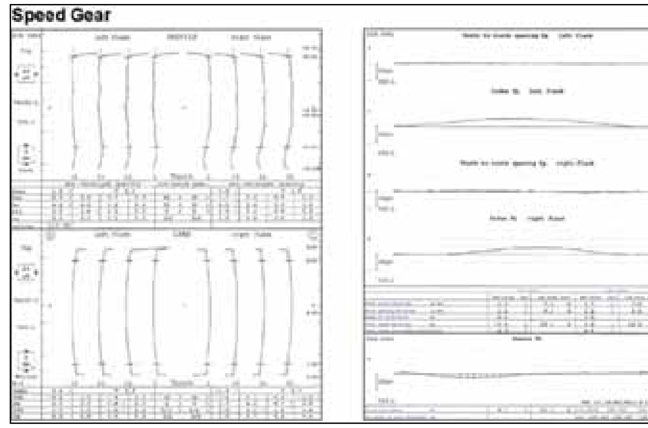

Figure 22—Machining example IV (quality).

Figure 23—Heat treatment.

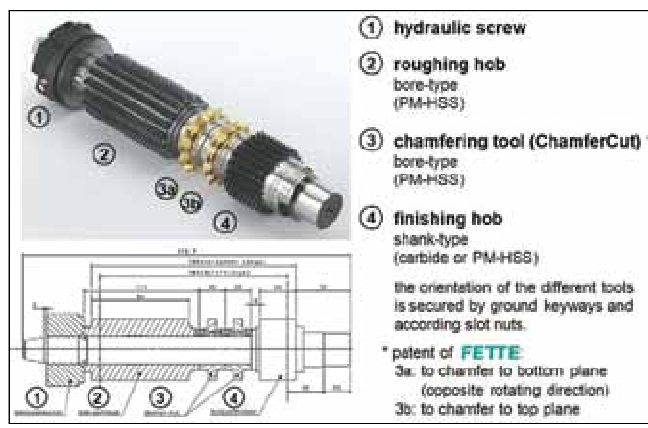

Figure 24—Tool for finish hobbing/chamfering.

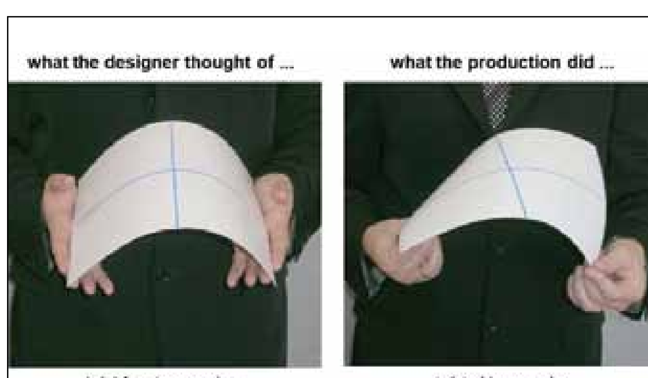

Figure 25—Twist.

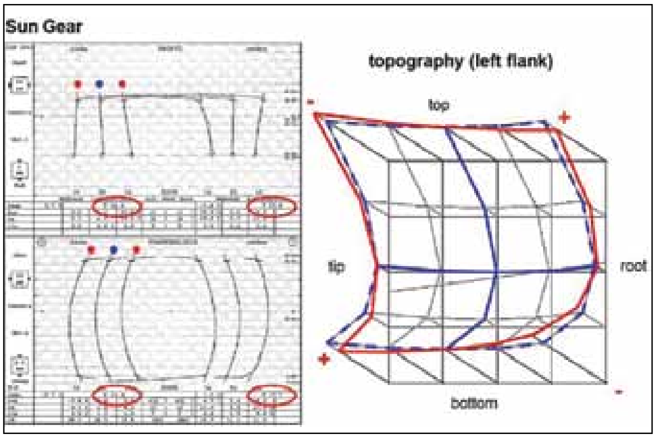

Figure 26—Difficulty of twisted tooth flanks.

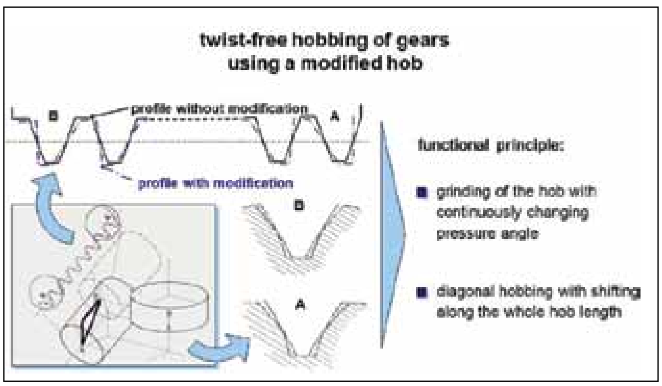

Figure 27—Principle of twist-free finish hobbing.

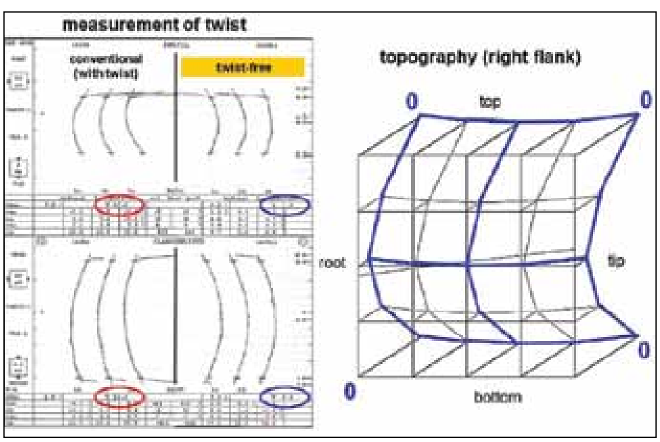

Figure 28—Topography with and without twist.

fact, the hob is causing an according counter twist.

Figure 28 shows the direct comparison of tooth flanks that were finish hobbed with and without the twist-free technology. As can be seen, the twist was reduced from 16 μm to almost zero. It is clear that the same technology is also suitable to achieve desired twist amounts that differ from zero. Therefore, an elimination of the twist is done in the same way as a decrease or increase of twist by just using different profile modifications along the hob. Since initial tests were very promising, further development of this technology continues accordingly.

Summary and Outlook

Several new developments regarding hobbing technology have been presented and discussed. Regarding modern tool designs, higher-alloyed substrates and new AlCrN coatings have increased tool performance, which leads to longer tool life and increased productivity. Especially on this last point, higher tool investment proves cost-effective because reconditioning costs are much higher than the initial tool investment and the machining costs are typically higher than the tool costs.

Furthermore, chamfering and deburring were discussed relative to process integration. Today, Gratomat and rotary deburring are the accepted deburring processes, but the ChamferCut technology is a new option and a breakthrough in chamfering quality—if the longer cycle times can be tolerated.

Finally, the case for finish hobbing as a chance to shorten the process chain was presented. It was pointed out that, with modern tools and machines, finish hobbing can compete with shaving quality. If different tools for roughing and finishing are used, new potentials for technology optimization arise. Indeed, finishing hobs with special profile modifications offer the capability of topological tooth flank modifications like twist, which were not possible until now. The so-called twist-free hobbing is presented as an application example.

In the future, it can be assumed that the ongoing development of substrates and coatings will offer further potential to improve productivity. Regarding finish hobbing, the application of new tool concepts and the improvement of tool quality might lead to more finish hobbing applications.

Dr. Oliver Winkel *studied mechanical engineering at the University of Technology (RWTH) Aachen, Germany. After working six years at the local Laboratory for Machine Tools and Production Engineering (WZL) as a scientist, he finished his PhD on dry hobbing with carbide hobs in 2004. That same year, Dr. Winkel joined Liebherr-Verzahntechnik in Kempten, Germany. Today, he is responsible for the technology development and application technology of gear cutting.*

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The Road Leads Straight to Hypoflex

Dr. Carsten Hünecke

State of the Art

Straight bevel gears are manufactured by means of primary forming, forming, or cutting processes. Examples of primary forming are casting and sintering. Casting is used on a large scale to manufacture straight bevel gears from non-metallic and non-ferrous materials for gear systems which are undemanding in terms of accuracy and power density. Sintered bevel gears are used in relatively large quantities in hand-held power tools like, for example, angle grinders. In comparison to other processes, it is difficult to avoid inadequate homogeneity, due to uneven densification. Dies are also very expensive to produce, and gear modifications are costly if dies have to be modified (Ref. 1).

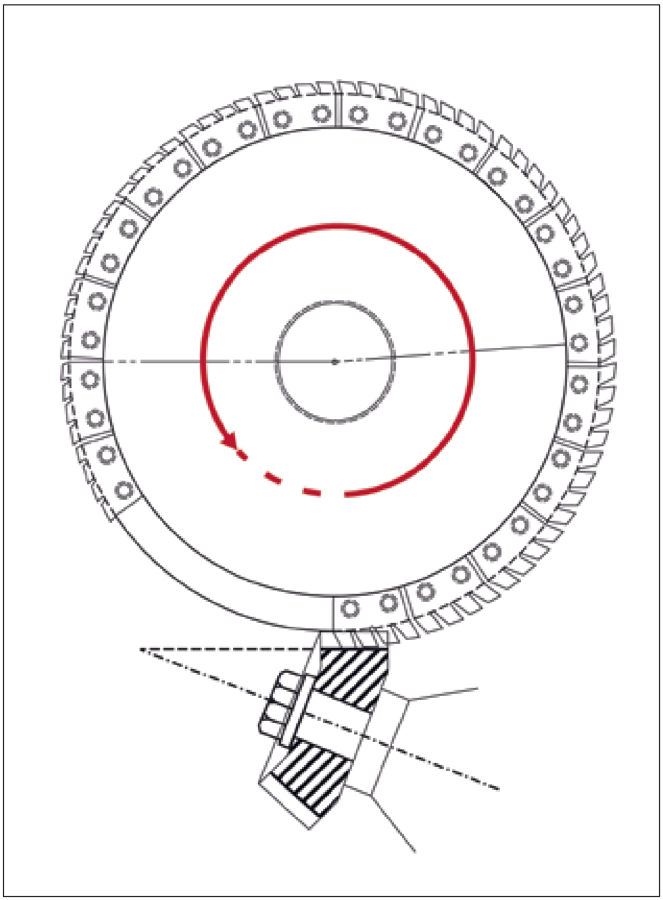
Figure 1—Revacycle broaching process.

Both forging and wobble pressing have proven to be useful as alternatives for mass producing differential bevel gears. Requirements in terms of tooth pitch tolerances and gear topography are lower than for running gears. The gear quality achieved with wobble pressing is roughly IT8 (Ref. 2). Nonetheless, cutting processes remain the first choice for greater accuracy or greater flexibility and in producing small batch sizes.

As far as soft machining is concerned, cutting processes like generate planing, hobbing and broaching may be noted. Hard machining of straight bevel gears occurs to only a very limited extent, by means of lapping or grinding. Grinding is also used for a few applications in the aircraft sector.

Planing by the Heidenreich-Harbeck process is still used to a limited extent in one-off and spare part production.

The Revacycle broaching process is used especially for the production of differential bevel gears. The tool is a circular broaching tool with a large number of differently profiled form cutter blades at the circumference. A first circular segment consists of roughing blades, with a slight outward offset to one another, followed by segments with finishing blades, leading to a gap in which the workpiece is turned by one pitch (Fig. 1). One tooth gap is produced for each revolution of the tool.

The finishing blade has a concave arc profile, which is reproduced in the workpiece, while the center point of the tool is displaced in a straight line, creating a straight tooth root. The tooth profile, which changes along the face width, and the lengthwise crowning are generated by the form of the individual cutter blades and by a tangential motion of the broaching tool.

Revacycle is characterized by its very high productivity, but the only means of influencing the tooth form is the tool. In consequence, this process is suited only for mass production.

A more general-purpose process is hobbing. Here, three different systems are in use, varying only slightly in the tools employed. These are Coniflex, Konvoid and Sferoid, Coniflex being the method used most.

The tool consists of two circular, intermeshing side milling cutters, which represent a crown gear tooth. The axes of the two side milling cutters—one for the left flanks, one for the right—are placed at a specific angle to one another, so the cutters alternately intermesh with each other, causing their main cutting edges to form a trapezoid profile. Since the cutting edges are not exactly in the plane of rotation of the respective cutters, but are located on a slight internal taper (Fig. 2), the teeth receive a fixed lengthwise crowning and a tooth root that is not straight but elliptical, with its lowest point in the middle of the tooth. The tooth's lengthwise curve deviates from the linear, depending on the tool and its settings.

The lengthwise crowning of the tooth is governed by the angle at which the two side milling cutters are inclined to each other and by the diameter of the tool. A change in this angle entails a change in the flank angle of the cutting edges, since the pressure angle of the tooth is otherwise altered.

The generating motion produces the tooth height profile. The two tools are swivelled around the apex while the workpiece turns on its axis. By means of different machine settings, it is possible to manufacture different bevel gears with a single tool.

Hobbing and broaching processes have been established for many years. The technology of these cutting processes dates back to the 1960s. They are wet cutting processes performed at relatively low cutting speeds. In terms of productivity and flexibility, they can no longer be compared to the dry cutting processes used today.

As opposed to spiral bevel gears, no known software tools are used. No modern program exists for dimensioning the gear or for the calculation and optimization of its contact behavior. Computer-aided topography measurement based on 3D nominal data is also lacking.

Theoretical Bases

Single-indexing and continuous-indexing processes are common for spiral bevel gears, employing face cutter heads as tools. Single-indexing processes machine single tooth gaps successively. The cutters are arranged in a circle and generate an arc-shaped, lengthwise tooth form.

If an outer circle is rolled off on another circle, an epicycloid is created. The circle that is rolled off is usually referred to as the rolling circle, with the radius E_b, and the fixed circle as the base circle, with the radius E_y. If the generating point of the epicycloid lies within the rolling circle, the resulting curve is known as a shortened epicycloid; otherwise, it is called an extended epicycloid (Fig. 3).

Continuous indexing processes employ a face cutter head with individual cutting edges arranged in groups consisting of inner and outer blades. Each group machines one gap. The number of groups is referred to as the number of cutter head starts or simply as the number of starts. In relation to the workpiece, a group of blades moves along an extended epicycloid. In continuous cutting processes for spiral bevel gears, the lengthwise tooth forms on the crown gear are therefore sections of extended epicycloids.

When spiral bevel gears are cut in a continuous process, the ratio of the number of starts to the number of crown gear teeth is equivalent to the ratio of the rolling circle radius to the base circle radius:

$$\frac{z_0}{z_p} = \frac{E_b}{E_y} \qquad (1)$$

A hypocycloid is produced when the rolling circle rolls on the inside of the base circle (Fig. 4). This is equivalent to reversing the direction of rotation of the cutter head compared to that for cutting an epicycloid.

How is it possible to generate a straight line, and hence a straight tooth, on this basis? In the special case in which the radius of the rolling circle is exactly half the radius of the base circle, all the points generated by a point on the rolling circle will lie on a straight line. In this case, shortened and extended hypocycloids become ellipses.

Hypoflex Process

The kinematics of the Hypoflex process rely on the relationship mentioned above (Ref. 2), i.e.—the fact that, in the theoretically exact case, the number of starts corresponds to half the number of crown gear teeth.

The number of crown gear teeth is not usually a whole, even number, and only in rare cases can the requirement be fulfilled exactly. Generally, the whole number nearest to

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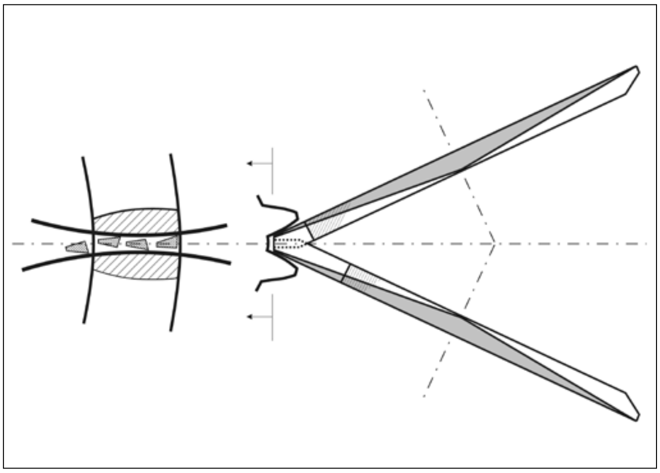

Figure 2—Hobbing with intermeshing side milling cutters.

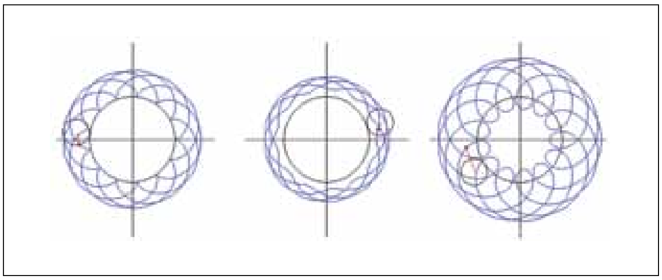

Figure 3—Epicycloid, shortened and extended epicycloids.

half the number of crown gear teeth is chosen as the number of starts. Tooth lengthwise curves (extended or shortened hypocycloids) are then generated with a radius of curvature of several meters, corresponding to a deviation of 2 to 3 µm from the straight line for usual face widths. This is a much smaller deviation than in hobbing or broaching by the methods described above.

The continuous indexing Hypoflex process is performed both as a completing and as a semi-completing dry cutting operation. In the completing process, a stick blade cutter head, possessing two blades per blade group—one inner and one outer blade—is used to machine the left and right flanks simultaneously, in a single machine setting. In semi-completing, only one cutter head is used, cutting the left flank in one machine setting and the right flank in another. A special feature of the latter process is that only one blade per group is employed. The blade has two cutting edges, and it is called TwinBlade by Klingelnberg. The disadvantage of a longer processing time in semi-completing as opposed to completing must be compared with the greater flexibility and easier realization of high numbers of starts when only one blade per group is used.

Hypoflex gears have a tooth height varying over the face width, whose dedendum and addendum angles can be chosen within a meaningful range. This makes it possible to retain the same type of blank when making a change from straight bevel gears previously produced in a different process.

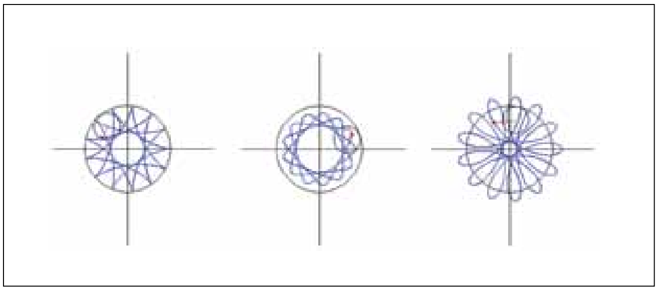
Figure 4—Hypocycloid, shortened and extended hypocycloids.

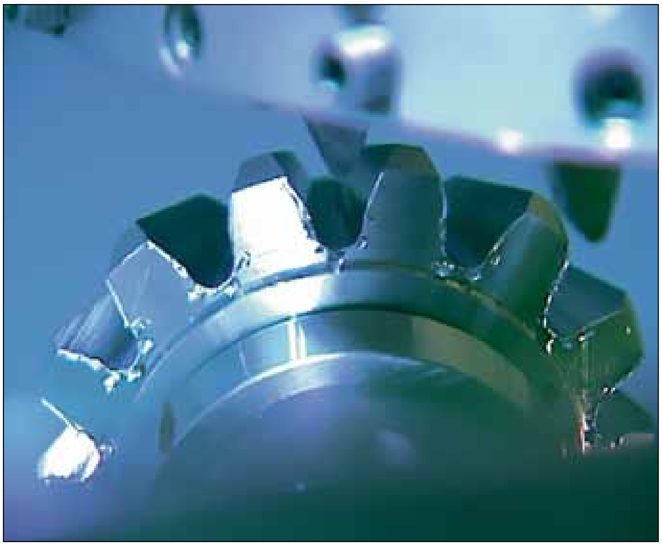
Figure 5—Bevel gear cut in the Hypoflex process.

Due to the difference between the root and pitch angles, a helix angle of 0° in the pitch plane can be realized only by cutting with different cutter radii for the inner and outer blade. The size of the difference is partly dependent on the dedendum angle and the pressure angle. The size of the group angle between two successive cutters of the same type in the continuous process is:

$$\varpi_{Gr} = \frac{360^{\circ}}{z_0} \qquad (2)$$

As the expert will recognize, a gap width deviating strongly from the desired value would occur when milling with the completing process with a blade sequence angle between the inner and outer blades, which equalled half the group angle. It is thus necessary to adapt the blade sequence angle. This means that the blades move closer together in comparison to an operation with bevel gears with a constant tooth height made in a continuous process. The size of the blade sequence angle is dependent on the number of starts, the dedendum angle, the pressure angle and the rolling circle or base circle radius. This criterion must be taken into account when designing the gear and when selecting a real cutter head.

The usual crownings are generated using various methods of modification. As in other bevel gear cutting processes, lengthwise crowning is produced by tilting the cutter head with adapted pressure angles. If a hollow cone modification is combined with the lengthwise crowning, a contact pattern located in the profile height direction occurs. Another method to generate a profile crowning is to use spherical profile blades. Further contact modifications (contact pattern and ease-off) can be achieved by applying the same method used for spiral bevel gears.

All potential methods of dimensioning the gear and calculating load-free contact behavior and load contact, including stresses—which are state-of-the-art technology for spiral bevel gears (Ref. 4)—are also used for Hypoflex. For the first time, it is also possible to measure the gear against 3D nominal data, using a computer-based calculation of the possible required machine setting corrections. This enables the user to produce straight bevel gears by the Hypoflex method in a closed-loop operation, with in-process testing of all quality-relevant attributes.

Using this process, straight bevel gears can be produced on existing Oerlikon bevel gear cutting machines, the only requirement being to update the machine software. The same applies for the cutter head adjusting device and the dimensioning and correction software. For the cutting operation itself, it is possible to use existing ARCON cutter heads with appropriate stick blades and numbers of starts.

Sample Gear

Figure 5 shows a bevel gear with the data listed in Table 1, designed for the axle drive of an off-road vehicle and cut using the Hypoflex process. Some contact analysis results are given in Figure. 7. The ease-off and contact pattern are in line with specifications collated from customers' data.

The gear was cut in a semi-completing process on an Oerlikon C 29 bevel gear cutting machine (Fig. 6), using a 14-start ARCON cutter head with cemented carbide stick blades. TiAlN-coated, 3-face blades were employed. The pinion was produced in 4.25 minutes and the wheel in 4.5 minutes. The pitch measurement according to DIN 3965 (Ref. 1) achieved quality 3 for the pinion and quality 2 for the wheel. Topography measurements of the tooth flanks also revealed only minor deviations from the desired surface, on the order of a few micrometers.

This represents a great leap forward in terms of both productivity and quality, as compared to the processes used to date.

Figure 6—Oerlikon C 29 gear cutting machine.

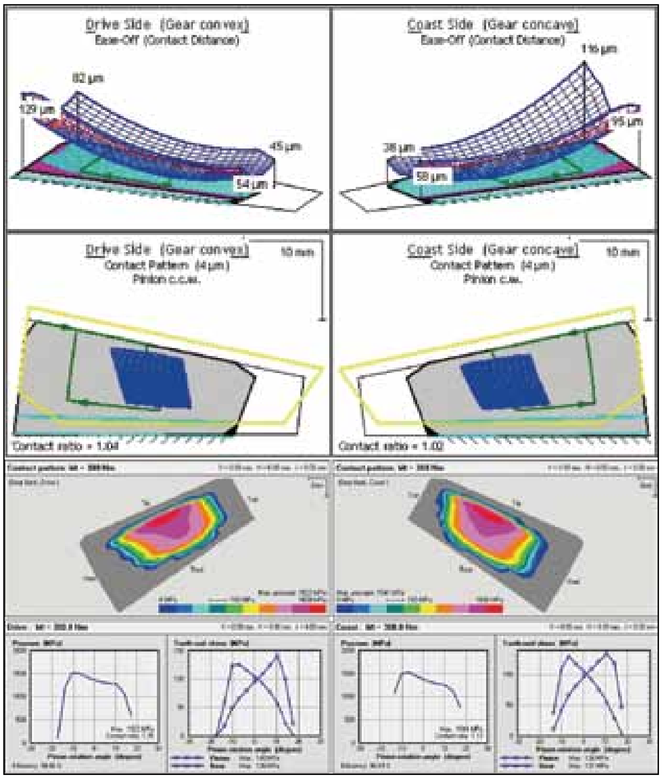

Figure 7—Results of contact analysis.

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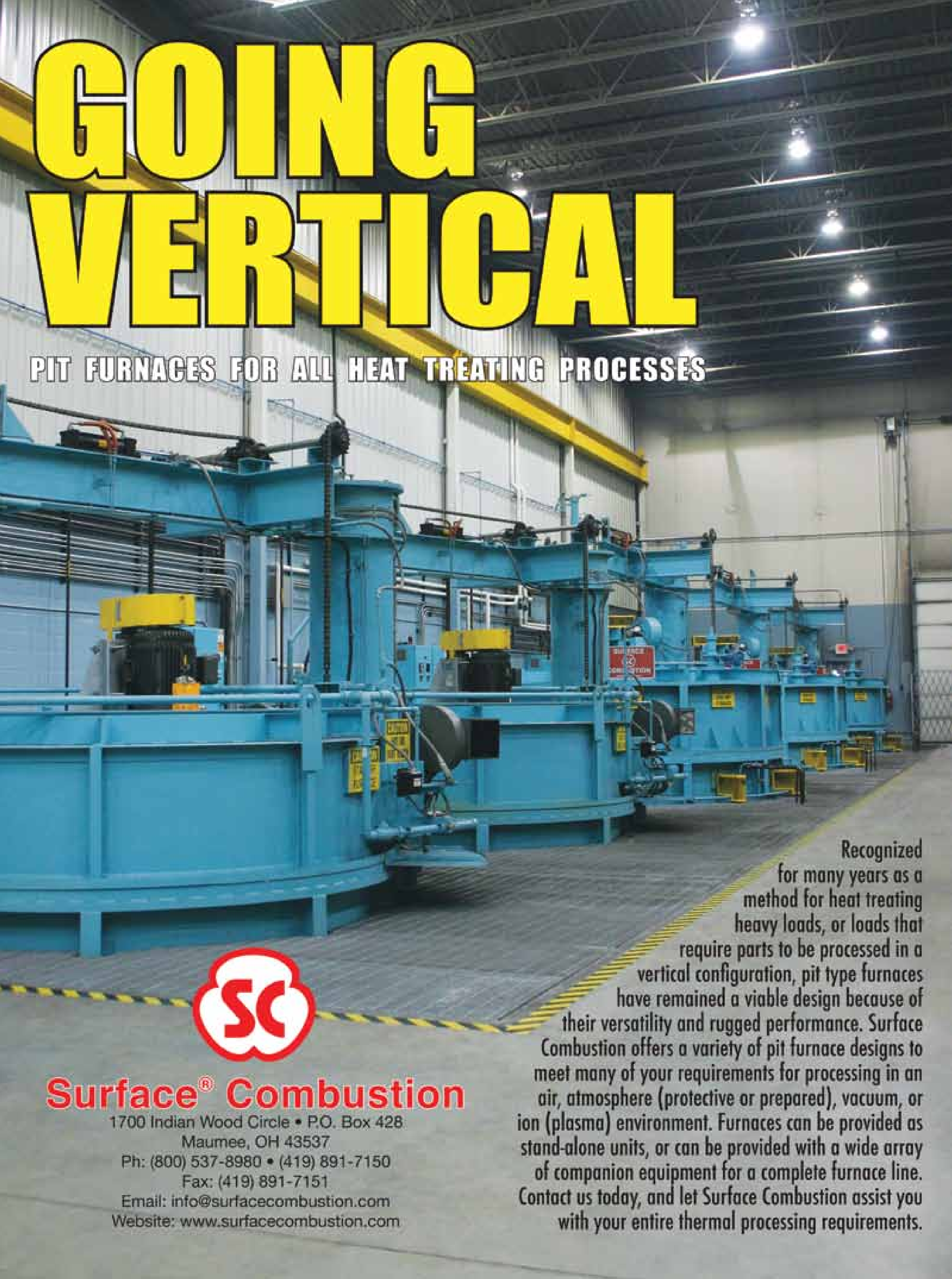
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High-Temperature Testing of Stanyl Plastic Gears: A Comparison with Tensile Fatigue Data

Dr. Ir. HGH van Melick and Dr. HK van Dijk

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Management Summary

This paper shows an experimental study on the fatigue lifetime of high-heat polyamide (Stanyl) gears running in oil at 140°C. Based on previous works (Refs. 1–2), an analysis is made correcting for tooth bending and calculating actual root stresses. A comparison with tensile bar fatigue data for the same materials at 140°C shows that a good correlation exists between gear fatigue data and tensile bar fatigue data. This insight provides a solid basis for gear designers to design plastic gears using actual material data.

Introduction

Plastic materials have been used in gearing for quite some time. Over the last decade the application field for plastic gears has extended from only low loads, positioning type of transmissions, to increasingly more demanding applications with high loads, high numbers of cycles and high temperatures. This implies that during the design process not only the quality of the geometry is important, but also the dimensioning with respect to stresses. The standards (ISO, DIN, AGMA) which are currently used by gear designers have a proven track record for metal gears; however, they certainly lack features that are of importance for plastic gears. In addition to this, the experimental data on gears available for today's gear materials are rather limited.

In a previous study, it was shown that the kinematics and stress distribution in a metal-plastic gear pair can be quite different from a metal-metal gear pair (Refs. 1–2). The main reason for this is the fact that the stiffness-strength ratio of plastics is lower, compared to steel. As a result, the deformation and tooth bending under loading are far more pronounced for plastic gears. Due to this load sharing over tooth pairs in contact (Fig. 1), the contact path and contact ratio are considerably different.

Figure 1b shows that the changes in load sharing influence the root stresses of the gear pair. It is not the modulus that directly affects the stresses, but the changes in contact ratio and tooth bending that—via load sharing—influence the root stresses.

From Figure 1a it is also observed that by going from a steel-steel pairing to a steel-glass-filled plastic pairing, the period of single tooth contact is halved. For the unfilled plastic case and the unfilled plastic at elevated temperature case, single tooth contact no longer occurs during meshing. With decreasing modulus the maximum load share decreases to a plateau value of approximately 2/3. This increase in contact ratio was shown to result in a substantial decrease in root stresses (Table 1).

The question now arises whether the root stresses can be related to material properties. For metallic materials, the correlation between material properties (tensile strength, fatigue strength, etc.) and the actual performance of a gear are quite well established. This is not the case for polymers. Along with

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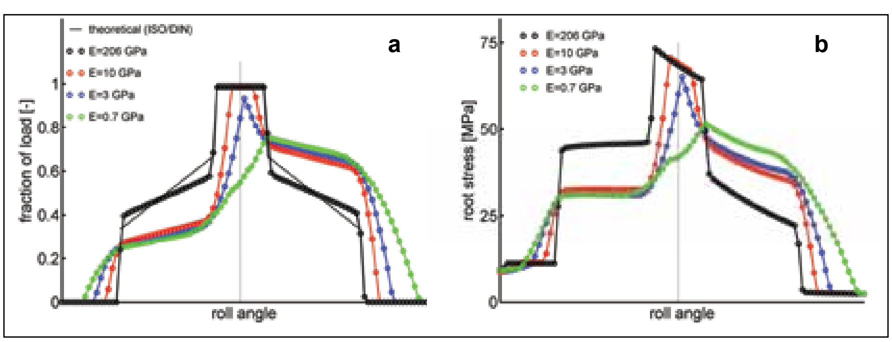

Figure 1—(a) load sharing and (b) root stresses as function of roll angle for a steel pinion and a steel gear (black circles), a glass-fiber (GF) reinforced-plastic gear (red circles), an unfilled plastic gear (blue circles) and an unfilled plastic gear at elevated temperature (green circles). The dashed black line is the load sharing according to (steel) theory (ISO 6336) and the dotted black line represents the pitch point.

Table 1—FEA Root Stresses versus ISO 6336 values upon varying the load share by changing the stiffness of the plastic gear in a metal pinion/plastic gear contact.			
Root Stress	Modulus	ISO 6336	FEA
Steel	E = 206 GPa	74.8 MPa	73.4 MPa
Plastic GF (30%)	E = 10 GPa	74.8 MPa	70.7 MPa
Plastic UF	E = 3 GPa	74.8 MPa	65.1 MPa
Plastic UF at high T	E = 0.7 GPa	74.8 MPa	51.7 MPa

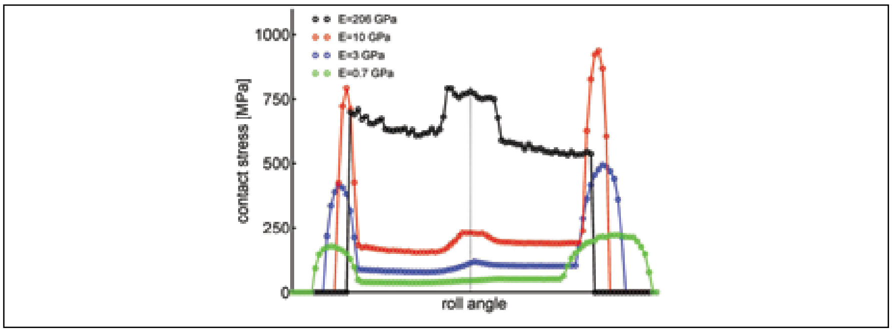

Figure 2—(Hertzian) contact stress as a function of the roll angle for a steel pinion meshing with a gear of various materials.

Table 2—Details of gear geometries		
	Pinion	Gear
Module	2 mm	2 mm
No. of Teeth	22	31
Pitch Circle Diameter	44 mm	62 mm
Base Circle Diameter	41.35 mm	58.26 mm
Tip Circle Diameter	48 mm	66 mm
Pressure Angle	20°	20°
Profile Shift	–	–
Tooth Width	13 mm	12 mm
Center Distance	53 mm	
Material	steel 16MnCr05	Stanyl
Root Radius Profile	0.38 mod	0.38 mod

differences in kinematics and stresses, the effect of testing conditions like temperature, strain rate, humidity, etc., play a huge role in their performance.

In addition, an increase in contact path length is observed in Figure 1 by going from the steel-steel mesh to the steel-plastic material at elevated T-mesh. The combination of increasing contact path length and tooth bending was also shown to have a big influence on the contact stresses in the same work (Refs. 1–2). The contact stress picture is shown in Figure 2.

As expected—based on contact mechanics and normalized calculations—the contact stresses near the pitch point where, according to classical theory, the maximum is found, decreases with modulus. However, due to the change in contact path, a preliminary contact of the tip of the plastic gear with the root of the pinion and a prolonged contact of the tip of the steel pinion with the root of the plastic gear are observed. This interference results in huge contact stress peaks at the beginning and end of the contact, due to the small contact radii and high forces, resulting in high contact stresses at high sliding velocities and, thus, in high pressure velocity values. Further study of the kinematics resulted in the expectation of substantial wear near the tip and the root of the plastic gear, for which observations in literature were shown to exist (Refs. 3–4).

Intent of this Study

Designing gears requires a degree of experience. Many new designs are based on proven concepts of the past. This is certainly true for plastic gears, where at the moment this comparative, best practice method is the safest way to operate. However, bottom line is that, in principle, a gear tooth is an odd-shaped bending beam, and the expected lifetime of this bending beam under fatigue loading should come close to the lifetime assessed in a lab scale test, provided that conditions are the same. For metals this is quite well established; however, for polymers this is certainly not the case. So if the aim is to assess the lifetime of actual gears under well defined testing conditions, this can be achieved by assessing the lifetime of tensile bars under the exact same conditions and trying to correlate the performance in terms of allowable stress for a certain number of cycles, via accurate numerical methods. There are three steps:

1. Generate high-temperature fatigue data for various Stanyl gears under oil lubrication. This approach was expected to result in fatigue failure of the gears by minimizing the amount of wear as much as possible while keep ing the temperature as constant as possible.
2. Generate high-temperature fatigue data for various Stanyl tensile bars at the same temperature.
3. Incorporate the influence of tooth bending on the root stresses at various torque levels, and determine whether a correlation exists between fatigue lifetimes measured on gears and those measured on tensile test bars.

Materials and Methods

Stanyl is a high-heat polyamide PA 46 material made by DSM Engineering Plastics. The material is characterized by a high level of crystallinity (70%), which results in the retention of mechanical properties at temperatures above the glass transition temperature of all polyamide materials. Beyond this the material exhibits wear resistance and good fatigue properties at elevated temperatures. The following grades were incorporated in this research program:

- Stanyl TW341, an unfilled grade
- Stanyl TW200F6, a 30% glass-fiber reinforced grade
- Stanyl TW200B6, a 30% carbon-fiber reinforced grade

As a comparison material, PEEK Victrex 450G (unfilled grade) was tested.

Test temperature was 140°C, as lubricant Nuto H-68 oil was used (spray lubrication), a standard ESSO motor oil. All materials were subjected to a 140°C oil aging test, to ensure that no mechanical property deterioration occurred during the lifetime test runs.

Gear geometry. The gear geometries are listed in Table 2; injection molding of the gears was performed by IMS Gear, Donaueschingen, Germany; tool layout was designed so that at T = 140°C, the gears were of the required size (compensating for the shrinkage and thermal expansion).

The test rig (Figure 3). The gear testing was conducted the University of Berlin (Ref. 5) on two identical, in-house built four-square testing devices (Refs. 6–7). This device contains two gear pairs, i.e.—a metal driving gear pair and the testing gear pair—connected by two shafts. Via a torsional spring on one of the shafts, a preset moment is applied on both gear sets. Using such a closed-loop system is very beneficial in that the input power is only required to overcome the frictional and hydrodynamic losses of the lubricated gears and the frictional losses in the bearings. Via an electronic control system, the moment on the gear sets is monitored and, at a steep decrease of this signal (tooth breakage), the test is stopped.

All tests (four torque levels for each material grade, each torque level measured 7-fold) were run at 3,000 rpm running speed of the pinion. During the testing, the gears were lubricated via spray lubrication with oil from a thermostrated oil bath. The bulk temperature of the gear (measured via a thermocouple inserted in a gear tooth) was measured during various tests and proved to be very close to 140ºC. Also, the gear flank temperature, measured by infrared camera, proved to be close to the set temperature of the oil.

Tensile bar fatigue testing. The tensile bar fatigue tests were run on standard ISO 527-1A injection molded specimens. The specimens were subjected to a cyclic loading at a specified stress and a frequency of 8Hz. At this frequency the heating of the specimens, due to viscous dissipation, is negligible and the tests can be considered as isothermal, with the loading of the specimen cycles between a maximum value (max. stress level) and 10% thereof (min. value), implying R = 0.1 (ratio min/max value). The tests were performed on Zwich-Roell servo-hydraulic dedicated fatigue testing equipment, equipped with temperature chambers to control the environmental temperature.

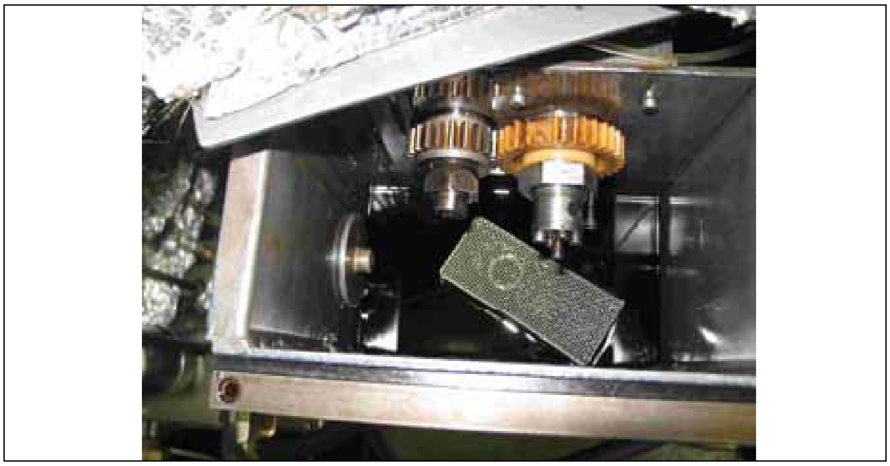

Figure 3—Detail of the gear test setup at the University of Berlin (Refs. 5–7).

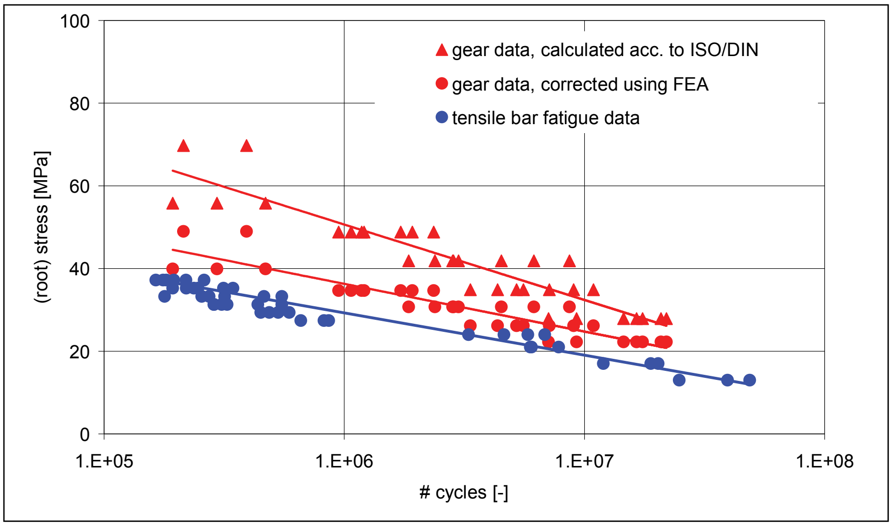

Figure 4—Experimental lifetime results for TW341 measured on gears and tensile test bars.

Experimental Results

Zooming in on Stanyl TW341. The tests of the unfilled material TW341 clearly showed a root failure, meaning that wear was negligible and that failure occurred in the region where the highest tensile stresses are expected during loading.

Via standardized calculations, the root stresses can be determined given the geometry and the applied torque. In Figure 4, the red triangles represent the data of ISO stresses versus the number of cycles until failure in a gear test. Clearly, the lifetime decreases linearly

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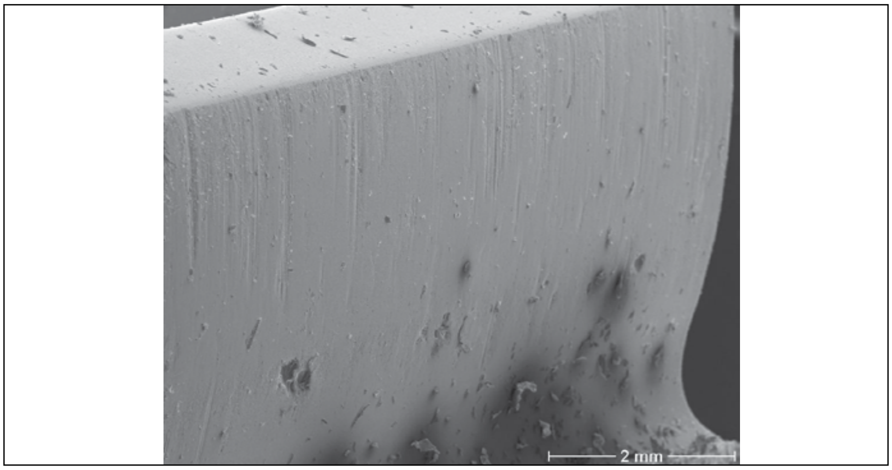

Figure 5—Detail of TW341 flank (SEM observation) after 3 million load cycles.

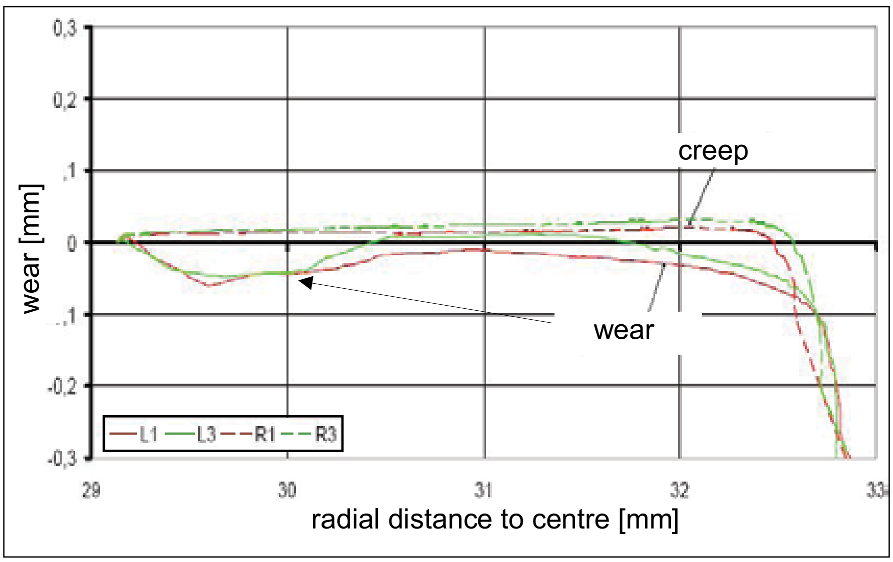

Figure 6—Wear of TW341 flanks after 1.1 x 10^7 load cycles.

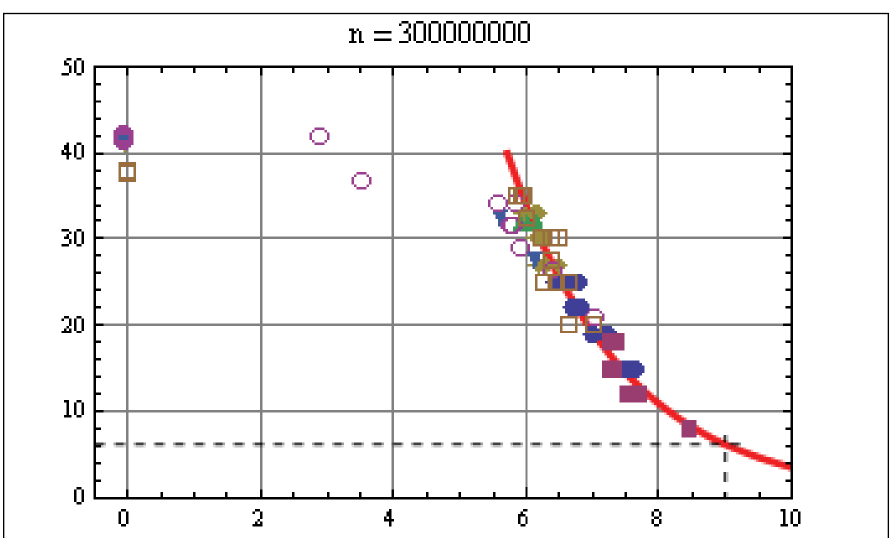

Figure 7—Fatigue results obtained for Stanyl TW341 tensile bar fatigue testing at 140°C.

on a logarithmic time scale.

The red circles represent the root stresses obtained by calculating these stresses by FEA. In this way a correction is made for the maximum stress due to tooth bending and load sharing. The blue circles, finally, represent fatigue lifetime measurements obtained upon tensile fatigue testing (ISO-527-1A test bars) at 140°C.

From Figure 4, the following can be concluded: Upon correcting the root stresses induced by the applied torque for tooth bending, a fairly good correlation between fatigue data measured on gears and tensile test bars respectively exists, the gear data being somewhat better. The reason for a better performance in gears compared to test bars is still subject to investigation. One of the reasons could be that the loading of a gear tooth is quite different from a test bar. A gear tooth experiences a peak load during a short period of the revolution, while during the remaining part of a revolution the load equals zero. In our case, this occurs at a frequency of 3,000 rpm or 50Hz, much higher than the applied testing frequency of the perfect sinusoidal loading at 8Hz in the test bars. The rate of deformation, to which these materials are quite sensitive, in a gear tooth is roughly 100 times higher than in the test bars.

As mentioned, the failure mode observed for the TW341 gear was a clear fatigue failure; hardly any signs of wear were observed in this case, as shown in Figure 5.

The low wear of TW341 at 140°C is further illustrated by one-flank profile measurements after over 10 million cycles (Fig. 6). For two separate gears (1 and 3) the deviation from the ideal involute profile is measured. Some minor wear scarring can be observed at the tip and root of the driven flank (L1 and L3) where, due to the tooth bending, interference occurs (Refs. 1–2). In addition, some deformation of the tooth due to creep can be observed by the positive wear on the idle flank (R1 and R3).

The good correlation observed

between tensile bar fatigue testing and gear testing was further exploited; tensile bar fatigue testing was further extended with a three-fold measurement at 8 MPa. This resulted in 300 million (300 x 10^6) load cycles without a fatigue failure occurring. The results obtained were subjected to a statistical analysis, and a sensitivity analysis was performed for the influence of the exact position of the failure point on the shape of the fatigue curve. A clear leveling off of the fatigue curve was observed, which was shown to be statistically significant.

The curve was further used to make an extrapolation to 10^9 number of load cycles, resulting in a stress level of 6 MPa.

In view of the good correlation with gear testing, it is now stated that Stanyl TW341 gears, when subjected to a stress level of 6 MPa, have a lifetime of at least one *billion* load cycles. These lifetimes are critical when considering oil pump-gear applications or balancer gear applications, to mention a couple of examples. With wear resistance at 140°C, Stanyl TW341 a good choice for these types of applications.

The resulting fatigue curve is shown in Figure 7. The red line through the data points has been fitted, followed by a statistical analysis, to establish whether the leveling off is significant or not. It was concluded that the leveling off indeed is significant, indicating the presence of a fatigue limit for Stanyl TW341 at 140°C. The factor *n* represents the number of cycles observed at 8 MPa stress.

Comparison of Stanyl TW341 and PEEK Victrex 450G. In Figure 8, a comparison is made between the lifetime of Stanyl TW341 and unfilled PEEK Victrex. The relatively short lifetime of the unfilled PEEK gears under these experimental conditions can be explained by the severe wear observed with PEEK 450G, as illustrated in Figure 9; the failure was clearly wear induced. Further, the relatively low level of crystallinity of PEEK results in a substantial drop in mechanical properties at/above the materials glass transition temperature of 143°C.

Zooming in on Stanyl TW200F6 (Stanyl 30% glass filled). Regarding the 30% glass filled grade, wear-induced fatigue failure was the observed failure mode. In Figure 10, gear testing results are compared with tensile bar fatigue testing results for both Stanyl TW200F6 and Stanyl TW200B6. The nature of the gear fatigue process seems to be somewhat different for the fiber-filled grades than the tensile bar fatigue process. For high loads, the lifetimes lie somewhat higher than the tensile bar fatigue data, similar to the unfilled material. For lower loads/higher lifetimes, the lines cross

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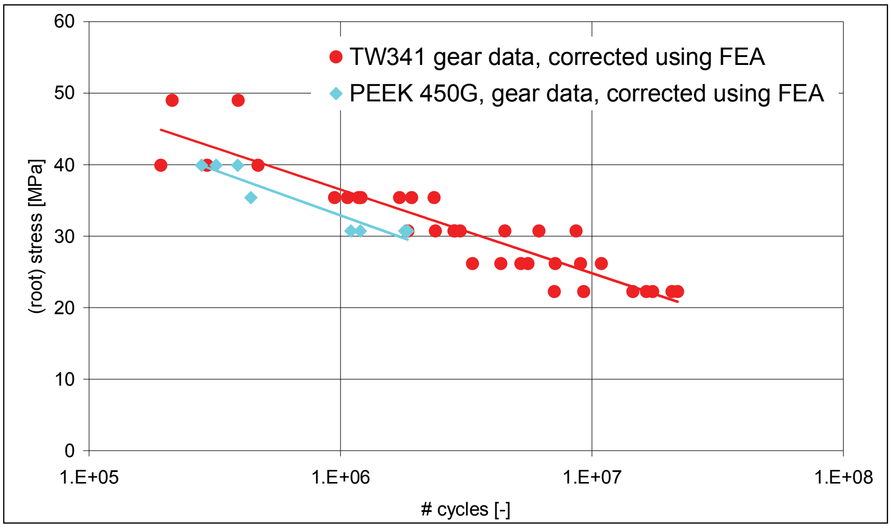

Figure 8—Root stresses (corrected for tooth bending) versus number of load cycles for gear testing of Stanyl TW341 (red) and PEEK 450G (cyan) at 140°C.

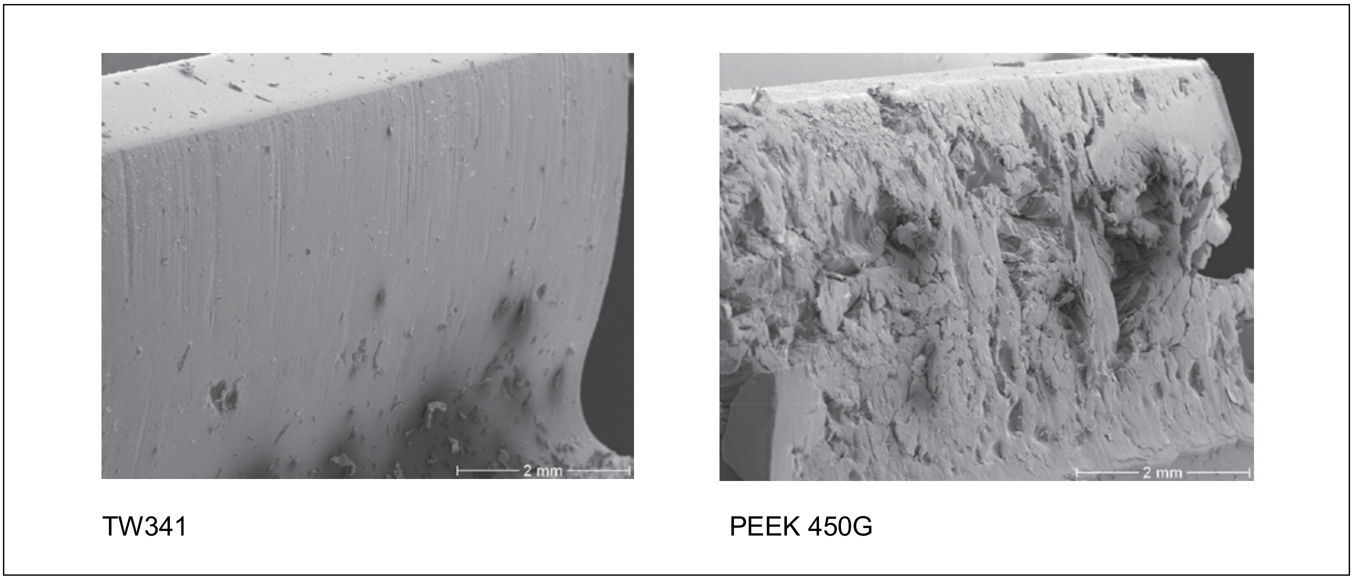

Figure 9—Wear comparison of Stanyl TW341 (left picture) and PEEK 450G after 3 million cycles at 140°C and a torque level of 10 Nm.

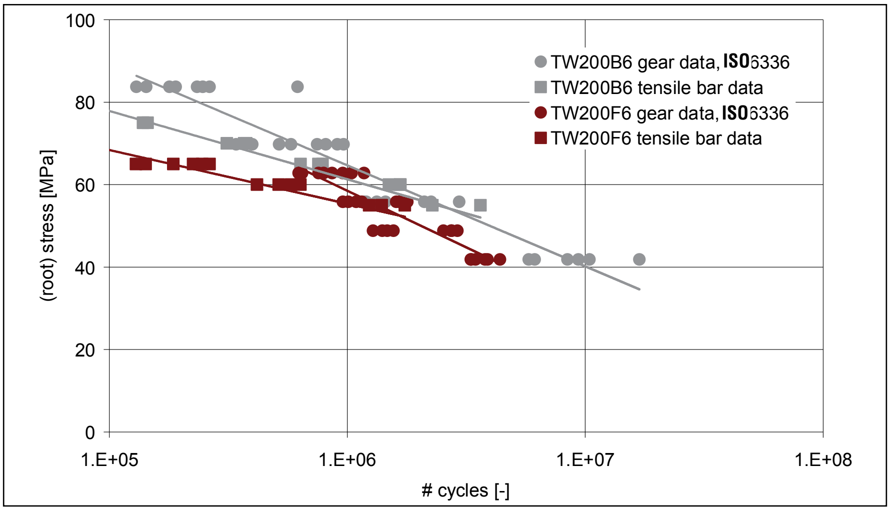

Figure 10—Tensile bar fatigue testing versus gear testing for Stanyl TW200F6 (top) and TW200B6.

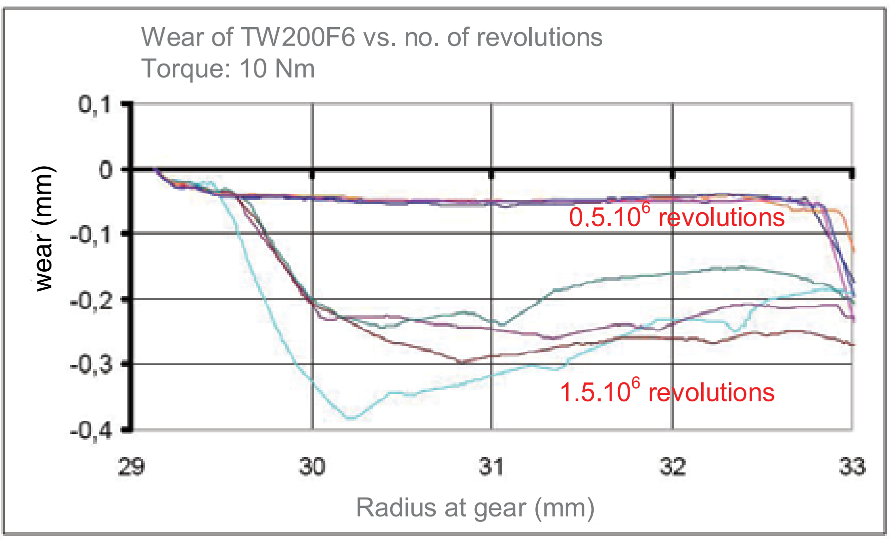

Figure 11—Illustration of wear observed during gear testing of Stanyl TW200F6 at 140°C under oil lubrication.

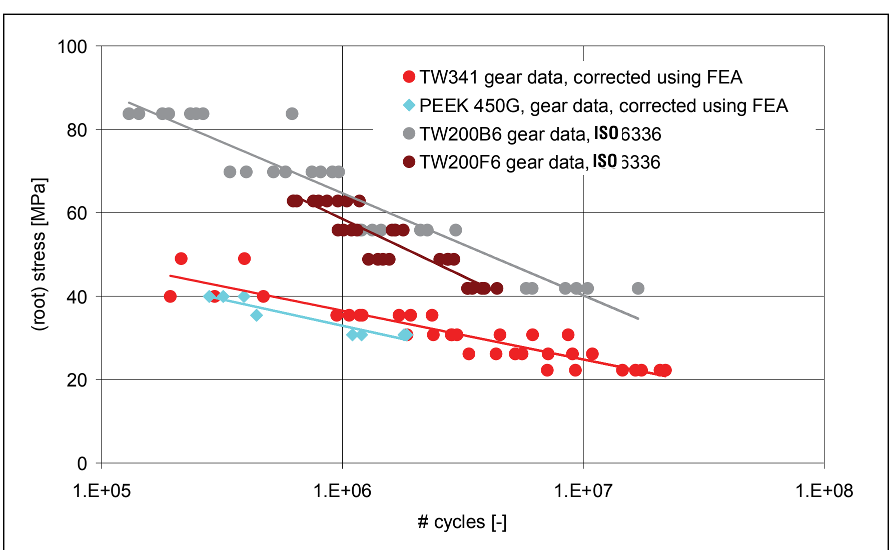

Figure 12—Gear fatigue results at 140°C under oil lubrication for various Stanyl grades and a PEEK material.

each other. This can be explained by the fact that, at these high numbers of cycles, the failure is wear-induced and not a true fatigue failure. The evolution of both failure processes over time can of course be very different.

For the fiber-filled materials, with Young's moduli of 5 to 10 times that of unfilled Stanyl, a correction for tooth bending is also made. However, the effect on the root stresses is only minor due to the relatively small bending of the teeth.

The final gear fatigue picture. Figure 12 presents the final gear fatigue picture after testing at 140°C with oil lubrication. In the instance of the unfilled materials, the root stresses have been corrected for tooth bending. A clear distinction can be seen between fiber-reinforced and unfilled grades. However, due to the steeper decay of the fiber-reinforced grades due to wear, the curves come closer to each other a very high number of cycles.

Conclusions

Various grades of DSM Engineering Plastics' high-temperature PA 46 have been tested as a gear at 140°C under oil lubrication. The data can be used for grade selection for high-temperature applications.

The concept of tooth bending of the plastic gear in steel-plastic gear combinations has been explored. Metal-based ISO-6336 results are an overestimation of root stresses calculated from applied torque levels, especially in (low modulus) unfilled plastic materials at elevated temperatures. Tooth bending is the underlying phenomenon for this, resulting in an increase of the contact ratio. This means that on average the applied loads are shared between more teeth, resulting in an overall lower root stress. The correct value of the root stress is therefore only obtained by using FEA, not by using ISO-6336.

When tooth bending is being taken into account and the correct root stresses are calculated, a fairly good agreement/correlation is obtained between fatigue data measured on gears and test bars respectively. This, however, is only the case if the failure mode is a true fatigue failure; for wear-induced tooth breakage, no correlation can be observed. For TW341 (true fatigue failure in the gear tests), a positive correlation with test bar fatigue was easily observed.

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Harold van Melick *is a senior research scientist working at the Material Science Centre of DSM Research. He is also a member of the Global Segment Team/Gears of DSM Engineering Plastics, a team leading the development of Stanyl in gear applications. He joined DSM after studying mechanical engineering at Eindhoven University of Technology, and receiving his doctorate in 2002 on the subject "Deformation and Failure of Polymer Glasses."*

Hans van Dijk *in 1978 began studies in chemistry at the University of Amsterdam. In 1988 he received his doctorate in the field of organometallic photochemistry. In that same year he joined DSM Research. After several positions there, in 2001 he became a product development specialist, a position he still holds. Gears and wear and friction phenomena in general are his areas of particular interest.*

SHOT PEENING UP CLOSE AND PERSONAL

(courtesy Electronics Inc.)

At the beginning of Electronics Inc's. (EI) shot peening workshops, Jack Champaigne, the company's president, gives opening remarks where he tells attendees that at anytime they have feedback, they should write it down on a thousand dollar bill and submit it to him.

Also known as the publisher of *The Shotpeener*, the well-humored Champaigne and his staff conduct shot peening/blast cleaning workshops and on-site training programs worldwide. They are attended by a range of specialists including product design engineers, machine operators, foremen, supervisors and maintenance and quality engineers. The next workshop takes place in Toronto, Canada, spanning two days of intensive instruction on all aspects of the metal finishing process.

Since the workshop is aimed toward a broad audience of all levels, covering the entire scope of shot peening education in two days seems like it could be challenge, but the EI education division staff have carefully organized the workshops and conducted many of them in the past. "We run four classrooms simultaneously because there are so many topics," Champaigne says. "Once you get over 30 students, it gets difficult to carry on. Typically we might have 40 to 50 topics, and you need 40 instructors."

For these reasons, enrollment is limited. "We can count on a minimum of 20 and a maximum of 40 attendees to a one- or two-day event," Champaigne says.

Topics attendees will learn about include air blast machine design, air blast machine maintenance, advanced intensity, applications, benefits and equipment, basic intensity, basics of media, an introduction to shot peening, peening coverage, rotary-flap peening, saturation curve practice, wheel blast machine design and wheel blast machine maintenance.

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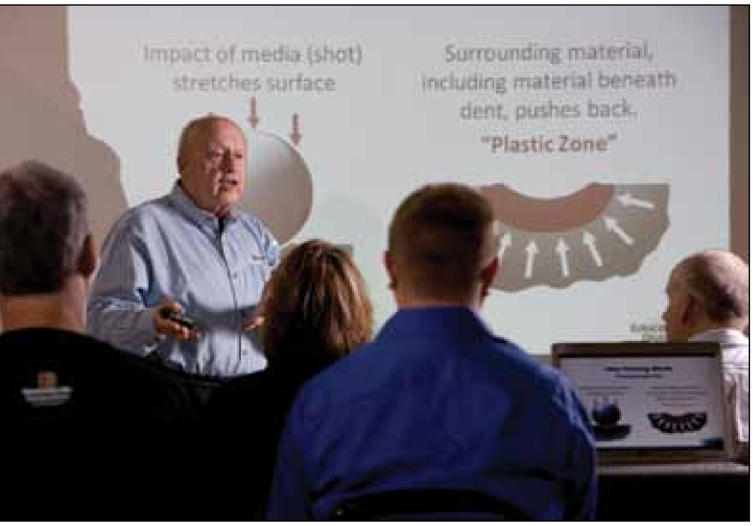


The two-day Canadian Shot Peening Workshop provides intensive instruction on all aspects of shot peening (courtesy Electronics Inc.).

"We concentrate on the basic entry level on the first day," says Dave Barkley, director of the EI education division. "The general knowledge—we can get through most of it in five to six hours."

Although gear peening does not have a topic of its own at the workshop, gears do come up frequently in discussing the different applications of shot peening. The EI focus is less about what you can use peening on, but about teaching the correct techniques. "It doesn't matter what you're applying the peening process to, it has to be done properly," Barkley emphasizes.

All EI training courses are approved by the Federal Aviation Administration (FAA) to meet the requirements for FAA employees who audit shot peening processes. The programs were actually developed specifically for FAA inspectors. At the end of each day, attendees have the option to take an exam that they will receive credit toward yearly FAA training requirements. Each day of training in combination with the appropriate exam awards eight hours of training by the FAA's IA and AMT programs. Exam levels include Shot Peening Level 1, 2 and Flapper Peening. EI launched the FAA training program in 2001, at which time Champaigne commented "We are very pleased to have formed this alliance with the FAA. It elevates shot peening training to the level of attention and importance it deserves in the aerospace industry."

The FAA certification is valuable for anyone in the aerospace industry where shot peening is a necessary process in achieving the high quality standards aerospace applications require. "Seventy percent of the students take the exam, and they want the FAA recognition," Barkley says.

One unique aspect of the workshop that differentiates it from other training courses is the concurrent trade show held in which shot peening vendors purchase booth space in the classrooms. "Some of them will also do a presentation they aim at their background," Champaigne says. "We ask them not to be too commercial. They pretty much adhere to that."

EI tries to intermingle the attendees and exhibitors by scheduling breaks and meals together as well as setting up the booths either around the periphery of the classrooms or in the back at the smaller, international workshops. This is useful for attendees because they have the opportunity to hear about more specific topics and applications from businesses with those specializations. "When we have breaks and lunches, if there's a question they have for a manufacturer that might have come to mind during the class, they can go back and ask them," Barkley says.

The number of exhibitors varies, as does attendance, depending on the location of the workshop. Although the international workshops are smaller than the U.S. counterpart, the smaller group size and simpler travel logistics are benefits. "There may be five to six exhibitors at an international workshop and more like 15 to 20 in the U.S. exhibits," Champaigne says.

It's difficult to predict whether there will be attendees from the gear industry at the upcoming Canadian workshop yet because most people typically don't signup more than four weeks prior to the workshops. However, according to Barkley, "As far as exhibitors go, we have people that have machines specifically for gears."

Three exhibitors build machines that are sold to gear manufacturers, including Engineered Abrasives and Wheelabrator.

Regardless of coming from the gear industry or not, the EI Education division's biggest priority remains to disseminate the most accurate information and promote the importance of shot peening. "One of the biggest challenges is explaining the difference between the intensity of the process," Champaigne says.

People have been taught indirectly by a company culture, he says, and many attendees leave the workshop feeling qualified and confident to change the status quo for the betterment of their organization.

"You hear someone say 'Aha!' And you know you've made a breakthrough."

The upcoming Canadian Shot Peening Workshop takes place April 28–29 at the Hyatt Regency Toronto, Canada. For more information, visit *www.electronics-inc.com/workshop_canada.html,* call (574) 256-5001 or (800) 832-5653.

March 30–31—Manufacturing Technology Forum. Gaylord Opryland Resort and Convention Center. Nashville, TN. The Association for Manufacturing Technology (AMT) and the National Center for Manufacturing Sciences (NCMS) host this technology forum, which this year is highlighting new initiatives addressing green manufacturing. Guest speakers will discuss what the current trends are, what is necessary and what manufacturers can expect regarding new requirements. As with past forums, attendees will learn about current R&D activities. A networking reception and dinner event will take place as well. For more information, visit *www.amtonline.org/calendar/2010amtncmsmanufacturingtechnologyforum.htm.*

April 13–14—Innovations in Bevel Gear Technology. Aachen University of Technology. Aachen, Germany. The Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University conducts this seminar introducing today's developments regarding manufacturing processes, design and application for bevel gears. Specialists in machine tool manufacturing, tool supply and drive train technology will present their experiences, opinions and visions. The targeted audience includes managers and experts in development, engineering, designing, researching, supplying, planning and manufacturing bevel gears. Topics covered include machine tools and production methods, the bevel gear manufacturing process chain, bevel gear production, angular drives in series application, straight bevel gears, materials and heat treatment and bevel gear design. For more information or to register, contact Mrs. Sabine Kaussen at *s.kaussen@wzl.rwth-aachen.de*, or +49 241-8023614.

April 19–23—Hannover Messe. Hannover Fairgrounds, Hannover, Germany. The world's leading trade show for industrial technology returns in 2010 with the usually full lineup of trade shows. The eight co-located shows include Industrial Automation, Energy, Power Plant Technology, MobiliTec, Digital Factory, CoilTechnica, MicroNano Tec and Research and Technology. Italy is the official partner country in 2010. For more information contact, visit *www.hannovermesse.de.*

April 21–22—Machine Shop Workshop. Renaissance Cleveland Hotel. Cleveland. The business of running a machine shop is the focus of this workshop that brings together hundreds of U.S. shop owners and managers. Educational sessions cover shop operations, lean manufacturing programs, workforce development and supply chain management. Real-world problems and solutions are presented in the sessions to help attendees improve performance and competitiveness in the global metalworking market. New to the 2010 program is a plant tour, where attendees visit a world-class machine shop to witness its best practices, lean strategies and other means for operations success. A lineup of over 10 speakers discusses various subjects that include wind turbine supply demands and automotive retooling. The workshop is conducted by *American Machinist.* For more information, visit *www.machineshopworkshop.com.*

April 27–29—POWTECH 2010. Exhibition Centre Nuremberg, Germany. This international expo for powder and bulk solids mechanical processing technologies and instrumentation is co-located with TechnoPharm, the international trade fair for pharmaceuticals, food and cosmetics. This is the first year the shows will also run concurrently to the World Congress on Particle Technology (WCPT6), which starts a day earlier. For more information, visit *www.powtech.de/en.*

May 10–14—Basic Training for Gear Manufacturing. Richard J. Daley College, Chicago. This AGMA training course covers gearing and nomenclature, principles of inspection, gear manufacturing methods, hobbing and shaping. The course is intended for those with at least six months of experience in setup or machine operation. Classroom sessions are paired with hands-on experience setting up machines for high efficiency and inspecting gears. For more information, contact Jenny Blackford at *blackford@agma.org* or (703) 684-0211.

June 8–9—CTI Symposium North America. Four Points by Sheraton Ann Arbor Hotel. Ann Arbor, MI. This event, organized by the German Car Training Institute (CTI), focuses on the latest technical innovations in automotive transmissions, hybrid and alternative drive trains with experts and suppliers from the United States, Asia and Europe. This year's focus will also address improving efficiency of today's drive trains. The symposium will examine current debates on economics, politics and the environment. Topics will be examined from the perspective of technology, customers and the context of market success. CTI aims to emphasize the potential of development tools in light of the financial crisis. For more information, visit *www.transmission-symposium.com/north-america.*

SME

INVESTS IN MANUFACTURING EDUCATION CENTERS FOR HIGH SCHOOLS

Tomorrow's global leaders will have to be tech-savvy and ready for advanced manufacturing jobs requiring skills in electronics, computers, software and automation. Continuing its mission to encourage young people to focus their education on science, technology, engineering and math, the SME Education Foundation is introducing Computer Integrated Manufacturing (CIM) courses at 400 Manufacturing Education Centers across the country. The Foundation will sponsor the course at pre-existing partner schools in Lee's Summit, MO, and Charlotte, NC.

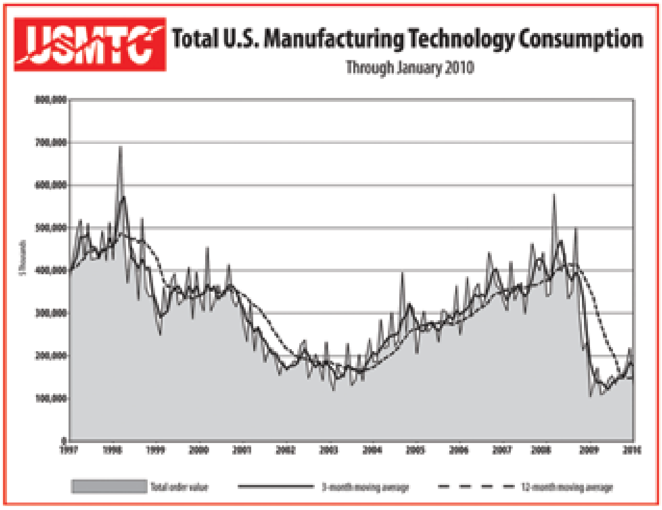
Through their CIM program, the SME Education Foundation is introducing high school students to careers in manufacturing, while engaging their industry partners and SME Chapter members. The CIM course, upgraded by the foundation's industry partner, Project Lead The Way (PLTW), enhances computer modeling skills by applying principles of robotics and automation to the creation of three-dimensional design models.

Bart A. Aslin, director, SME Education Foundation, launched the new initiative with the presentation of a $40,000 check to the Lee's Summit R-7 School District's Summit Technology Academy located in Lee's Summit, MO, for the creation of its first CIM laboratory serving high school students in the Kansas City region. The award was presented at a special reception at Summit Technology Academy on Tuesday, February 16.

"Our programs have to reflect and respond to problems in the global market. And, we've run out of time. We need parents to be hands-on and encourage their children, and we need industry and educators to mentor students and each other. Or, the global economy will move along without us," Aslin says.

The event, attended by area educators, engineering professionals, parents and PLTW students included a tour of the new lab, a demonstration of its robotic arm and a preview of the new manufacturing-based curriculum. PLTW has more than 60 schools in the metro Kansas City area, serving more than 9,000 students.

January Manufacturing Technology Consumption Up



January U.S. manufacturing technology consumption totaled $130.96 million, according to the American Machine Tool Distributors' Association (AMTDA), and the Association for Manufacturing Technology (AMT). This total, as reported by companies participating in the United States Manufacturing Technology Consumption (USMTC) program, was down 40.3 percent from December but up 26.2 percent from the total of $103.77 million reported for January 2009.

These numbers and all data in this report are based on the totals of actual data reported by companies participating in the USMTC program. "Many customers placed orders in December to take advantage of tax relief measures, pulling orders out of January 2010," says Peter Borden, AMTDA president. "The good news is that January 2010 orders are still 26 percent ahead of January 2009. Fortunately, there are measures moving through Congress that will expand these benefits, incentivizing manufacturers to invest in capital equipment in 2010."

The USMTC report, jointly compiled by the two trade associations representing the production and distribution of manufacturing technology, provides regional and national

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U.S. consumption data of domestic and imported machine tools and related equipment. Analysis of manufacturing technology consumption provides a leading economic indicator as manufacturing industries invest in capital metalworking equipment to increase capacity and improve productivity. For more information on this and other studies, visit *www.amtonline.org*.

Advanced Machine & Engineering

APPOINTS PRODUCT MANAGER

Christian Schedler has been promoted to the position of product manager of the Speedcut Saw Technology Division of Advanced Machine & Engineering (AME). In his new role, Schedler will oversee P&L responsibility for the division including its sales, application engineering, product management and project management functions. Prior to his promotion, Schedler worked as a global service rep for a German Machine Tool company and as a designer of carbide saws at AME.

Christian Schedler

During the last two years, AME's Speedcut Division has invested in new production and measuring equipment and concentrated heavily on R&D and saw blade innovations to improve the tool life of carbide and cement tipped circular saw blades. Schedler has a background in R&D, engineering and product manufacturing as well as broad assembly and service experience.

JRM International

APPOINTS SALES MANAGER

Juergen Walters has been hired as the sales manager for the gear products division of JRM International, Inc. Walters comes to JRM with 14 years' experience as a sales and application engineer with Saint-Gobain Abrasive products in Germany. During this time he has worked with the gear industry and automotive industry in Germany. He also has experience with die spring and tool grinding companies. With knowledge and training in the areas of bonded and coated abrasives, he has worked with these customers to improve their processes and procedures.

"We are happy to have Juergen on board our gear products division," says James Mattox, president of JRM International, Inc. "His extensive background and training in the area of abrasives will be invaluable working with our North American customer base for all types of grinding applications. As the North American partner with Burka-Kosmos, of Frankfurt, Germany, we strive to work very closely with our customers in the area of improving quality, reducing cycle times and helping control costs. Having Juergen available to work in our customers' plants and aid them in improving their grinding processes will be a great benefit to both our customers and JRM International, Inc."

Juergen Walters

Kurt Manufacturing

SIGNS AGREEMENT WITH LEADER CHUCK SYSTEMS

Kurt Manufacturing Company, located in Minneapolis, MN, recently signed an exclusive agreement with Leader Chuck Systems Ltd. in Birmingham, England to distribute Leader Chuck's MMY MultiChuck Concentric Clamping Systems in the United States, Canada, Mexico, Central and South America. The Leader Chuck MMY line consists of manual self-centering static workholding for machining centers, milling machines and grinders. These products integrate with Kurt's high density workholding towers and other devices to provide productivity and precision.

"Adding the Leader MultiChuck MMY system gives our customers more options in designing the highest productivity workholding for their machines," says Steve Kane, global sales and marketing manager at Kurt. "Our vise customers are looking for ways to expand their machine output and Leader MultiChuck MMY products have a proven track record of award-winning performance for many years throughout the United Kingdom and Europe."

"Like Kurt workholding in U.S. industry, Leader Chuck is a very successful brand for over 50 years in European industry," says Mark Jones, managing director at Leader Chuck. "We are extremely pleased to be a partner with Kurt to bring manufacturers innovative workholding for both new and existing machine setups."

Goellner, Inc.

APPOINTS VICE PRESIDENT, SALES AND MARKETING

Goellner, Inc., located in Rockford, IL, recently announced the promotion of Greg Champion to the position of vice president of sales and marketing. Goellner, Inc. is the holding company for Advanced Machine & Engineering and Hennig, Inc., two suppliers of the machine tool, power generation, primary metals and other industries.

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Champion has several years of experience with Hennig, Inc., and over 20 years of experience in various management positions in the machine tool and machine tool accessory industries.

In his new role, Champion will oversee all sales and marketing activities, including the strategic direction and management of Goellner's worldwide marketing and sales initiatives. He will also be developing new business opportunities, both domestically and globally. Champion will direct the sales and marketing departments of both Advanced Machine & Engineering and Hennig, Inc. and will work in conjunction with the staff at both locations.

Reishauer Corp.

ANNOUNCES CHANGES TO SALES TEAM

Reishauer recently announced the appointment of Ben Cernohous to the position of regional sales manager for machines and diamond/CBN dressing tools. Cernohous will be responsible for mid-Atlantic states and portions of Canada. He previously held the position of service and project engineer at Reishauer and has been with the company for five years. "Ben brings a keen technical understanding of electronics and gear technology with him along with his enthusiasm and intense work ethic," says Dennis Richmond, vice president at Reishauer.

Ben Cernohous

George Dee

Regional Sales Manager George Dee has announced his retirement after two decades of service to Reishauer. Dee began his career in the late eighties covering the mid-Atlantic states and portions of Canada. He was responsible for machine sales. Dee and his wife, Elaine, reside in Aurora, OH. "We wish him all the luck in his next adventure," Richmond says.

Inductoheat

RECEIVES ISO 9001:2008 CERTIFICATION

Inductoheat Inc. recently received its ISO 9001:2008 certification for induction heating coils, power supplies and ancillary equipment, which improves workflow and optimizes heat treating performance. The company has successfully implemented a quality management system that adheres to the worldwide standard for design and manufacture of equipment for the induction heating of metals. In addition, the certification validates the company's commitment to quality standards with regards to its product lines.

"Maintaining ISO certification is a quality standard for our organization," says Douglas Brown, president of Inductoheat. "ISO certification affirms the high level business competency Inductoheat Inc. demonstrates, from the quality of products to our operational discipline."

Höganäs AB

OPENS CENTER TO ENCOURAGE PM PART APPLICATIONS

The Power of Powder (PoP) Centre opened for business in October 2009 in Sweden to create more business opportunities in powder technology. The unit will serve as an innovation and solutions center to bring together PM parts makers, end users and Höganäs for closer, more cost-effective cooperation to encourage new PM parts applications.

More than 150 leaders from the international powder metal community attended the October 15 opening event where Höganäs CEO, Alrik Danielsson discussed the powder metal industry moving forward.

"We believe the future success of the PM industry lies in the interaction between application knowledge, design aspects, process conditions and powder concepts,"

continued

Danielsson said.

Other speakers included Patrick Reinhold, Volkswagen Material Technology/Metal Groups Laboratory, Shigehide Takemoto, project general manager, Toyota Production Engineering Division and Cesar Molins Jr., director general, AMES, S.A.

The PoP Centre will provide access to a new state-of-the-art Dorst 800-ton CNC compacting press supported by Alvier PM Technology R&D tools to simulate actual production conditions.

Global PM Database

SEES EXPANSION

The Global PM Property Database (GPMPD) has been extended by the addition of 80 data lines of new fatigue endurance limit information. This new information covers a range of Fe-Cu-C grades in both pressed-and-sintered and powder-forged conditions. It comes from the analysis of published PM fatigue information carried out by Technical University of Aachen group, led by Professor Paul Beiss, that also provided the full SN content incorporated into the database during 2009. The GPMPD is a free online aid for designers and engineers that provides physical, mechanical and fatigue data relating to a wide range of ferrous and nonferrous PM materials. The database was created in a collaborative effort between the Metal Powders Industries Federation (MPIF), the European Powder Metallurgy Association (EPMA) and the Japan Powder Metallurgy Association (JPMA). To access the database, visit *www.pmdatabase.com.*

SME

ELECTS FIRST WOMAN PRESIDENT

The Society of Manufacturing Engineers (SME) has elected a woman to lead the organization for the first time in its 78-year history. Barbara Fossum was officially sworn in last November at the Society's Awards and Installation Banquet in Dearborn, MI. Fossum brings a diverse academic and industrial background to SME. She's an independent consultant and coach in the areas of strategic planning, process engineering and business planning. Fossum is also a senior research fellow of the IC2 Institute of the University of Texas at Austin. She holds a doctorate in operations management, a master's in business administration, a master's in mathematics/computer science and a bachelor's in physics.

Barbara Fossum

Fossum has been a member of the SME since 1989 and has served on the Society's Executive Committee and Board of Directors, Ad Hoc Lifelong Learning Committee and the CASA/SME Board of Advisors. She was also an editor of CASA's Blue Book series.

In her new position, Fossum would like to work with organizations to refine the image of manufacturing as a good career option and develop educational paths that prepare the future generation for jobs in manufacturing.

"I believe SME can be a catalyst among professional organizations to make progress towards a national manufacturing strategy," Fossum says. "Working together, government, industry and academia can rebuild U.S. manufacturing capability in key industries."

ABA-PGT

RECEIVES ISO 13845:2003 MEDICAL DEVICE CERTIFICATION

ABA-PGT, Inc. was recently awarded ISO 13845:2003 certification, a quality management system standard for the development and production of medical devices. The company produces high-volume, precision-molded plastic gears and high-precision tooling. ABA-PGT was also awarded re-certification of ISO 9001:2008 at its headquarters in Manchester, CT.

continued

N E W S

"ABA-PGT, Inc. has always provided a product of consistently high quality and the ISO 13485:2003 certification reinforces that commitment to our new and existing medical industry customers," says Terry Holmes, vice president of sales and marketing.

The certification ensures ABA-PGT's continued adherence to customer specifications and regulatory requirements. For more information, visit *www.abapgt.com*.

Oven Industries, Inc.

RECEIVES AEROSPACE CERTIFICATION

Oven Industries, Inc. recently announced it has been awarded official accreditation to the AS9100 international aerospace quality standard. This standard enables the company to actively bid on aerospace and defense contracts globally and clears the way to work with OEMs and their Tier One manufacturers across the United States and Europe.

The AS9100 standard provides qualification to be considered an aerospace supplier, public recognition, internal validation of procedures and controls and independent feedback to foster continual improvement. Most major aircraft engine manufacturers including Airbus, General Electric's Aircraft Engine Division, Boeing, Raytheon, Rolls-Royce Allison and Pratt & Whitney require AS9100. Oven Industries AS9100 certification was achieved in 10 months from the project launch and ensures that the company has the right procedures and track record to do the most stringent aerospace work in the future.

True Precision Plastics

WELCOMES GENERAL MANAGER

Daniel Leaman has joined True Precision Plastics, an injection molding company headquartered in Lancaster, PA, in the position of general manager. Leaman has over 35 years of injection molding experience, and in the 1990's, he was responsible for high levels of growth and customer satisfaction during his prior tenure with True Precision Plastics. The company supplies injection molded components in more than 50 materials, and offers 33 to 725 ton capability while providing secondary operations such as over molding, hot stamping, chrome plating, machining, sonic welding and pad printing.

Broadwind Energy

PLANS EXPANSION OF GEARBOX CAPABILITIES

Broadwind Energy, Inc. recently announced the expansion of its Precision Repair and Engineering services with enhanced megawatt (MW) gearbox refurbishment capabilities. For MW-scale wind turbines in North America, gearbox repair and refurbishment have traditionally been performed outside the U.S. by non-domestic sources. Broadwind believes it will be the first independent supplier of wind energy products and services to offer enhanced MW gearbox repair and refurbishment capabilities in North America.

"With a large portion of the approximately 35,000 MW installed base of wind turbines in the U.S. now coming out of warranty, we see a growing need for a comprehensive solution for MW gearbox refurbishment services that Broadwind can provide," says Broadwind Energy CEO J. Cameron Drecoll. "By adding gearbox refurbishment up to 3 MW to our existing suite of kilowatt gearbox offerings, we will continue to grow our 'one-source strategy' to help leverage existing customer relationships by adding additional services for our customers and cross-selling opportunities for Broadwind."

Broadwind anticipates that its enhanced wind turbine gearbox refurbishment capabilities will be fully operational in the second half of 2010, and will enable approximately 500 MW of annual wind turbine gearbox refurbishment, testing and field replacement. Site selection discussions for Broadwind's gearbox complex are underway and focused on the Abilene, Texas, area, which is in close proximity to the world's largest fleet of MW turbines.

Continued from page 84

HPII came to Chicago, met with my father and myself, and we made available our offices to him, which started our relationship. Eventually, we helped him locate office and warehouse space. One day, Herman called me and said, "I have someone who would like to say hello to you."

"Who is this?" I asked, and it was David Goodfellow. "What are you doing here?" I asked.

David replied, "Herman just hired me to be the president of American Pfauter, and I am going to be moving from Syracuse to Chicago."

Their offices were only a half-mile from ours, and since we had a big warehouse with heavy-duty cranes, that was the beginning of a multi-year collaboration. In the beginning, American Pfauter had only a handful of employees besides Herman: David Goodfellow, Geoff Ashcroft (now with Gear Consulting Group), Brian Cluff (now with Star-SU), Dennis Gimpert (now with Koepfer America), Hans Grass (now with Bourn & Koch), Olanda Gabaldi (now with Star-SU), and shortly after, Dennis Richmond (now with Reishauer America).

American Pfauter continued to grow, and later included many other familiar names of the gear industry: Martin Kapp (Kapp Coburg), Bill Miller (Kapp Tech USA), Fred Shomaker (Star-SU), Steve Peterson (Star-SU), Ken Flowers (Machine Tool Builders), Antonis Theodoro (Machine Tool Builders), Jack Carlson (Reishauer America), Rick Piller (Schiess) and Dan Fleming (Koepfer America). That company became the basis and influenced most every gear machine tool manufacturer or distributor, even today.

In 1987, David bought Barber Colman Cutting Tools, which became Pfauter Maag Cutting Tools. In 1992, they bought ITW Cutting Tools, which was folded into Pfauter Maag. With more than 420 employees, eventually David arranged the sale, in 1997, of the Pfauter factories in Germany, American Pfauter, Pfauter Maag Cutting Tools, and the Pfauter factories in Brazil, to The Gleason Works, who are the owners of these companies today.

David subsequently formed an agency that combined representation for the Star Cutter Company and Samputensili of Italy, known as Star SU, where he is today still president.

When David was to marry his present wife, Iolanda, he asked me to be his best man, and, at the church, the minister commented that David, a Lutheran, was marrying Iolanda, a Catholic, in a Presbyterian church with a Jewish best man, and David, like he's done most of his career, was covering most all of his bases.

All of the above history flashed through my mind about how intertwined the lives and careers of David Goodfellow, Herman Pfauter II and myself became. As I said earlier, in many respects, this represents a big part of the history of the gear machine tool industry.

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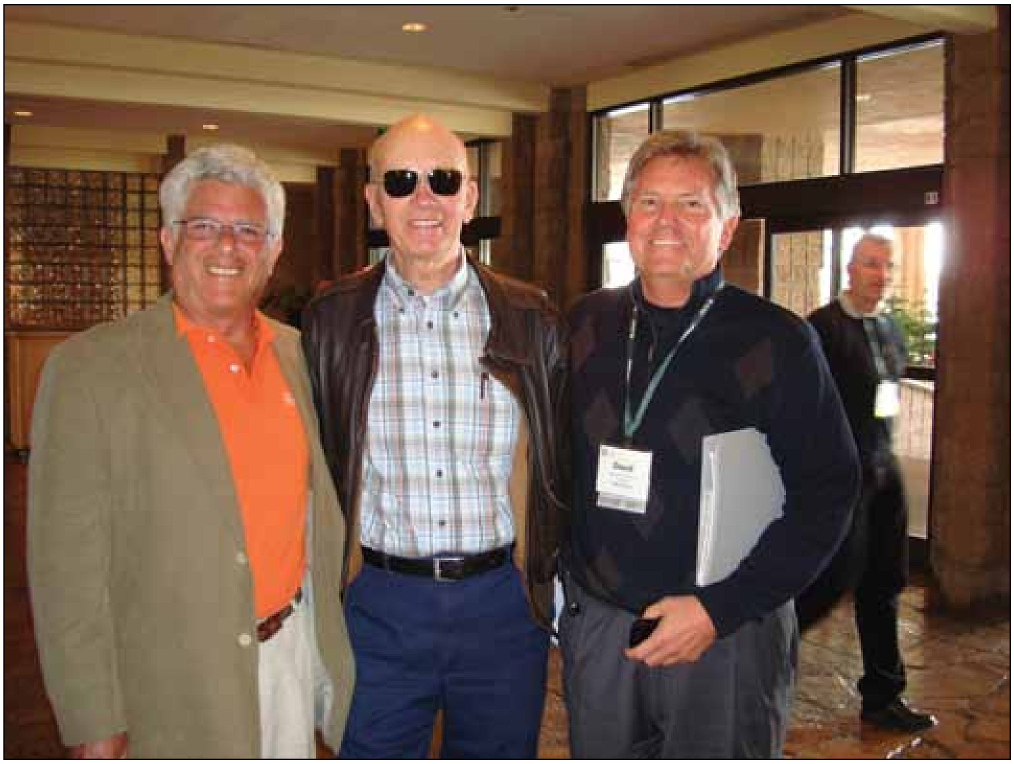
Old Friends and Gear Machine Memories

A REFLECTION BY MICHAEL GOLDSTEIN, PUBLISHER & EDITOR-IN-CHIEF



From left to right: Michael Goldstein, Herman Pfauter II and David Goodfellow.

I was leaving the AGMA Annual Conference at the Lowe's Ventana Canyon Resort in Tucson, my bags already loaded in the taxi, when I went back into the lobby for a second and was spotted by David Goodfellow, president of Star SU.

David waved me over, saying "Here's someone you want to say hello to."

Tall, black hat, and sunglasses, the man turned around, and we looked at each other, searching for recognition. Finally, David said, "Michael Goldstein, Herman Pfauter." We both knew each other very well, but probably haven't seen each other in over 15 years.

We chatted briefly, and I jumped into the taxi. But on the way to the airport, a flood of memories started going through my head, which caused me to think about the unique confluence of careers among myself, David and Herman Pfauter II, a confluence that embodies a significant part of the gear machinery industry's history.

Let me back up. I was working for my father at Cadillac Machinery as a third-generation used machine tool dealer. We had never represented any new machines, but in the summer of 1971, we decided that we were going to pursue the agency for a gear testing machine that would detect and eliminate nicks on the flanks of gears. The machine was manufactured by Daldi & Matteucci (DEMM), with offices in Milan and a factory in Porretta Terme, Italy. My father was scheduled to go to negotiate the contract and learn the technology, but a week before he was to leave, he broke his foot and wound up in the hospital. When I visited him, he told me that he wanted me to go in his place, which I did. This was my first big business trip overseas. I hired an Italian lawyer and negotiated the best I could.

After we agreed to terms, I moved to Bologna to learn the technical aspects of the machine in order to both sell it and service it. It was during this trip that I was introduced to some of the things that I've enjoyed the rest of my life—gnocchi, espresso, balsamic vinegar, prosciutto, parmesan cheese, grappa and an appreciation to learn to slow down and appreciate life as we go through it.

Shortly after I returned, I received an inquiry for this machine and its technology from New Process Gear in Syracuse, NY, and I went to visit the young engineer who was in charge of the machine tool purchases. His name was David Goodfellow. I invited him for dinner, which—uncharacteristically—he accepted. He told me that in his position, he was constantly invited out to dinner and declined most invitations. That was the beginning of a lifelong friendship that continues today.

At the time, the Herman Pfauter Machine Tool Company was represented by the Fellows Corporation. Herman Pfauter II (HPII) was living in California, driving a psychedelic school bus. But in 1971, the Pfauter family urged him to return to the family business to set up an exclusive agency for Pfauter machines in the United States.

Continued on page 79

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