August 2007

GEAR TECHNOLOGY

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The Journal of Gear Manufacturing

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- Captive vs. Commercial
- New Vacuum Processes

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GEAR TECHNOLOGY

August 2007

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Closed-end gears fixtured for processing at Bodycote's New Berlin, WI. plant.

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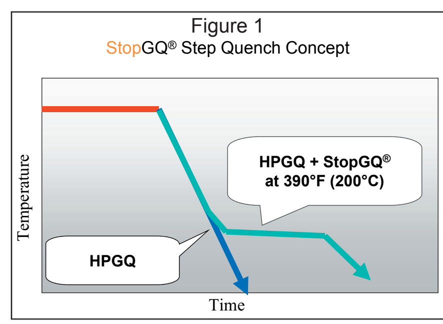

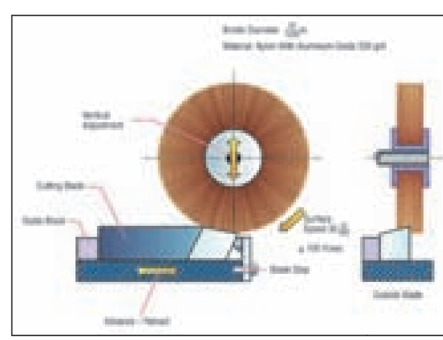

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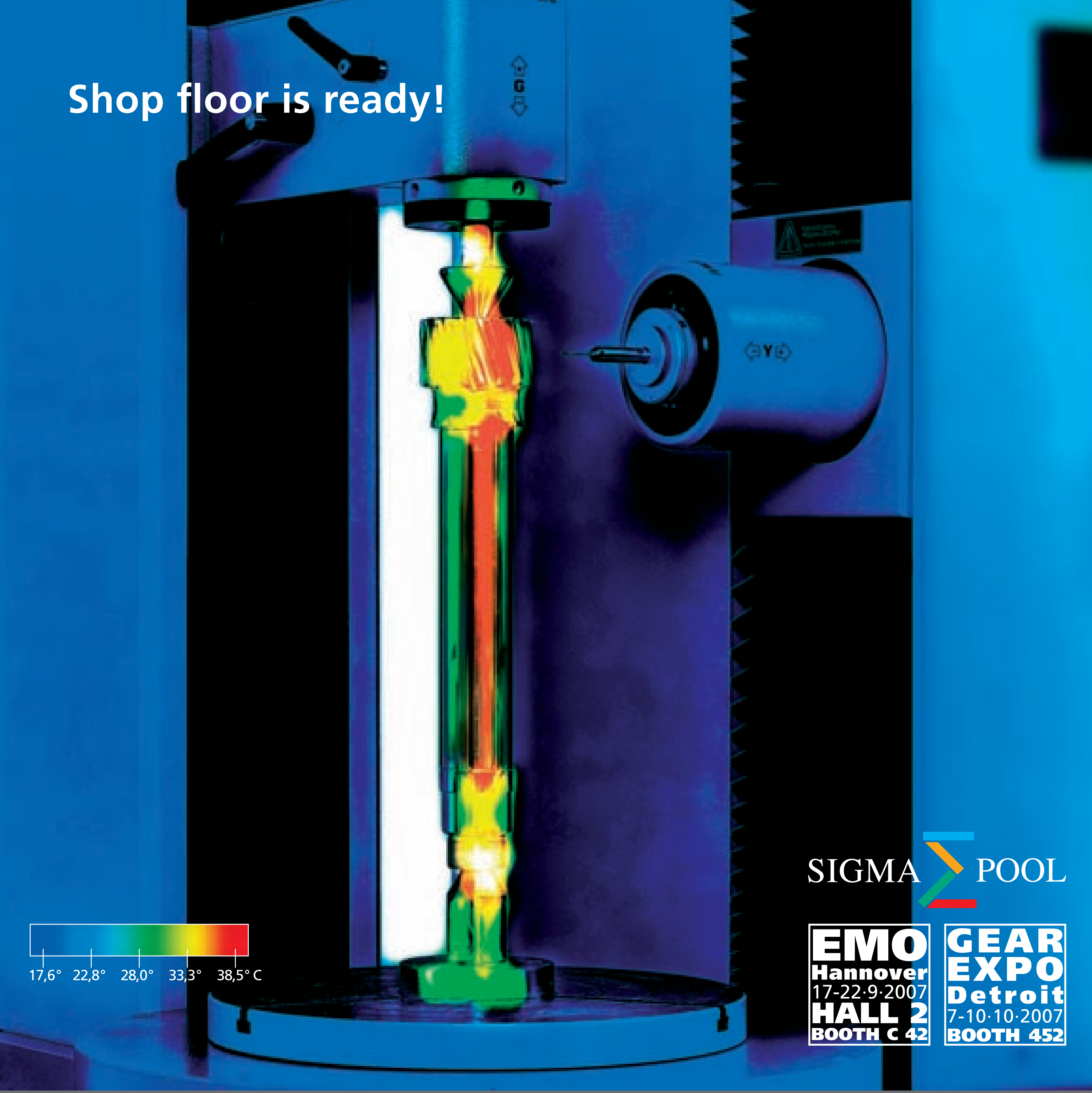

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Cover photo courtesy of Solar Atmospheres, showing its vacuum carburizing furnace supplied by sister company Solar Manufacturing. Gears supplied by Rush Gears.

THE WAR

Coming September 2007

I recently had the opportunity to attend a presentation given by Ken Burns and Lynn Novick about their upcoming 7-part documentary *The War*, which is scheduled to air on American public television (PBS) beginning in late September. Included in the presentation was a 1½-hour preview of the film.

When the presentation was over, I was physically and emotionally stunned, as were most of the people in the audience.

This is not just another war story, but a story about *The War*, WWII—the one that engulfed most of the world, the one in which 50 million people died. At the presentation, Burns and Novick described their approach and reasons for making this film.

I realize as I write this that many of you readers are German, Japanese or Italian and might think about this film as a story told from a victor's standpoint, but it is universal in its scope and treatment. The film's war-era footage comes from the British, German, Japanese and American archives. It includes interviews with veteran German soldiers, U-boat captains, sailors and civilians. This is not a story about famous historical battles or decorated heroes. It's not a story about who won or lost the war. Rather, it's a compelling story about the people who lived during that time and how the war affected them.

Its impact on older people, like some of the veterans in the audience, was significant. Those people lived through this time. Those of my generation, who were born during the war, remember our fathers and uncles and cousins who went off to fight, some returning to tell their experiences. But even for those born later, who may not have any direct connection with WWII, the universal themes and lessons allow everyone to relate.

Saipan, 1944. Credit: U.S. National Archives and Records Administration. Courtesy of PBS.

Guadalcanal, Solomon Islands, February 1, 1943. Credit: AP Images. Courtesy of PBS.

When you see footage of thousands of men on a beach, or on ships at sea, and then cut to interviews with veterans, wives, children, sisters and brothers, you get a sense of the enormous loss and destruction caused by that war—or any war, for that matter. Each of those thousands was an individual, and they had wives, children, sisters and brothers who thought of them and feared for them while they were gone. Seeing this film—and I only saw a fraction of it—imparts a better understanding of the impact on everyone involved.

Bringing such a huge and overwhelming world event down to the personal level was extremely important to Burns and Novick. In a recent interview, the filmmakers explained why they didn't use professional historians. "We wanted to make sure everyone in our film was either in the war or waiting anxiously for someone to come back from the war," Burns said. "You can make a film with historians 20 or 30 years from now," Novick added.

At the presentation, they said they needed to make this film now because WWII veterans won't be around to interview in another 10 years. According to the filmmakers, WWII veterans are dying at the rate of 1,000 per day.

For their interviews, Burns and Novick picked four towns—Mobile, AL; Sacramento, CA; Waterbury, CT; and Luvern, MN—that they thought would give them a good cross-section of America geographically and economically, with a good mix of farming, manufacturing and urban communities. The filmmakers went to those towns and advertised their project, wanting to meet, talk to and film everyone and anyone that had some experience related to that time.

One of the most powerful effects this film had on me was the realization of how young the soldiers were. Do you know any 18-year-olds? Sons, daughters, nieces, nephews? Can you imagine any of them going off to fight in a war? How about the kid who mows your lawn or bags your groceries? Can you picture any of them fighting for their lives, fighting for their countries? One of the things the film expresses very

Hartford, Connecticut, June 1942. Credit: Library of Congress. Courtesy of PBS.

well is that those kids—naïve, patriotic and indestructible—were the only ones who could have done what they did.

My dad went into the army in 1944. At 26 years old, he was one of the oldest guys in basic training. America, at the time, was an insulated nation that—for better or worse—became a world power—not for conquest, not for land, not for wealth, but for freedom.

Production of this film began before 9/11 and shouldn't be viewed in the context of what is going on today—and yet it should.

I recommend that you watch this series. It's not entertainment, it sometimes isn't easy to watch. In fact, it's sometimes damned hard to watch, but it's important to know, understand, and to some extent experience the war through the eyes of those who were there.

You can watch multiple Hollywood versions of the war or read countless books with columns of statistics and maps and charts, but only by hearing and understanding it through the participants and the survivors can you truly understand the horrors, the sacrifice and the legacy of that time.

Michael Goldstein,
Publisher & Editor-in-Chief

P.S. Burns and Novick collaborated previously on the documentaries *Baseball*, *The Civil War* and *Jazz*, among others.

The War will be shown on PBS Sunday, September 23 through Wednesday, September 26, then Sunday, September 30 through Tuesday, October 2. It is also available for purchase on *shoppbs.org*.

Sprockets Don't Mesh

Dear Editor:

I received my [June issue of] *Gear Technology* with the subscription page on the front. After taking off the renewal form, I was dismayed to see what was on the front cover. The picture is two sprockets meshing together as if they were gears. I know this because we make these sprockets. They are two aftermarket, inverted-tooth chain sprockets that fit a GM V-8. I hope you realize that sprockets do not mesh together like gears as you have them depicted.

If you are going to market your magazine to gear companies, you should take more care in what goes on your cover.

Trevor Myers,
Cloyes Gear and Product, Inc.,
Fort Smith, AR

Editors' reply: *Trevor, you got us. We let that one slip through. You will be pleased to know, however, that we try very hard to ensure that our covers and other artwork are realistic and accurate, and we reject more images than we approve. Sometimes, though—especially on the cover—we have to go with something more stylistic than practical, because the ideal image is not available. Of course, we welcome submissions of cover images from our readers and advertisers. For example, this issue's cover was provided by Solar Atmospheres from a photo shoot of real gears being heat treated. If you'd like to submit artwork for our consideration, please contact our art director, Kathy O'Hara, telephone at (847) 437-6604 or via e-mail at* kathyohara@geartechnology.com.

Inspired

Dear Editor:

Boy, did the childhood memories jump out of me the day I turned to the last page of the July 2007 *Gear Technology* issue and saw the "High Gear" game. I received one of these games for Christmas when I was six or seven years of age. I remember spending hours playing with the spinning gears and pinching my little fingers between the teeth. Thinking back, I wonder if this game gave me the drive for working with machinery. I am in my twenty-first year as owner of a gear cutting job shop.

Yours Truly,
Jimmy Peterson,
P&M Machine,
Gladewater, TX


ADDENDUM

Were Your Childhood Memories in HIGH GEAR?

Loyal *Gear Technology* reader and Interstate Castings vice president Greg Bierck came across "High Gear" at a vintage toy store in Indianapolis, IN. "High Gear" was introduced by Mattel in 1962. In the game, players compete to work their four pegs through the ten meshed gears. (The box says there are 35,568 possible gear combinations.)

An excerpt from Bierck's letter…

I am a collector of toys and really don't remember ever seeing this game when it came out. My first thought was that it might not have been a big seller. My second thought was what a good way to show and teach a child how mechanical things work with such a game. I wondered how many people now in the gear industry may have played with this game as a child? I admit to being 53 years old and would have been 9 years old at the time, but would have really enjoyed it, as I like mechanical things. I also got to thinking what a child of 9 years old would think about this game today. I would think that since it's not high-tech enough, there would be little to no interest from today's typical 9 year old.

My point being that gears make the world we know work. I'm in the foundry business, and castings also make the world function as we know it today. Yet, how many people really know anything about our industries, the challenges we face, or that we need to continue to find young people who may be interested in what we do to carry on? Hands-on, fun learning tools like this game just are not out there anymore to challenge our youth at an early age to use their imaginations and actually experience how things may work.

Who will actually be dreaming, designing and manufacturing anything in this country in 15 years? Will it all be done by other countries? I'm afraid so. And when it happens, we will no longer be a leading industrial world country. It's happening now. Would toys and games that stimulated hands-on learning at an early age, much like the Mattel game, keep us a world leader? Maybe.

Bierck's musings lead us to wonder if any of our other friends in the gear industry remember playing "High Gear" in the 1960s. *Gear Technology* would love to hear from any of the game's original enthusiasts.

Send your comments to
publisher@geartechnology.com
or
go old school and write us at:
Gear Techology
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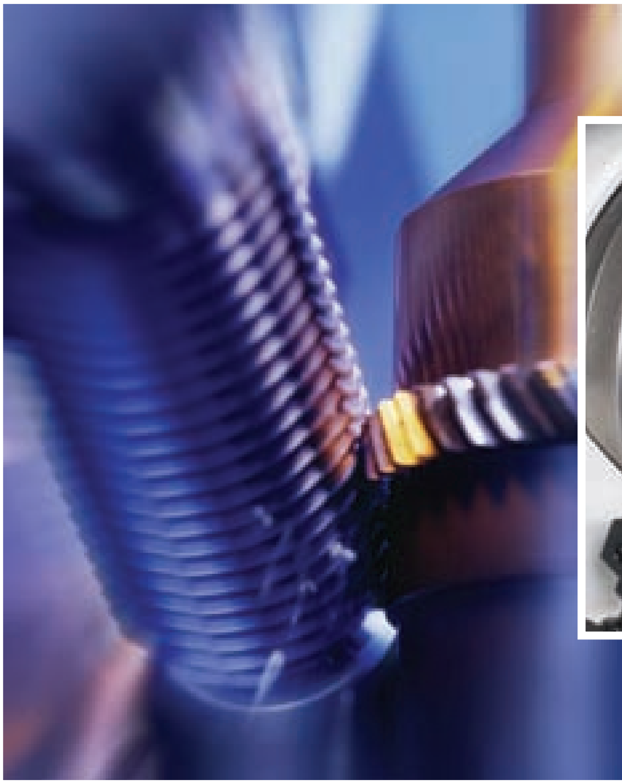

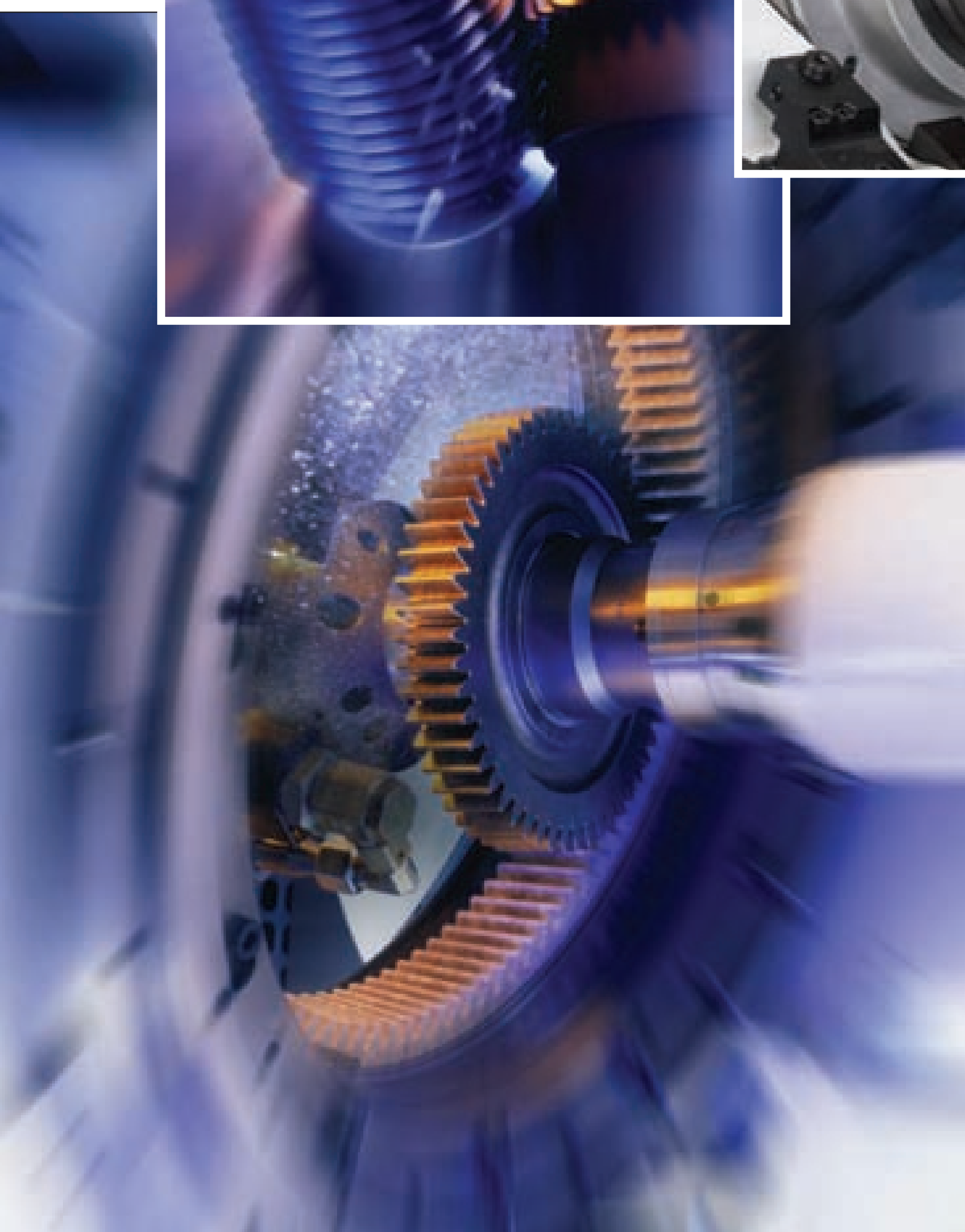

Gleason's EMO Booth

TO PREMIER NEW HOBBING, HONING AND TESTING MACHINES

Booth A56 in Hall 2 at EMO Hannover will be the site of the world premier of several new technologies from Gleason Corp.

The 210H hobber is designed for dry hobbing. The work area is completely isolated from the machine bed to minimize thermal expansion caused by contact with hot chips. It incorporates a stainless steel cutting chamber with steep inclination to ensure that chips fall clear of the work area.

Additionally, a cam-driven, double-gripper loader is fully integrated and reduces part load/unload times to three seconds.

According to Gleason's press release, the 210H utilizes a patent-pending hob drive system to eliminate complicated mechanical and hydraulic clamping systems. A "D-Drive" type enables the spindles to transmit more torque with less runout and accommodate larger diameter hobs for greater performance and longer tool life.

Other features include an easy access service module that consolidates hydraulics, lubrication and pneumatics, optional on-board chamfering and deburring, availability of the latest Siemens or Fanuc controls and alternate chip conveyor arrangements from either the side or rear of the machine to meet any cell/systems arrangement.

Gleason also plans to debut its new patent-pending 150SPH power honing machine with Spheric® honing for finishing hardened spur and helical gears.

According to the company's press release, the machine is based on feedback from more than 150 Gleason-Hurth honing machines sold.

Its directly driven honing head operates at speeds up to 3,000 rpm. Various tool systems can be used to satisfy requirements of different component geometries. In particular, Gleason concentrated on requirements for gear honing to achieve low-noise surfaces or for machining involving contours when developing this technology.

The latest version of the Spheric Honing software runs on the Siemens 840D. The software also provides process data calculation. Its integrated loading system facilitates short loading and non-productive times as well as a link to the customer's automation concepts.

Finally, Gleason's 360T universal gear tester for 90° angular bevel and cylindrical gears will be available for the first time at EMO.

The 360T permits CNC-controlled testing of most any gear set type. Patent-pending and available in either fixed 90° or full angular configurations, its gearhead motion ranges from 65–185°. Additional features include fully automatic SFT and SBN checking of all gear sets and tool-less arbor installation and adjustment.

For more information:
Gleason Corp.
1000 University Ave.
P.O. Box 22970
Rochester, NY 14692-2970
Phone: (585) 473-1000
E-mail: *sales@gleason.com*
Internet: *www.gleason.com*

Marposs

REDESIGNS WIRELESS BORE GAGE

Marposs Corp. will present its new M1 Wave wireless bore gage with an optional inductive battery charger at South-Tec 2007, Oct. 2–4 in Charlotte, N.C.

Equipped with a Lithium-ion battery pack that features a minimized memory effect, the new M1 Wave inductive bore gage allows for continuous use without any need for battery replacement.

A fully recharged gage provides approximately 36–40 hours of use. When full recharging time of 5–6 hours is not possible, the gage may be used in "cycle measure and charge" mode (one measure, one refill shot while waiting for the next workpiece), thus enabling the M1 Wave wireless gage to be used on a 24/7 basis.

The new M1 Wave Inductive bore gage, which uses Bluetooth® wireless technology to transmit data to the receiving electronic unit, incorporates IP67 contactless recharging technology. The inductive rechargeable feature may be retrofitted to existing M1 Wave wireless gages that use alkaline batteries for operation. No battery replacement is necessary.

In addition to the new M1 Wave Inductive rechargeable bore gage at South-Tec, Marposs will present its DigiCrown™ line of digital pencil probes, Quickset™ modular, retoolable bench gauge system, and Mida™ line of touch probes, laser tool setters, on-machine measurement software, and machine tool monitoring systems.

For more information:
Marposs Corp.
3300 Cross Creek Pkwy.
Auburn Hills, MI 48326
Phone: (248) 370-0404
Internet: *www.marposs.com*

MAG Fadal

DEMONSTRATES VERTICAL MACHINING CAPABILITIES AT EMO HANNOVER

MAG Fadal will introduce the new FX series machines and the VMC 6535HTX high-torque machining center at EMO Hannover 2007. The company will also demonstrate 10 vertical machining centers with applications ranging from high-volume production to machining of large molds, titanium and heavy steel

A "Profit Center" within the exhibit will include all three of the FX machine sizes, with X/Y/Z axes travel from 22" x 16" x 20" to 40" x 20" x 20". Employees will demonstrate production machining, including thread milling, rigid tapping and secondary operations (such as deburring and engraving).

The set of 2216FX, 3016FX, and 4020FX machines perform complex 3D mold work as well as job shop and small part applications. According to the company's press release, the new 4020FX, as well as the smaller FX machines, can be equipped with either the Fadal MP control or a Fadal GE Fanuc 0i-MC control with advanced software for programming, operation and troubleshooting. An optional AI contour control adds "look ahead" capability to optimize acceleration and deceleration of the cutting speed. Rigid box-way construction with integral flame-hardened ways, and Steinmeyer ETA+ dual-mounted ballscrews, reduce reversal error and provide increased stiffness.

Two MAG Fadal VMC 6535 machining centers will be exhibited. A 10,000 rpm, 40-taper 6535, with X/Y/Z travel of 65" x 35" x 34", will demonstrate its capability for large aluminum mold machining. Titanium and hardened steel cutting will be featured on a 6535HTX equipped with a 50-taper, 6,000 rpm high-torque spindle (48 hp peak power, 441 ft.-lbs. peak torque)

continued

and air/oil lubrication. The machine is designed for aerospace, automotive and other applications. Cutting rates up to 600 ipm, with rapid travel rates up to 900 ipm, can be achieved.

For more information:

MAG Fadal Machining Centers
20701 Plummer St.
Chatsworth, CA 91311
Phone: (818) 407-1400
E-mail: *info@fadal.com*
Internet: *www.fadal.com*

LMC Workholding

OFFERS LARGE SIZE CHUCK

LMC Workholding offers large size power chucks for high-speed applications and extra large thru-holes for large-bore lathes. LMC offers three standard models of large chucks, with larger chuck sizes available by special order.

The three standard power chuck models include the 18" with 6.5" thru-hole, 21" with 7.5" thru-hole and 24" with 8" to 10.5" thru-holes. LMC also offers the corresponding thru-hole hydraulic actuators to match the chucks. According to the company's press release, these chucks offer the quality tolerance needed for large workpiece applications.

For more information:

LMC Workholding
P.O. Box 7006
1200 West Linden Ave.
Logansport, IN 46947-7006
Phone: (574) 735-0225
E-mail: *info@logan-mmt.com*
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Bodine's New Gearmotors

DELIVERS MORE TORQUE

Bodine Electric's CG gearmotor, an extra-rugged line of variable speed AC inverter-duty and permanent magnet DC gearmotors, was developed specifically for the company's most powerful electric motors, the 48R-AC inverter-duty, and 42A permanent magnet DC motors. This integral gearmotor design allows the CG to deliver up to 1,000 lb-in. of torque, or nearly twice the torque of any previous Bodine product.

According to the company's press release, numerous components of the CG gearmotor were designed for higher than usual performance. The motor and gear head are assembled as an integral unit, so the possibility of leaks at the motor-gearhead seal or misalignment between motor and gearhead is eliminated. The new CG gearhead features a three-stage, selectively hardened gearing cluster, permanently lubricated with a special, high-performance lubricant. Its aluminum-cast body, and extra heavy-duty bearings and seals enhance performance, even in tough applications.

Because the gearhead is unvented, the gearmotors can be mounted in virtually any position by means of its extra-wide face-mounting flange. Bodine says its driveshaft, 1" diameter, is almost twice as large as those typically found in comparable products and allows the CG gearmotors to deliver improved output torque to the load.

These gearmotors are specifically designed for applications such as platform lifts, heavy-duty plant automation equipment, and other equipment where long life and high load capacity are critical.

Edmund Glueck, manager of product development, says, "It's the largest gearmotor Bodine has designed to date."

For more information:

Bodine Electric Co.
2500 W. Bradley Pl.
Chicago, IL 60618
E-mail: *info@Bodine-Electric.com*

Mitsubishi's Three Newest Machines

SLATED FOR GEAR EXPO DISPLAY

Mitsubishi Gear Technology Center plans to display the GE25A hobber, the ZE24A grinder and the ST40 CNC shaper at its Gear Expo booth.

The GE25A hobber is based on the wet and dry cutting concept of the GE15A and GE20A. Stainless steel guarding protects key parts of the machines' work area from hot flying chips. Additionally, the GE25A has larger castings, bearings and ball screws. According to the company's press release, the hob head drive delivers high torque with cutter speeds up to 1,500 rpm. Mitsubishi will demonstrate the machine dry hobbing a gear near its capacity in less than one minute at the show.

The ZE24A has been in the works for the past two years. For the first year, a prototype machine was placed in a Japanese manufacturing facility in order to gauge its performance at a leading transmission manufacturer. Mitsubishi says it completed that test, and several machines have been sold in the meantime.

The ZE24A is an upgrade of the ZE15A and will be displayed with full automation. A grinding demonstration will take place featuring the same gear being hobbed by the GE25A, and customers may watch the entire grinding process, which includes automation, meshing, wheel balancing and dressing.

Finally, the company will display its ST40 CNC programmable lead guide shaper in booth 148 at Gear Expo.

For more information:

Mitsubishi Gear Technology Center
46992 Liberty Dr.
Wixom, MI 48393
Phone: (248) 669-6136
E-mail: *info@mitsubishigearcenter.com*
Internet:
www.mitsubishigearcenter.com

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Brevini's New Gearboxes

OFFER GREATER OUTPUT FROM SMALLER UNITS

Brevini has combined the low weight and high reduction ratios of its planetary gear stages with the higher capacity, strength and durability of bevel helical gears to produce a hybrid design for medium- to large-sized industrial applications.

The new Posiplan PH and BPH shaft-mounted range of gearboxes employ the planetary stages at the input end and the helical stage at the slower, higher-torque output side. The result is a hybrid gearbox that allows a reduction in size or an increase in capacity over a more traditional design.

Jon Snaith, general manager for sales, says, "In the past, some engineers have been reluctant to design a planetary shaft-mounted gearbox into the machine because the driven shaft does not engage all the way through the gearbox. The Posiplan, in contrast, has a helical final stage reduction, thus removing this objection."

Available in 10 motor sizes, the series works with motor performance curves to optimize the efficient working input speeds of common frame sized motors.

According to the company's press release, the high power-to-weight properties of Brevini planetary gearing enable both series of gearboxes to offer OEM designers a lighter and more compact solution than traditional helical and helical/bevel alternatives. A modular cast casing design and a broader range of mounting options reduce manufacturing times, while maintenance engineers and plant managers using the gearboxes in replacement situations utilize the latest labyrinth sealing technology and high performance bearings in harsh environments.

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Offering nominal torque capacities up to 27,000 Nm (soon to be extended to 67,000 Nm), the Posiplan PH and BPH range of shaft-mounted gearboxes are suitable for use in applications such as bucket elevators, mixers, conveyors and crushers and are ideal for many other industrial applications requiring medium/low speed and high-torque.

Using these gearboxes in a shaft-mounted configuration offers fitment in any orientation and can be used to replace exposed transmission alternatives such as belts, chains and pulleys.

The in-line Posiplan PH series offers ratios from 12:1 to 2,000:1 within the one casing, without the need for a "plug-in" additional helical gearbox in the drive train. The units provide a solution for space and weight-restricted conveyor or mixer applications where designers need high levels of torque from a low-weight and highly efficient design. The series achieves torque outputs ranging from 5.8 KNm to 67 KNm via single-, double- or triple-stage planetary inputs and a single-stage helical output for shaft diameters of 70 mm to 140 mm.

Offering similar levels of performance, the Posiplan BPH series provides reduction ratios of 30:1 up to 1,000:1 as standard and are more suited to applications requiring 90° operation such as cranes, crushers, extractors or continuous extruding assemblies. The smallest 29 kW, 70mm output shaft version consists of a standard Brevini input with parameter optimized Gleason bevel gear assembly. A single Brevini planetary stage further reduces transmission speeds to a final helical gear output. However, higher torque models (BPH20, 23 and 25) are supplied fitted with a single reduction planetary stage input or a two-stage planetary input for maximum speed reduction.

Output options available include hollow shafts: cylindrical with keyway, cylindrical hollow shaft for shrink disc, as well as splined shafts. Input variations include adaptors for IEC, NEMA and hydraulic motors, flexible and fluid couplings, clutches and torque limiters, and belt couplings. Units are also available with torque arms, backstops, breaks, auxiliary drives as well as oil filtering and cooling systems.

For more information:
Brevini Power Transmission UK
Planet House
Centre Park
Warrington, Chesire WA1 1QX
U.K.
E-mail: *sales@breviniuk.com*
Internet: *www.brevini.co.uk*

Gear Expo 2007 Show Preview

October 7-10, 2008 • Cobo Center • Detroit, Michigan USA

AGMA Fine Tunes Gear Expo Format

The organizers of Gear Expo 2007 promise to combine the most popular features of shows past with some innovations for this year's attendees. By the time the show closes on October 10, the association hopes its targeted 175 exhibitors walk away with new insights leading to profitability and renewed contacts.

Cheers to Gears

The American Gear Manufacturers Association is sponsoring a cocktail hour for all attendees on Monday, October 8, after the show closes. While the particulars are still under wraps, AGMA vice president Kurt Medert says the networking opportunity will be invaluable.

"The idea behind the cocktail reception is to give visitors and exhibitors a casual means of interacting with one another and to catch up with old acquaintances after a full day of activity on the show floor," says Medert.

Back to Gear School

In addition to the socializing opportunities, there is a strong educational component at this year's Gear Expo. The Solutions Center, which Medert says was a hit with audiences in 2005, returns for another run. There are 24 presentations slated for 30-minute time slots, all of which are free to attendees.

In order to better maximize the visitor's time this year, the Solutions Center's programming will be consolidated into two days with Dr. Mike Bradley's "Gear Market Report" as the keynote on Monday and a presentation by Eric Fedewa, an

Continued......

$395 for SME/AGMA members and $445 for non-members and can be completed at *www.sme.org/gears*.

In the middle of the show is SME's course on "Effective Heat Treating and Hardening of Gears," a morning dedicated to evaluating alternative heat treating methods, controlling and monitoring processes, controlling distortion and more. Registration is $395 for SME/AGMA members and $445 for non-members and can be completed at *www.sme.org/gears*.

Also undertaken by the SME is "Advanced Gear Processing and Manufacturing" on Wednesday, October 10. Throughout the six-hour seminar, industry leaders will investigate chronic problems, factors that impact tool life and performance, and compare technologies. Registration is $395 for SME/AGMA members and $445 for non-members and can be completed at *www.sme.org/gears*.

For the power transmission crowd, the American Bearing Manufacturers Association is sponsoring "Why Bearings Fail," a four-hour-long primer on the causes of bearing failure in gearboxes and related equipment for OEMs and end users.

One final note on educational offerings in conjunction with Gear Expo. The Basic Gear Manufacturing Course, which will be held September 10–14 at Richard J. Daley College in Chicago, will be repeated in a classroom-only version at the Cobo Center. Presented by Michael Tennutti of Gleason Cutting Tools, the classroom course will train participants on standards nomenclature; gear involute geometry; inspection procedures and interpretation of results; manufacturing processes; hobbing, shaping and shaving; troubleshooting the gear manufacturing process; improvements in productivity and discussion of common problems. Participation is $395 for AGMA members and $495 for non-members. For registration, visit AGMA's website at *www.agma.org*.

automotive industry expert from CSM Worldwide presenting "The Outlook for the Automotive Industry" as Tuesday's anchor address.

Additional learning opportunities take place in the form of the Fall Technical Meeting. Held concurrently with Gear Expo, this year's FTM sessions are: Manufacturing and Testing Gears, Hypoid and Bevel Application Design; Innovative Application Solutions; and Making Gears Work for Life. This year's Fall Technical Meeting includes 18 presentations. More information about the presentations can be found in the sidebar on page 31.

The American Bearing Manufacturers Association and the Society of Manufacturing Engineers are once again setting up shop at Gear Expo with their own education programs.

SME's "Understanding Gear Metrology and Inspection" is scheduled on October 8 and promises a deeper understanding of technical metrology and inspection issues unique to the gear manufacturing and processing industries. Registration is

2007 Fall Technical Meeting Schedule of Events

Sunday, October 7

9 a.m.–5 p.m.
Registration

1 p.m.–5 p.m.
Technical Session I: Alternative Materials and Designs

- "Estimation of a Lifetime of Plastic Gears," by Stefan Beerman of KISSsoft AG
- "Study of the Correlation Between Theoretical and Actual Gear Fatigue Test Data on a Polyamide," by Steve Wasson of DSM Engineered Plastics
- "Material Integrity in Molded Plastic Gears and Its Dependence on Molding Practices," by Tim Vale of ABA-PGT
- "Applying Elemental Gear Measurement to Processing of Molded Plastic Gears," by Glenn Ellis of ABA-PGT
- "Vacuum Carburizing Technology for Powder Metal Gears and Parts," by Janusz Kowalewski and Karol Kucharski of SECO/Warwick Corp.

7 p.m. – 8:30 p.m.
Welcoming Reception (Held at the Detroit Marriott Renaissance Center. All other events will be at the Cobo Center.)

Monday, October 8

7:00a.m.–12:00p.m.
Registration
7:00 a.m.–8:00 a.m.
Continental Breakfast

8 a.m.–12 p.m.
Techical Session II—Current Updates

- "Using Barkhausen Noise Analysis for Process and Quality Control in the Production of Gears," by Stephen Kendrish, Theo Rickert and Robert Fix of AmericanStress Technologies
- "Grinding Induced Changes in Residual Stress of Carburized Gears," by Robert LeMaster, Bryan Boggs, Jeffrey Bunn of the University of Tennessee at Martin and Camden Hubbard and Thomas Wilkins of Oak Ridge National Laboratory
- "Manufacturing Net Shaped Cold Formed Gears," by Dennis Engelmann of Milwaukee Wire Products
- "The Ikona Clutch and the Differential," by John Colbourne, Vladimir Scekic and Sasha Tesic of Ikona Gear
- "The Gear Dynamic Factor: Modern and Historical Perspective," by Donald Houser and David Talbot of the Ohio State University

12 p.m.
Annual Awards Luncheon

Monday afternoon is open time to visit Gear Expo. Attendance is free for Fall Technical Meeting Participants.

Tuesday, October 9

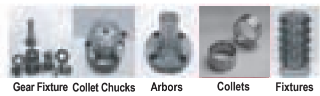
7 a.m.–12 p.m.
Registration
7 a.m.–8 a.m.
Continental Breakfast

8 a.m.–12 p.m.
Technical Session III: Load Capacity and Micropitting

- "Helicopter Accessory Gear Failure Analysis Involving Wear and Bending Fatigue," by Gregory Blake and Doug Schwerin of Rolls-Royce Corp.
- "The Effect of Start-Up Conditions on Gear Performance and Life—Failure Analysis and Case Study," by Raymond Drago of Drive Systems Technology
- "The Influence of Grinding Burn on the Load Carrying Capacity of Parts Under Rolling Stress," by Fritz Klocke, Tobias Schröder, and Christof Gorgels of RWTH Aachen University of Technology
- "Roughness and Lubricant Chemistry Effects in Micropitting," by A. Olver, D. Dini, E. Laine of Imperial College and D. Hua and T. Beveridge of Caterpillar Inc.
- "Experience with Disc Rig Micropitting Test," by M. Talks and W. Bennett of QinetiQ Fuels and Lubricant Center

1 p.m.–5 p.m.
Technical Session IV: Bevel Gear Design and Manufacture

- "Straight Bevel Gear Cutting and Grinding on CNC Free Form Machines," by Hermann Stadtfeld of The Gleason Works
- "Simulation Model for the Emulation of the Dynamic Behavior of Bevel Gears," by Christian Brecher, Tobias Schröder and Adam Gacka of the RWTH Aachen University of Technology
- "Bevel Gear Model," by Ted Krenzer, Consultant
- "How to Determine the MTBF of Gearboxes," by Gerhard Antony of Neugart USA LP



Hotels

Whether you're walking the show floor or sitting in lectures, the AGMA encourages all Gear Expo participants to book accommodation in one of three hotels with pre-negotiated show rates. Guests must make their own hotel reservations, and the rates are current through September 10, 2007. Online booking is available at *www.gearexpo.com.*

- Detroit Marriott Renaissance Center
  $164/night
  Reservations: (313) 568-8000 or (800) 352-0831

This is considered the Gear Expo 2007 Headquarters and is three blocks from the Cobo Center with indoor access to the People Mover.

- Detroit Downtown Courtyard by Marriott
  $154/night

Reservations: (313) 222-7700 or (800) 321-2211

This hotel has indoor access to the People Mover. Guest room renovation is currently underway.

- Holiday Inn Express Hotel and Suites
  $109/night
  Reservations: (313) 877-7000 or (800) HOLIDAY

Group code: AGM

This hotel is two blocks from Cobo Center and one-half block from the People Mover.

As of July 24, 2007, the total number of gear and machine tool manufacturers, forging companies and software suppliers was 159. Medert says that by opening day on October 7, they hope to have more than 175 exhibitors and a high quality level of attendees.

"We are looking forward to welcoming everyone to another successful Gear Expo. There are new features to the show this year, but, as always, the real purpose is to match gearing professionals with exhibitors that can help their companies run more effectively and profitably," sums up Medert.

ONLINE

Additional Gear Expo information can be found online at

www.geartechnology.com

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New Vacuum Processes Achieve Mechanical Property Improvement in Gearbox Components

Aymeric Goldsteinas

***Aymeric Goldsteinas** leads the Prospective and Innovation team at ECM in Grenoble, France. Acting as liaison between R&D and sales, he demonstrates ECM's technologies to customers worldwide. He began with ECM in 1998 as an R&D engineer and helped to create the patented Infracarb process with acetylene. He has also helped develop and patent several other heat treating processes, including low pressure vacuum carburizing and high pressure gas quenching processes. Goldsteinas holds a bachelor's degree in life sciences and a master's degree in science and technology.*

Management Summary

This paper introduces new process developments in low-pressure carburizing and carbonitriding using either high-pressure gas quenching or interrupted gas quenching. (In this article, the interrupted gas quenching method used is StopGQ®, a registered trademark of ECM.) Comparison of mechanical properties which result from each process will be discussed. The reader will discover how the optimization of carbon and nitrogen enrichment and the mastering of gas quenching can improve fatigue strength and impact properties.

Introduction

Increased performance requirements in automotive and other industries demand higher strength characteristics from components such as gears and pinions. Those requirements translate into a need for improved impact properties and fatigue strength. The technical solution to address the need for expanding the performance envelope has required the development and optimization of new processes.

A research program was launched by ECM using the flexibility of low-pressure vacuum carburizing in combination with high-pressure gas quenching (LPC + HPGQ) to investigate several new vacuum processes:

- LPC + HPGQ + StopGQ quenching
- LPCN (low-pressure carbonitriding) + HPGQ
- LPC + HPGQ + StopGQ quenching

Marked improvements in mechanical properties were found as a result of the optimization of both surface enrichment techniques and quench parameters. The conventional process, LPC + HPGQ + tempering, was used as a benchmark for all tests.

StopGQ Quenching Concept

Once a workload has been hardened or case hardened, tempering is necessary. Conventional high-pressure gas quenching looks to bring the entire workload to room temperature as rapidly as possible. Interrupted quenching involves halting the cooling process in the temperature range of 350–400°F (180–200°C) and introducing an isothermal hold (Fig. 1) in order to perform an "auto-tempering" step in the gas quenching cell, thus avoiding the need for subsequent tempering. Instrumented full-load trials of gears (Fig. 2) helped determine the correct time delay before initiation of quench interruption as a function of quench pressure.

LPCN Studies

Atmosphere carbonitriding is typically performed in the temperature range of 1,475–1,650°F (800–900°C). Typical case depths are 0.010–0.020" (0.25–0.50 mm), although deeper and shallower cases can be achieved.

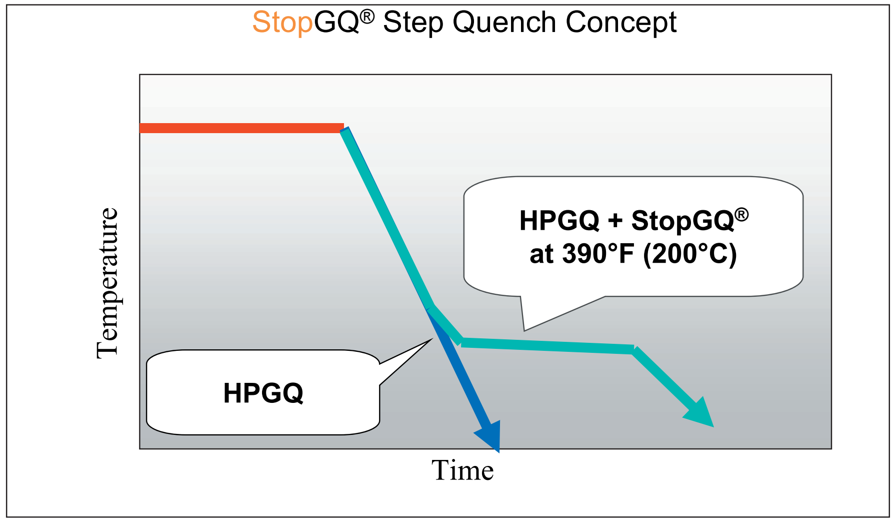


Figure 1—StopGQ quench concept.

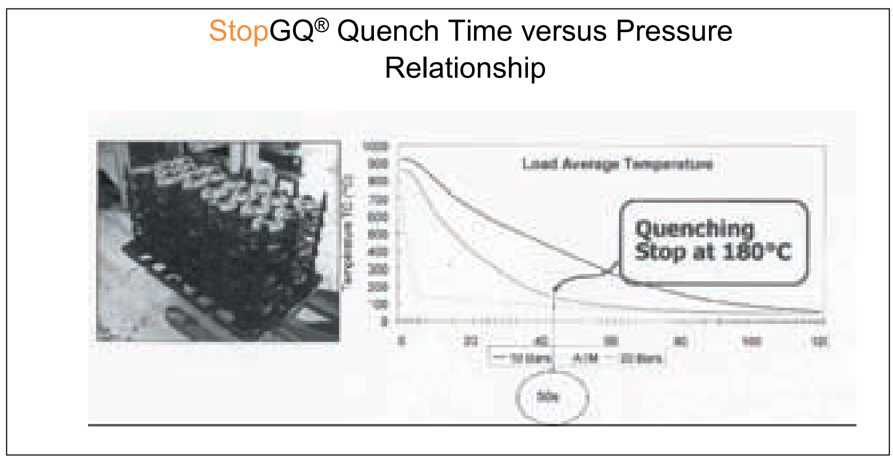


Figure 2—StopGQ quench time versus pressure relationship.

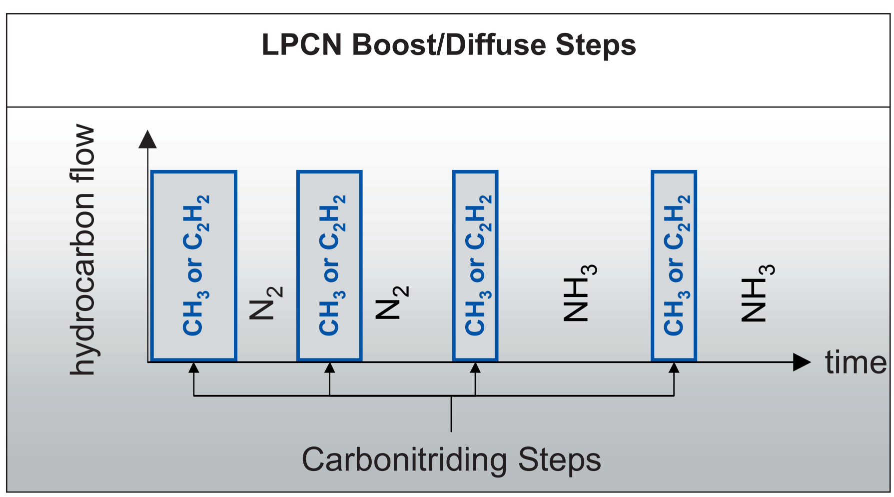


Figure 3—LPCN boost/diffuse steps.

Surface carbon is normally in the range of 0.6–0.8%, and surface nitrogen content is in the range of 0.15–0.30%.

The principle of low-pressure vacuum carbonitriding is to alternate the boost/diffuse gas mixtures between hydrocarbon gas (propane or acetylene) and nitrogen or hydrocarbon gas and ammonia (Fig. 3). Processing pres-

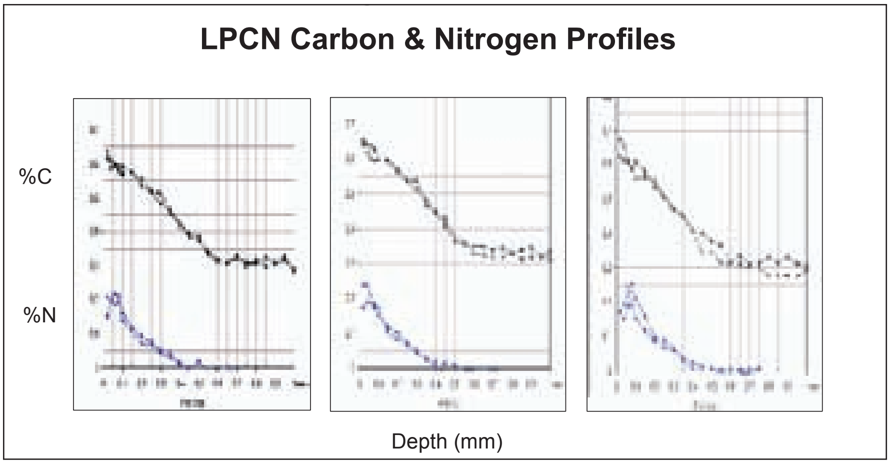


Figure 4—LPCN carbon and nitrogen profiles.

Table 1—Results

	Carbonitriding Temperature, °F (°C)	Carbon (%)	Nitrogen (%)	Effective Case Depth, Inches (mm)	Microstructure
Target Values		0.6–0.8	0.15–0. 30	650 HV (58HRC) @ 0.020" (0.5 mm)	
	1700 (930)	0.88	0.13	0.024 (0.62)	Martensite + Austenite (<20%)
	1750 (960)	0.80	0.14	0.040 (1.00)	Martensite + Retained Austenite (<20%)

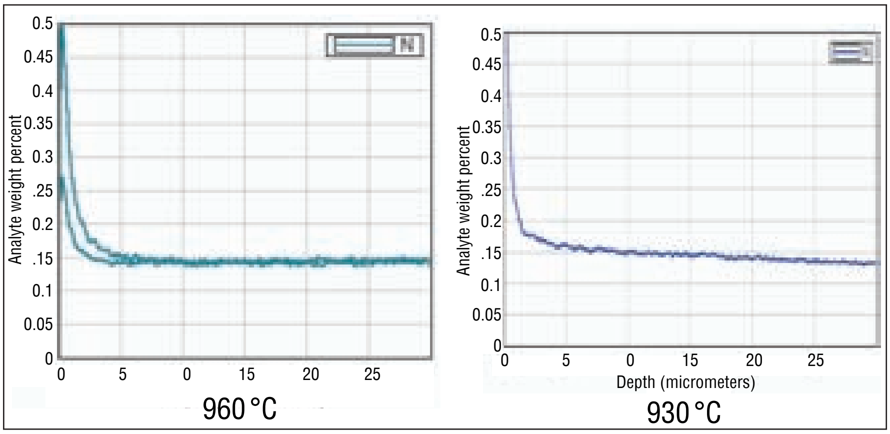


Figure 5—LPCN elevated temperature test results.

Table 2—Specification targets for test gears

Steel Grade	Effective Case Depth @ 52.5 HRC (550 HV) Inches (mm)	Surface Hardness (HV 20)	Core Hardness (HV 50)
5130	0.020–0.030 (0.5–0.7)	690–900	320–500

Figure 6—Gear test load.

sure was equivalent to LPC—that is, in the range of 4–15 torr (5–20 mbar). Ammonia is added during the later boost/diffuse steps and during the final soak. The amount and duration of the carbonitriding steps depends on the depth and nitrogen concentration desired.

Trials (Fig. 4) were conducted on SAE 5130 (29MnCr5) pinions at 1,615°F (880°C), followed by direct quenching using 8-bar nitrogen. Samples used were placed in the top, center and bottom baskets of the load. Analysis of carbon and nitrogen content involved two different technologies: GDOS (Glow Discharge Optical Emission Spectrometry) to measure the nitrogen concentration of the surface to a depth of 0.0015" (40 µm) and WDS (Wavelength Dispersive X-Ray Spectroscopy), accurate to a depth of up to 0.060" (1.5 mm). These techniques confirmed that the profiles using LPCN were equivalent to what was produced by atmosphere carbonitriding.

Additional LPCN tests (Fig. 5) were conducted at higher temperatures to investigate cycle time savings. Typical carburizing temperatures of 1,700°F (930°C) and 1,760°F (960°C) were selected for study. Process parameters were similar to the trials at 1,615°F (880°C). GDOS profiles were conducted to determine the nitrogen content at the near surface up to 0.0012" (30 µm). Results indicated a nitrogen content of 0.5%, falling rapidly to 0.15% below the near surface at 1,700°F (930°C) and the same behavior was observed at 1760°F (960°C). The nitrogen profile was achieved at 1,700°F (930°C) up to 0.015" (0.4 mm) and up to 0.40" (1.0 mm) at 1,760°F (960°C). These tests indicate that the process can work at high temperatures as well.

Fatigue and Impact Studies

Specification targets (Table 2) were selected for gears (Fig. 6) of SAE 5130 (29MnCr5) material.

Hardness and effective case depth results (Table 3) achieved targeted values. This confirmed that there was no metallurgical difference to influence fatigue strength results.

One of the mechanical property tests employed was to determine impact properties. Impact samples (Fig. 7) were tested in a pendulum type impact tester at 50J.

The result of impact testing when compared to LPC + HPGQ revealed, as one might expect, a strong benefit of tempering on impact properties. Noteworthy is the improvement over LPC + HPGQ achieved by interrupted quenching or by LPCN + HPGQ. These results indicate that additional testing is required to optimize results. The use of LPCN + HPGQ with StopGQ quenching (Fig. 8) resulted in impact values exceeding those of LPC + HPGQ + tempering.

Another mechanical test employed was that of rotating bending fatigue involving a notched sample geometry (Fig. 9). The test was run for 1 x 10^7 cycles.

The results of rotating bending fatigue testing (Fig. 10) indicate all of the new processes improve strength values over those of either LPC + HPGQ or LPC + HPGQ + tempering.

Realized Objectives

An improvement in fatigue strength was realized using the "auto-tempering" effect achieved by StopGQ quenching. The effect of nitrogen present in the surface layer of LPCN parts was revealed in higher impact and fatigue strength values (Fig. 11).

Table 3—Hardness and Case Depth Summary

Steel Grade	Thermal Treatment	Hardness (HV)		Case Depth, Inches (mm)
		Surface	Core	
5130	LPC + HPGQ	885	440	0.015 (0.39)
5130	LPC + HPGQ +Tempering	800	445	0.015 (0.40)
5130	LPC + HPGQ with StopGQ Quenching	872	460	0.018 (0.45)
5130	LPCN + HPGQ	927	460	0.015 (0.38)

Note: Quench pressure was 13 bar (nitrogen) for each test run.

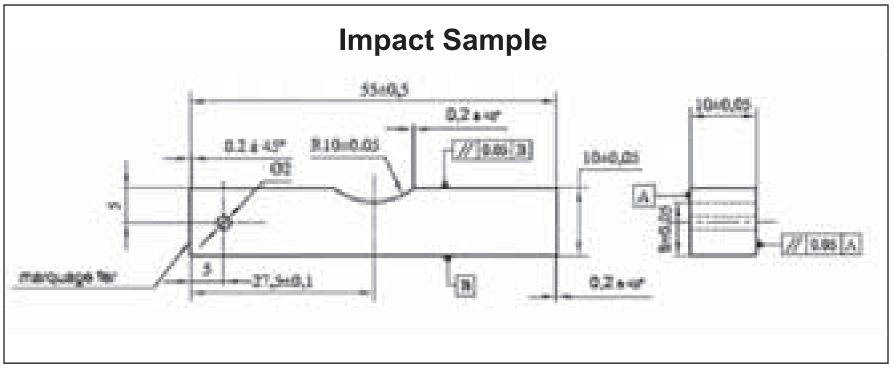


Figure 7—Impact sample.

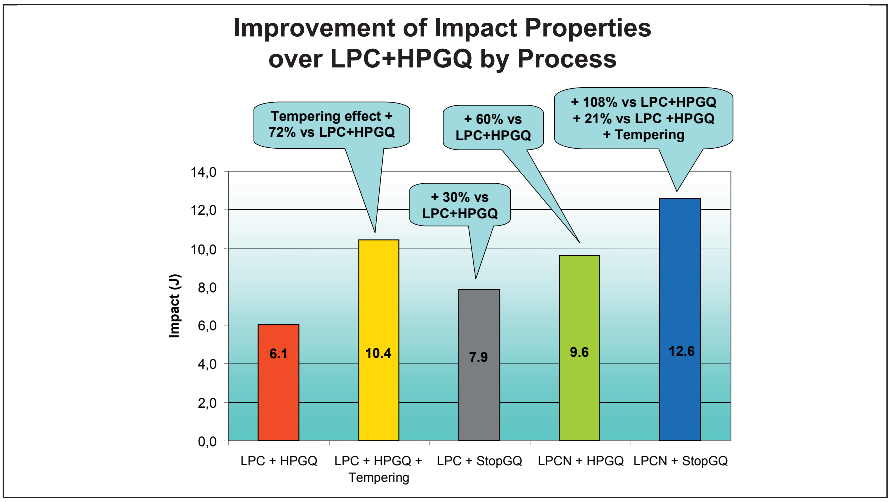


Figure 8—Improvement of impact properties over LPC+HPGQ by process.

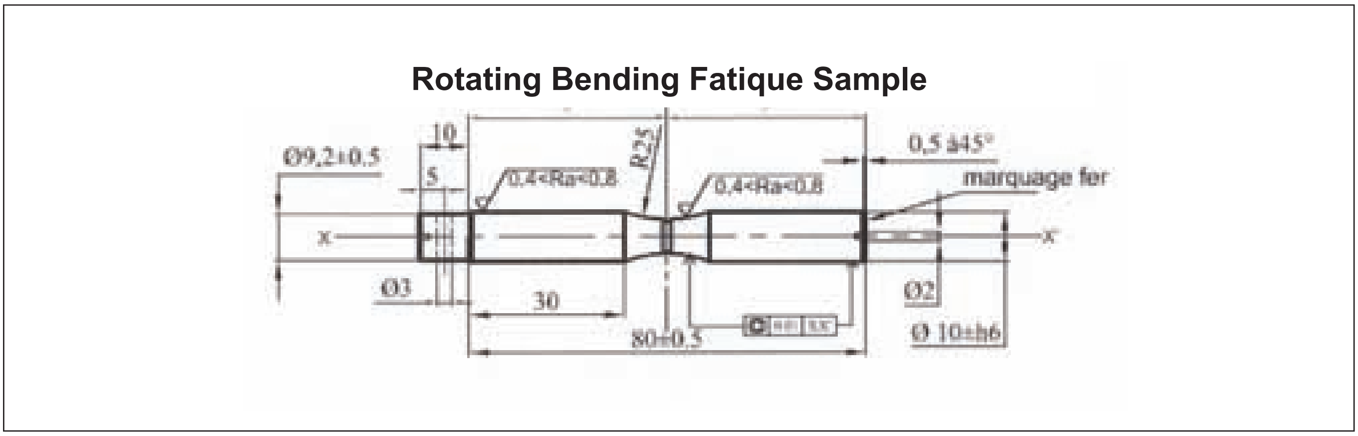


Figure 9—Rotating bending fatigue sample.

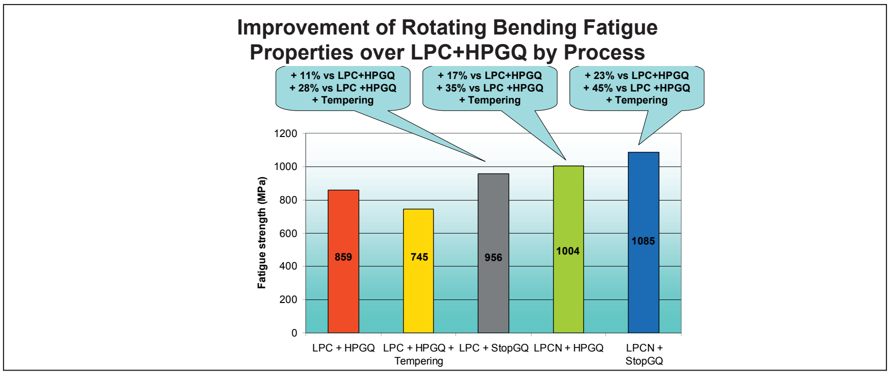


Figure 10—Improvement of rotating beam fatigue properties over LPC+HPGQ by process.

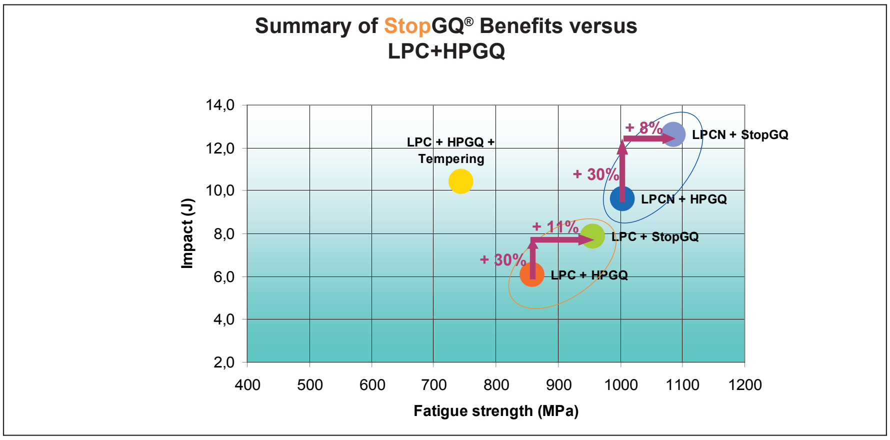


Figure 11a—Summary of StopGQ® benefits versus LPC+HPGQ.

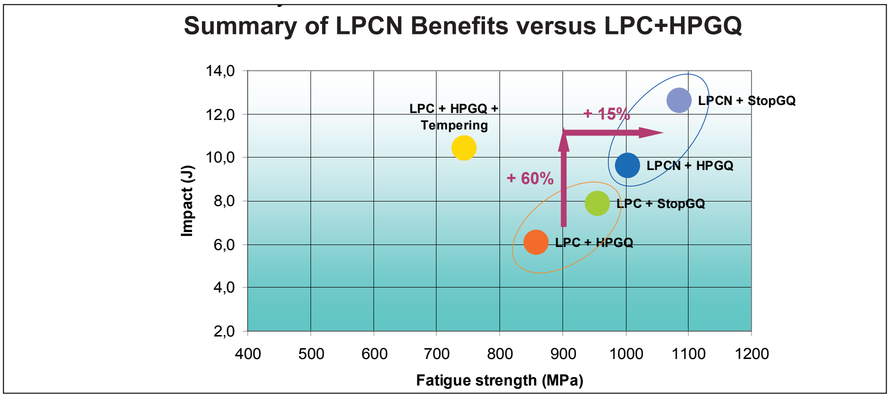


Figure 11b—Summary of LPCN benefits versus LPC+HPGQ.

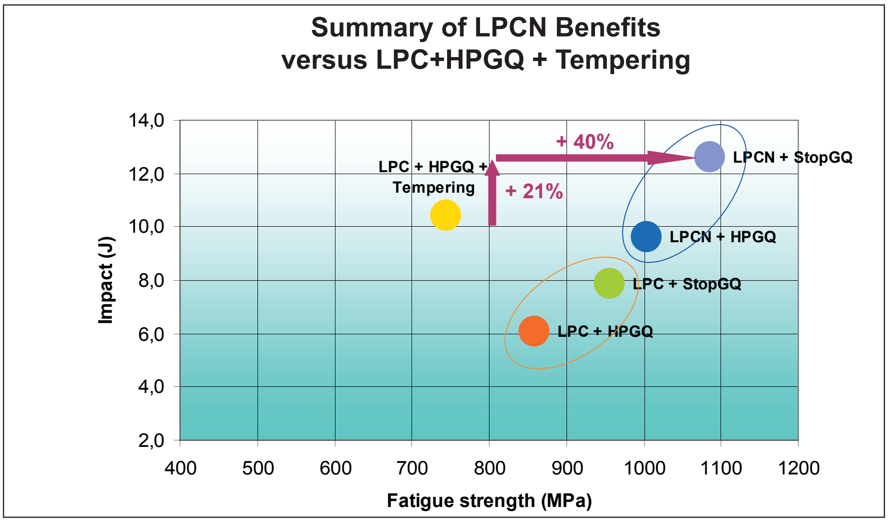


Figure 11c—Summary of LPCN benefits versus LPC+HPGQ +

Dilatometry studies (Fig. 12) showed less contraction with an interrupted quench compared to direct high-pressure gas quenching. During the StopGQ quench, quadratic martensite is transformed into cubic martensite plus ε carbides, resulting in an automatic tempering effect. This was demonstrated by rupture analysis (Fig. 13), which revealed higher ductility in the core of the material processed with LPCN + StopGQ quenching.

Scanning electron microscopy (SEM) analysis at 3,700X comparing LPC and LPCN microstructures found fine precipitates of carbonitrides in the latter, which are believed to have a strong influence on fatigue strength (Fig. 14).

These trials allowed the following conclusions to be reached:

- Conditions were established to predict and control carbon and nitrogen concentration profiles.
- The metallurgical parameters which act on resistance in fatigue inflection of gear teeth for a fixed hardened depth were better understood.
- Results indicate improvements in fatigue resistance of gear teeth compared to low-pressure vacuum carburizing treatments applied to gear boxes.

Future Studies

Future research and development efforts will target further understanding of the role of nitrogen on mechanical properties. Those efforts will include microstructural analysis of grain boundaries to determine if the grain size has been refined. In addition, further optimization of the influence of StopGQ quenching temperature and hold time will be investigated.

Acknowledgment

The author would like to thank Ascometal for their assistance in the testing and evaluation of certain technical results presented in this article.

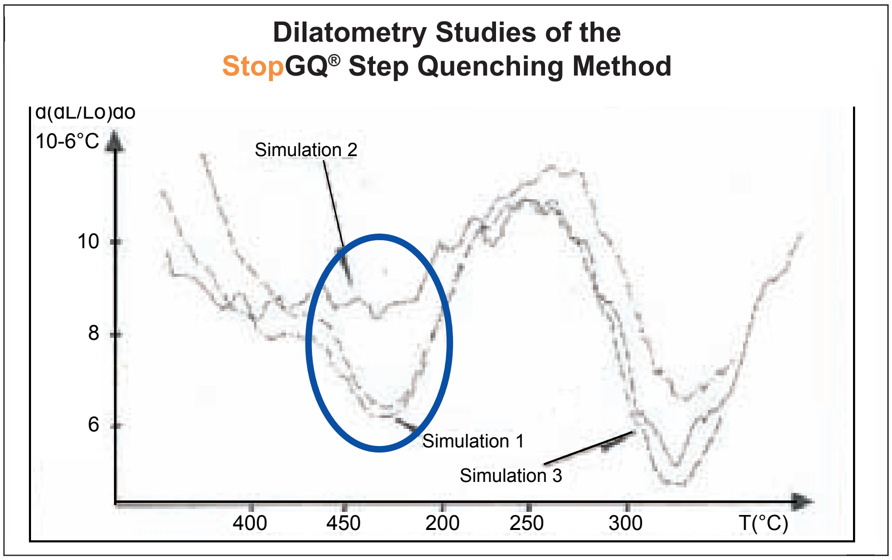


Figure 12—Dilatometry studies of the StopGQ quenching method.

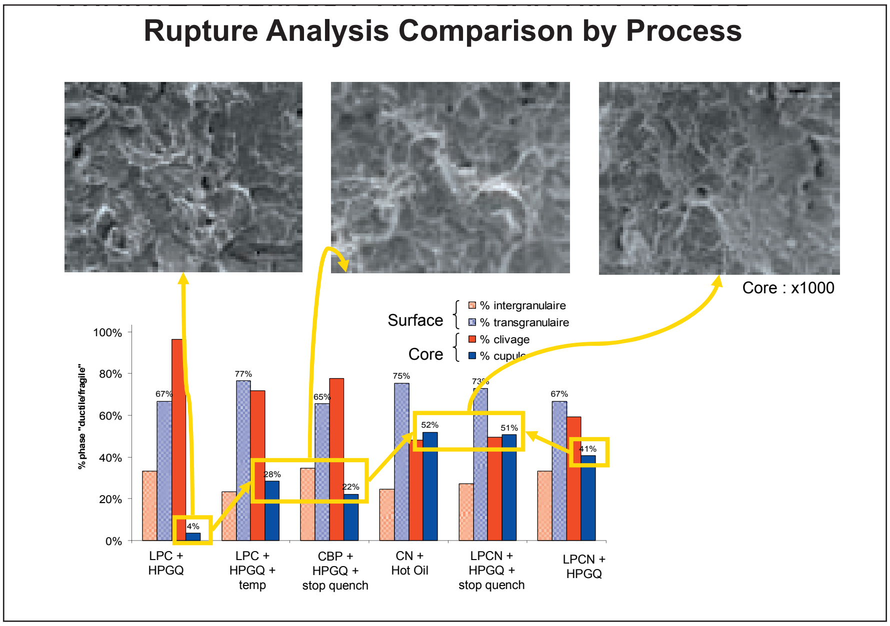


Figure 13—Rupture analysis comparison by process.

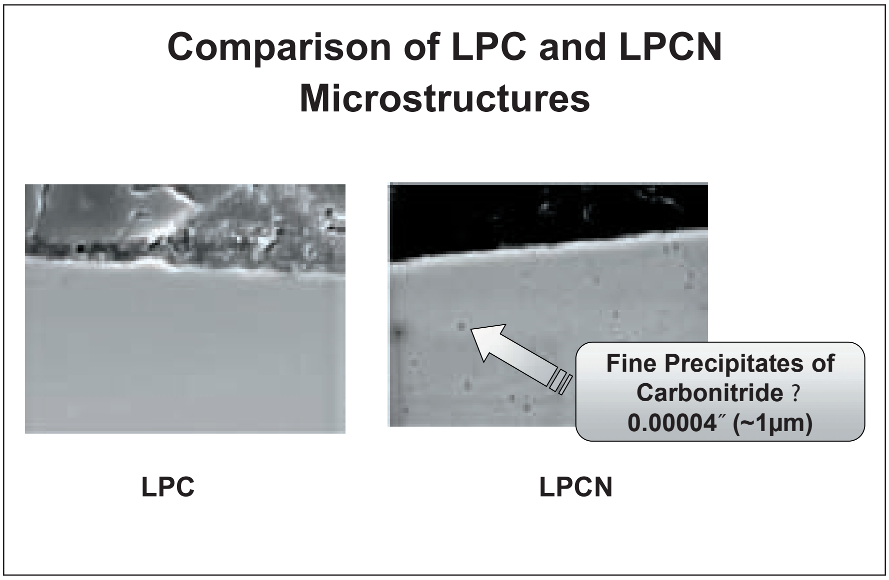
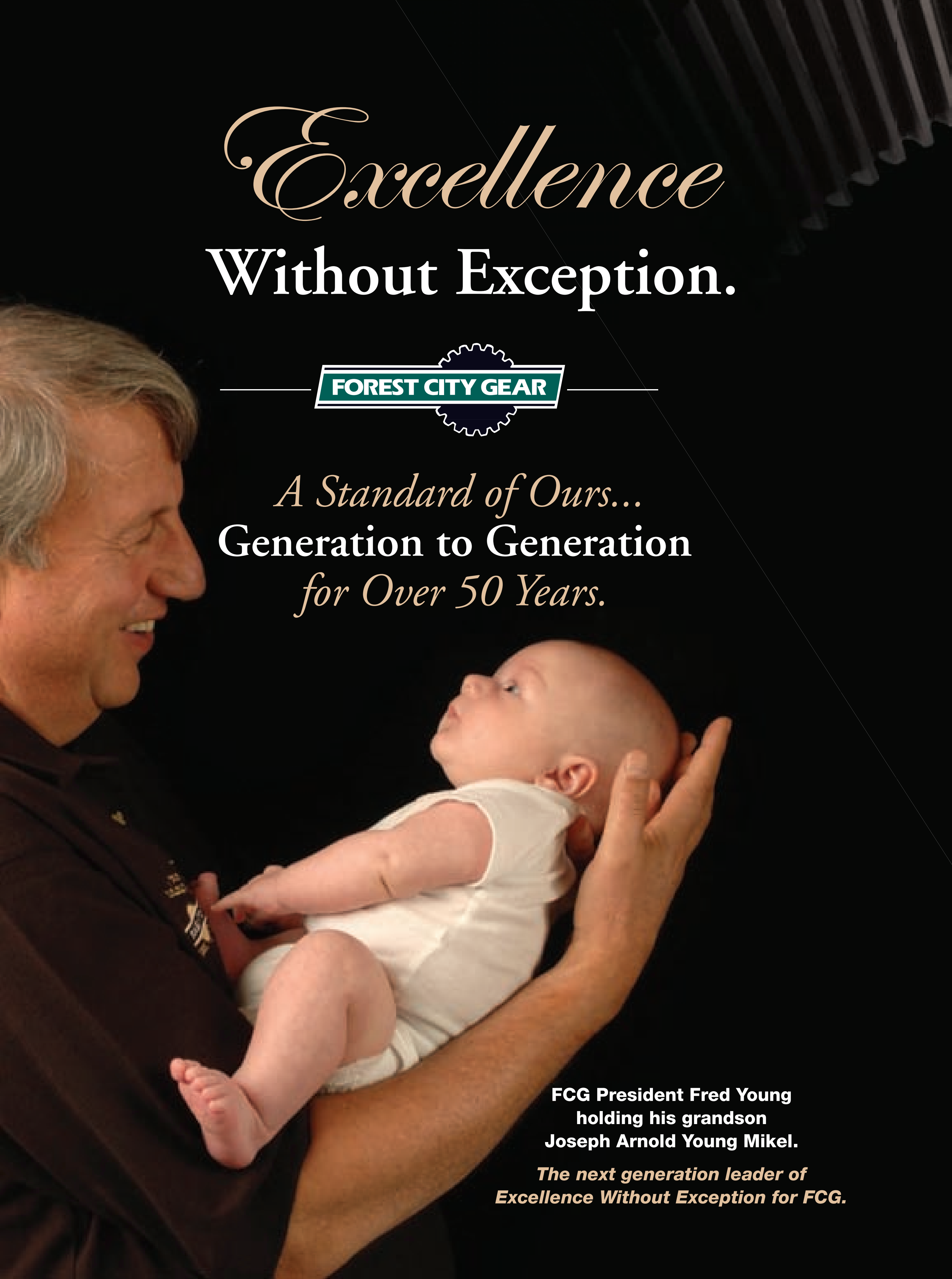


Figure 14—Comparison of LPC and LPCN microstructures.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The Optimal High-Speed Cutting of

Hermann J. Stadtfeld

Management Summary

This article presents a summary of all factors that contribute to efficient and economical high-speed cutting of bevel and hypoid gears. The influence of factors like tool material, tool coating, work gear blank material, tool geometry and speeds and feeds are discussed, and recommendations are given for optimal parameters. A diagram showing graphs that explain the dependencies between cost per part and two- or three-face-coated blades is introduced.

In addition to tool life graphics and typical photos of worn and damaged carbide blades, two possibilities to add material to an existing blade point for increased tool life are shown. This article does not present the solutions for all possible problems of every existing high-speed dry cutting installation, but it gives a guideline that can help find ways to improve and optimize individual cutting scenarios.

Introduction

High-speed carbide dry cutting went through an evolution with respect to speeds and feeds and the kinematic relationship between cutting blade and work, which eventually resulted in many improvements available today. The dependency of many important parameters upon the particular situation of a certain job often makes it difficult for a manufacturing engineer to establish an optimal cutting scenario.

For many years, the question of three-face-sharpened blades versus two-face-sharpened blades has been discussed. However, it never really was a question of how many faces were sharpened, but rather with how much flexibility the geometry of the major surfaces that form the cutting edge could be adjusted to the particular situation of a certain job. The expression "certain job" refers to the cutting method: face hobbing or face milling, generating or non-generating, the basic parameters of the gear set design as well as the blank material and its crystal structure. The second significant aspect of three-face sharpening is the all-around coating that is required if the protecting layer of coating was removed due to the grinding of front face and side relief surfaces.

An analysis of the different parameters and their influence on the performance of the cutting process allows us to establish five, nearly independent areas of attention:

- Blade geometry and placement in the cutter head.
- Cutting edge microgeometry.
- Surface condition of front-face and side-relief surfaces.
- Speeds and feeds in the cutting process.
- Kinematic relationship between tool and work (climb or conventional cutting, vector feed).

The article presents explanations and guidelines for optimal high-speed cutting depending on cutting method, part geometry and manufacturing environment, which also help to choose the right blade system to give the manufacturing engineer detailed information to support the effort of optimizing cutter performance, tool life and part quality.

Cutting Tool Material

The preferred tool material for dry cutting processes is extra-fine-grain carbide. Carbides are cemented, sintered composite materials of tungsten carbide (WC) and one or more metallic binding elements. The best experience in dry cutting of bevel gears occurred in applying K-grade (ISO designation) carbides that only contain the single binding element cobalt (Co). Depending on the cutting depth, it has been found that a cobalt content of 12% shows the best cutting results for larger size gears and a cobalt content of 6% is advantageous for smaller gears. For instance, semi-truck size gears have 350–500 mm ring gear OD, compared to passenger car size gears with 140–260 mm ring gear OD. Between those size ranges, both materials can be used equally well. The lower cobalt content increases the hardness and the wear resistance of the cutting tool, but makes it more brittle, which increases the risk of cutting edge chipping.

The higher cobalt content enhances the toughness of the tool, which reduces the wear resistance. Figure 1 shows two diagrams which indicate fracture toughness and wear resistance as functions of the cobalt contents (Ref. 1). The best compromise for different workpiece materials and jobs from automotive to truck size is evident by a composite of 10% cobalt and 90% tungsten carbide.

The diagrams in Figure 1 show with their different color graphs the influence of the grain size with respect to toughness and wear. The extra-fine-grain sintered structure delivers the best overall performance compared to finer as well as coarser structured materials.

The excellent cutting experience with extra-fine-grain materials is also a result of the high sintering quality with low variation in composite density and a highly homogeneous structure as a result of the sintering process of extra-fine-grain carbide particles.

Bevel Gears

Cutting Tool Coating and Cutting Edge Rounding

The purpose of cutting tool coating in the area of chip forming action is to provide a surface layer with high hardness and low surface roughness. This protects the carbide cutting edge and surroundings from chemical reactions and isolates the basic substrate from the chip flow with respect to wear and temperature.

It seems to be a basically different task to protect the cutting edge of a two-face sharpened blade vs. the cutting edge of a three-face sharpened blade. The three-face sharpening requires an all-around coating, which delivers a cutting edge that is formed by a coated front face, as well as a coated side-relief surface including top relief area and also covering the clearance side surface.

The blade that is only coated on the front face (two-face sharpened blade as shown in Figure 2) has a protection on the front face, where the surface stress from chip forming is the highest, and where the chips are being molded to their final form with a high relative surface speed. The unprotected side relief surface has a continuous sliding contact with the flank surface of the work. The individual parameters of a particular cutting process will make the difference between high contact forces that lead to rapid wear and cutting edge chipping or a result in a negligible side relief wear with an un-chipped appearance of the cutting edge (Ref. 2).

The edge-rounding radius dimension and the micro blend between edge rounding and front face coating are the key parameters to achieve low cutting forces, optimal plasticization and chip shearing action. The optimal edge-rounding radius for today's high-speed dry cutting for only front-face-coated blades lies between 5 μm and 10 μm. Figure 3 shows, on the left side, a device for edge rounding of carbide blades with permanent front face coating. The nylon bristles of a rotating brush contain aluminum oxide. The brush traverses sideways while it is rotating with a circumferential velocity vector that is lined up in the 3–7 mm interference zone between cutting edge and brush with the direction of the cutting edge. The photographs on the right side of Figure 3 show on top the cutting edge before edge rounding, and the photos below show the cutting edge after rounding. The upper section in the photographs with the darker color is the coated front face, the light colored stripe is the cutting edge and the area below is the side relief surface. The influence of edge rounding is evident by the reduced micro craters and the smoother transition between the cutting edge and the coating.

At the beginning of carbide dry cutting operations, the

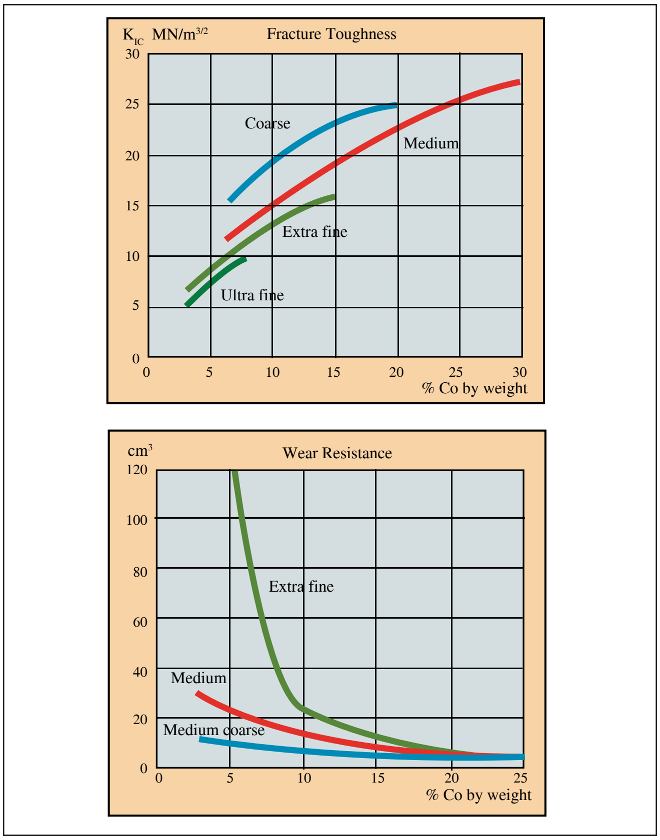

Figure 1—Fracture toughness and wear resistance of carbide.

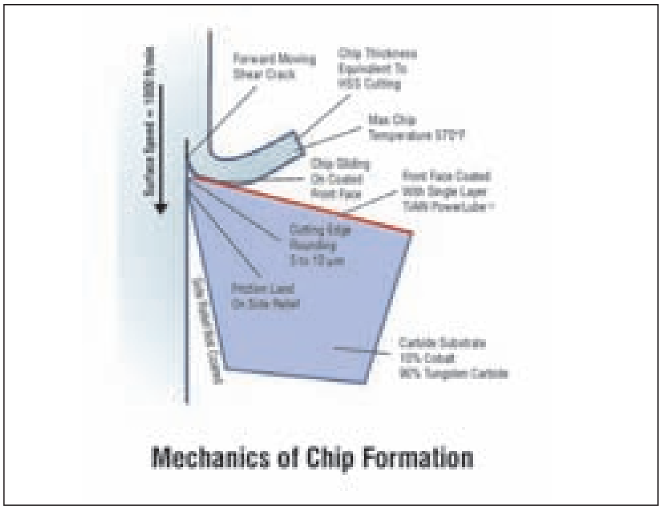

Figure 2—Chip removal mechanics.

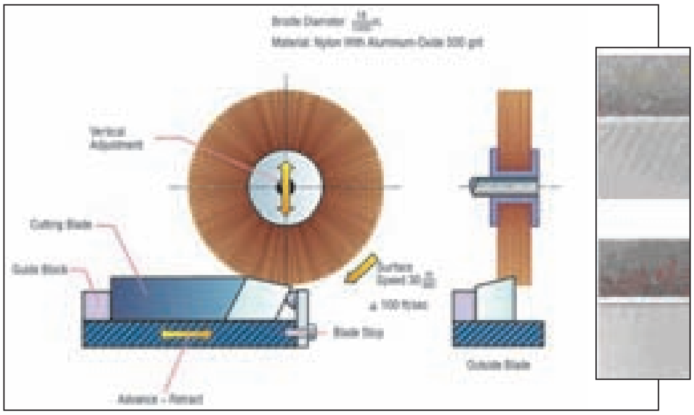

Figure 3—Edge rounding device and cutting edge before and after rounding.

best cutting results were obtained using a TiAlN coating with a composition of 50% Titanium and 50% Aluminum-Nitride.

Both single- and multi-layer coatings were tested in many cutting trials. Today, the commonly used and highest performing coatings are derivatives of a single 10 µm-thick layer of TiAlN with the trade names AlNite® and TiAln-X. The coating table in Figure 4 gives an overview of some physical properties of coatings in use today for chip removing operations (Ref. 1).

Workpiece Material and Structural Treatment

Gears in industrial gear boxes and automotive/truck transmissions are generally manufactured from carburizing steels, which provide a hard and highly durable surface and a core with high toughness after case hardening. Commonly used materials for manufacturing of bevel gears are:

A) AISI 5117 or ISO 16MnCr5 with tensile strength 600 N/mm2

B) AISI 3215 or ISO 18CrNiMo6 with tensile strength 800 N/mm2

C) AISI 4119 or ISO 20MoCr4 with tensile strength 700 N/mm2

AISI 5117 provides best machinability and behaves well during heat treat and quenching with respect to distortion, internal stresses and the mechanical properties of surface and core.

AISI 3215 delivers high core hardness after heat treatment (above 40 HRC), is sensitive to heat treat distortions and is critical with respect to tool life.

AISI 4119 cannot provide the same high mechanical properties as AISI 3215, but shows better machinibility. It is often used as a compromise between AISI 5117 and AISI 3215.

Manufacturing of small batch production is mostly done from bar stock material. In a mass production environment, the blank material is forged to a shape that approximates the turned blank contour closely with a decent stock allowance. In both cases, the steel structure is not optimal with respect to machinability and should be annealed or normalized.

The photographs in Figure 5 show the structure of a forged blank after etching with nitric acid with a magnification of 200x. The left photograph in Figure 5 shows a coarse structure from ferrite with little but concentrated grain borders of pearlite and graphite.

Although the structure will change during the case hardening and quenching process to provide the desired properties of the finished gear, turning and cutting of the soft material according to the left photo in Figure 5 will deliver medium to low tool life.

	TiN	TiCN	AlNite®	AlNite® -X TiAIN-X	TiAIN X.CEED	TiAIN +WC/C	AlCrN	nACo
	Balzers BALINIT® A	Balzers BALINIT® B	Balzers BALINIT® Futura Nano	Balzers BALINIT® E.TREME	Balzers BALINIT® X.CEED	Balzers BALINIT® HARDLUBE	Balzers BALINIT® ALCRONA	Plat it
Hardness (HV .05)	2300	3000	3300	3500	3300	3000	3200	4590
Coefficient of Friction (against steel, dry)	0.4	0.4	0.30-0.35	0.4	0.4	0.15-0.2	0.35	0.45
Maximum Service Temp	600 C 1112F	400 C 752 F	900 C 1652 F	800 C 1472 F	900 C 1652 F	800 C 1472 F	1100 C 2012 F	1200 C 2192 F
Coating Color	Gold	Blue-Grey	Violet-Grey	Violet-Grey	Blue-Grey	Dark Grey	Blue-Grey	Violet-Blue
Coating Structure	Mono layer	Multi-layer	Nano	Mono-layer	Mono-layer	Multi-layer	Mono-layer	Nano

Figure 4—Table with commonly used physical vapor deposition (PVD) coating types.

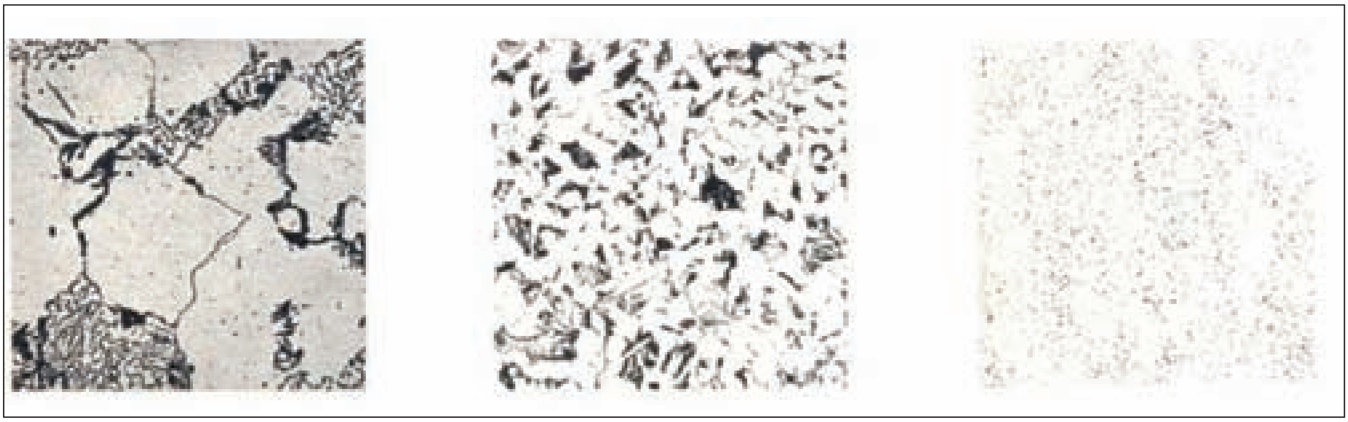

Figure 5—Steel structure of a forged blank (left), after normalizing (center) and after annealing (right).

For optimal cutting performance with respect to surface finish and tool life for both high-speed steel wet cutting or carbide dry cutting, it is recommended to change the structure to a more homogeneous appearance with a smaller ferrite grain size. The result of normalizing is shown in the center of Figure 5. The right side photograph shows the fine structure after annealing the forged material. Forming a chip means generating a crack through the structures shown in the three photos. Such a crack will follow the softer graphite, which is between the hard ferrite particles. It is obvious that, in case of a very coarse structure, the cutting edges frequently hit large ferrite particles. In some cases, this splits the ferrite but more likely will move the large ferrite particles out of its way, which causes extensive wear of the cutting edge and results in a rough surface finish. An extremely fine structure will cause edge build-up and tearing with a scuffed-appearing surface finish.

Optimal for dry high-speed machining with carbide is a structure between the center and right-hand-side photo (Figure 5).

Feeds and Speeds

The original surface speed recommendation of 330 m/min for high-speed carbide bevel gear cutting came from cylindrical gear hobbing with carbide hobs. At the beginning of high-speed bevel gear cutting, it became evident that the chip thickness has to exceed a certain minimum value to reduce cutting edge chipping and abrasive wear on the side relief surface. In other words, it was not only possible to use large chip thicknesses in high-speed bevel gear cutting but it proved to be required in order to achieve good and consistent tool life. Figure 6 shows the dependency between chip thickness, surface speed and tool wear as a qualitative diagram. A medium chip thickness, which is equivalent to an average end chip of 0.08 mm (automotive size parts), delivers the best results from medium to high surface speeds. Low surface speeds cause edge build-up and high surface speeds result in excessive side relief wear. An optimal surface speed is found as the optimum between lowest wear and short cutting times between 250 and 300 m/min.

There are certain cutting conditions to consider that basically differ from each other. At the beginning of a non-generated plunge cut, only the blade tips are exposed to a cutting action. As the plunging proceeds, the cutting edges perform more and more chip removal until the end of the plunge cycle, when the chip load is the highest. The tips of the blades are cutting material from the first contact between cutter and part until the end of the cycle. As the tool feeds into the material of the blank, the tip is of course first and will take chips during the entire plunge process. In the case of a 10 mm tooth depth, this means the tip is involved in taking chips for the entire 10 mm. If the cutting section of the blade is 10 mm tall, then the section in the example given that is 9 mm away from the tip (toward the cutter body) will only be in cutting contact the last 10% of the cutting and therefore experience less wear.

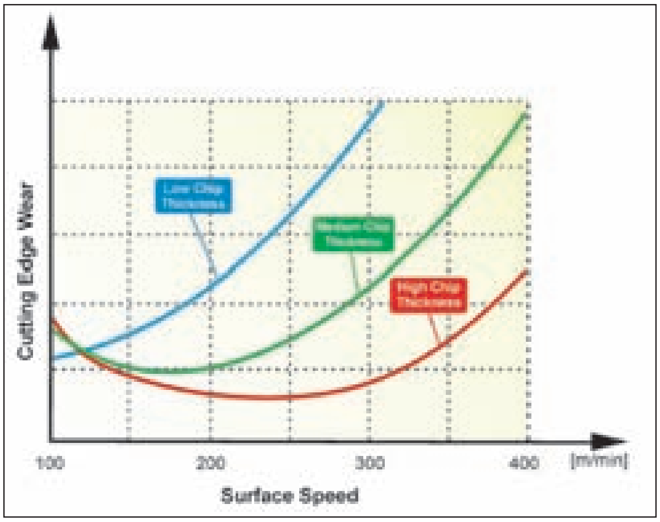

Figure 6—Tool wear as a function of chip thickness and surface speed.

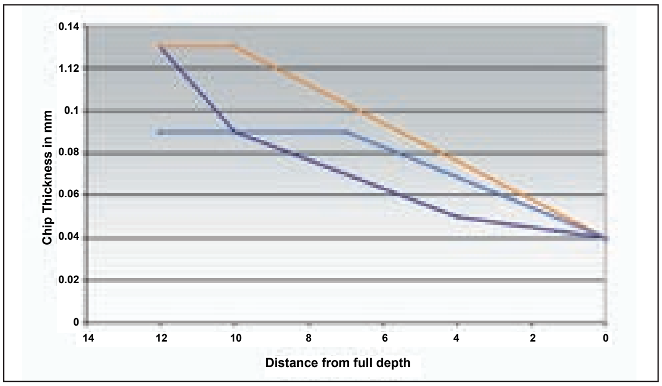

Figure 7—Single ramp for optimal chip load.

The requirement from a cutting cycle is to protect the blade tips from chipping and wear and minimize a blade pressure angle change that is caused by the difference in time that the different sections of the cutting edges have in contact with the slot they cut. The single ramp, shown in Figure 7 (orange graph), is the result of many cutting trials and parameter studies that have been conducted to optimize cutting performance. The proportionally reduced plunge feed rate while the full depth position is being approached (abscissa) leads as a result to a constant or slightly increasing chip load. The third cutting condition is the "dwell" on the end of the cycle.

In face milling, the cutter has to make one additional revolution at the end of the plunge. This assures that the widest or tallest blade has the possibility to take a last small chip to achieve consistent flank form, from slot to slot and also to reduce the spacing error. The dwell time is calculated to be just 5% longer than required for one revolution. The fact that some blades will take a small chip during the dwell rotation and others may only rub along the flank surface is very negative for the tool life. It is recommended, depending on the face width, to reduce the dwell time to the lowest value that assures that every cutter blade passes one additional time through the slot, after the plunge feed motion comes to a halt.

In face hobbing, the dwell time is calculated as the hunt-

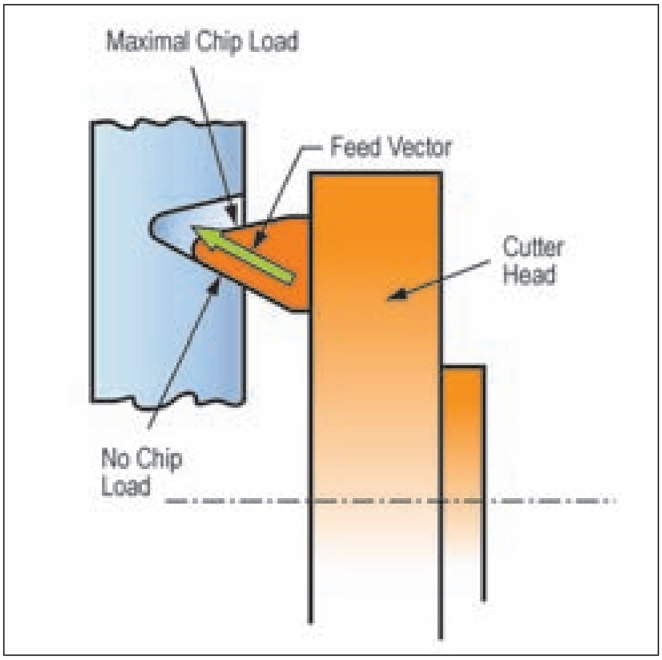

Figure 8—Extreme vector feed.

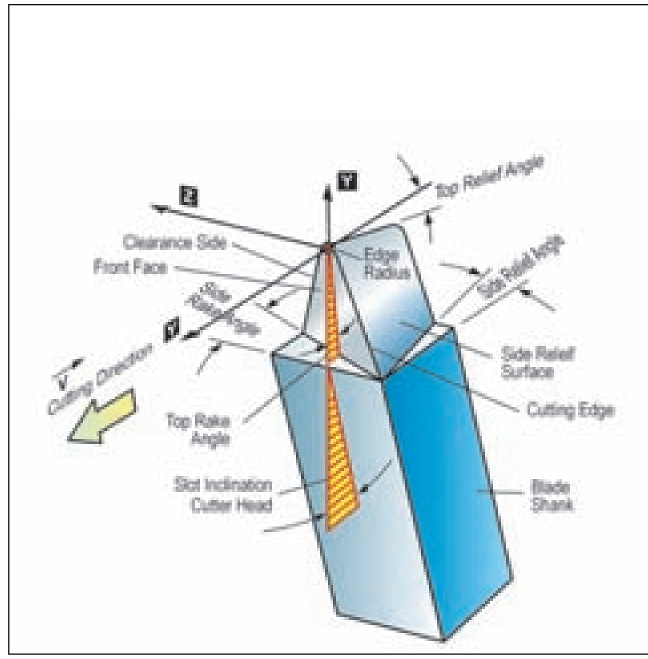

Figure 9—Blade angles and blade nomenclature.

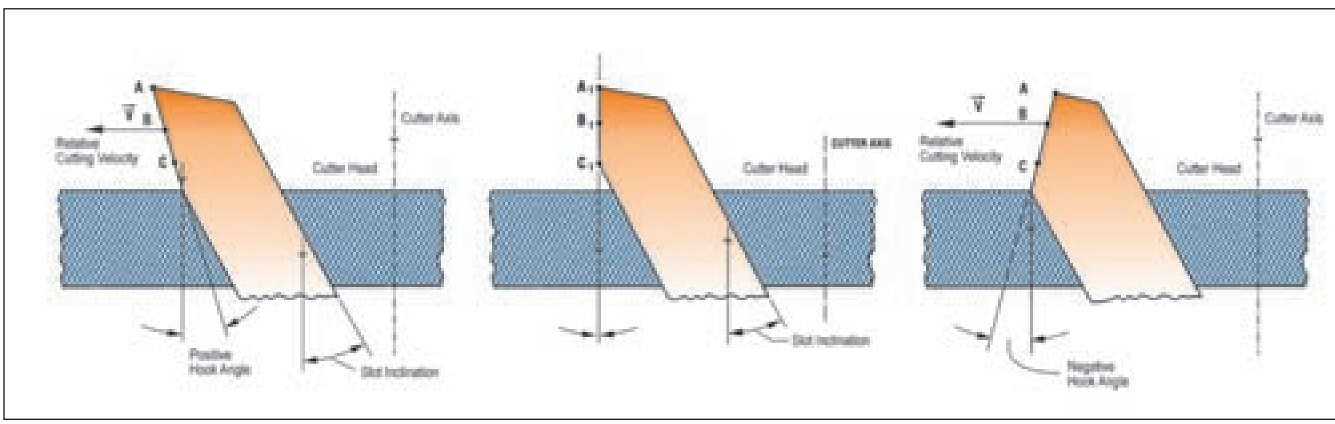

Figure 10—Blade hook angles.

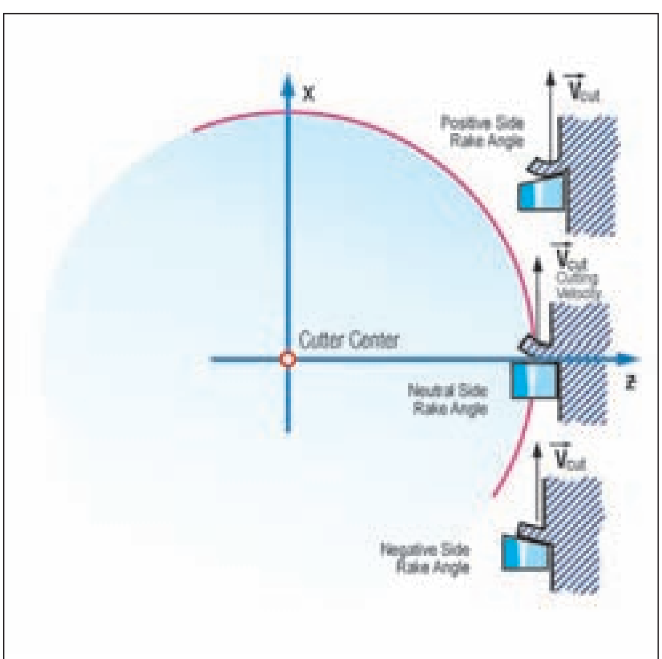

Figure 11—Blade side rake angles.

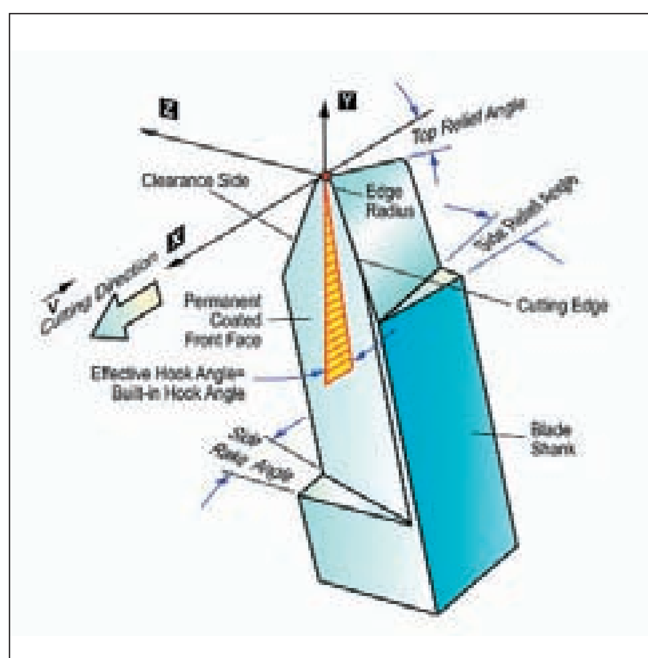

Figure 12—Blade with permanent-coated front face.

ing between cutter and work. If the work has 37 teeth, then the cutter is required to make 37 additional revolutions after reaching the full depth position. This assures that every blade is sent through every slot before the cutter withdraws and the cycle ends. Similar to face milling, the dwell in face hobbing provides better spacing and more consistent flank forms.

Balancing cutting edge wear between inside and outside blades is a very desirable technique to extend the tool life of a cutter head. In many cases, the inside blade experiences significantly more wear than the outside blade, e.g., for the plunge cutting of non-generated ring gears. A very effective plunge cycle modification is the use of a plunge feed vector, which is oriented as profile tangent of the inside flank. The principle of the so-called extreme vector feed is shown is Figure 8. It is possible in cases of high inside blade wear to balance the wear between inside and outside blade, which can in some cases double the tool life.

Optimal Tool Geometry

Angles like side rake and effective hook angle are the primary technological angles that influence the chip formation process. The relief angles like side relief angle and top relief angle are secondary technological angles that have an influence on the wear mechanism only (Fig. 9). The technological angles do not influence the tooth geometry and can be used for the optimization of the cutting process (Ref. 3).

In three-face sharpening, all three blade surfaces that form the cutting edge, the tip and the secondary cutting edge at the clearance side are ground for blade sharpening. Since the coating is removed from all cutting edge forming surfaces, a coating after three-face sharpening is required. In such a case, the advantages due to the freedom of defining all technological angles optimal for every individual job are superimposed with the positive influence of the all-around coating, which will subsequently occur if only the blade shank is masked to avoid multiple layers of coating from changing the blade shank dimensions.

This has to be compared to a two-face sharpening. Here the front face keeps its permanent coating during the entire life of a blade stick. The re-occurring cost of the coating as a consequence of three-face sharpening—as well as the shipping, handling and elapsed time—generate additional costs that have to be justified by higher tool life and a more economical cutting process.

It is possible to optimize all technological blade angles in a three-face sharpening process and then try to match the same blade geometry with permanent, front- face-coated blades. This presents three basically different types of blades:

Blade Type 1—Three-face-sharpened and all-around-coated with optimal angles.

Blade Type 2—Two-face-sharpened, front-face-coated with standard rake and hook angle.

Blade Type 3—Two-face-sharpened, front-face-coated with optimal angles.

The blade hook angle, as shown in Figure 10 in the left diagram, forms a sharp cutting edge around the tip of a blade. For high-speed steel cutting, this was desired. A neutral rake angle for the tip, as shown in the middle diagram of Figure 10, was the limit of an allowable hook angle for high-speed steel cutting. For permanent-coated front faces, the effective hook angle results from the "interaction" of side rake angle and blade pressure angle. This leads to the definition of the cutter head slot hook angle such that, within the variety of expected blade pressure angles, the effective hook never became negative. The slot hook angle is 4.42° in face hobbing cutters and 7.42° in face milling cutters as they are defined for PENTAC® cutters.

For a high-speed carbide cutting environment, the hook angles of high-speed steel cutting appear too high. The hook angle makes the tip of the blades more or less sharp. In the case of high-speed cutting with carbide blades, chips are formed with a high kinetic energy.

Plasticization of steel to form chips with a high content of kinetic energy in the process requires less sharp cutting edges then conventional high-speed steel cutting. A situation between the center and right-side graphic in Figure 10 delivers the best tool life results. The three-face sharpening enables finding an individual optimum for every job.

The side rake angle of 12° in pre-raked blades was based on the experience with high-speed steel cutting. Carbide high-speed cutting requires a lower side rake angle. Here the optimum can be found between Figure 11's center and bottom sections, depending on workpiece material and job-specific parameters.

Most cutting experience with three-face-sharpened blades pinpoints an optimal side rake angle between 3° and 6° and an effective cutting edge hook angle between 0° and 4° (the positive angle corresponds to Figure 10, left-hand side). It is proposed in this article to develop cutter heads with a 4-5°, built-in slot hook angle and to use pre-raked blades with a side rake angle of 4-5° to establish Blade Type 3 as a true alternative to three-face-sharpened blades (Type 1). The pre-raked blade design in Figure 12 can be mounted in a cutter head with a 4° slot hook angle to represent Blade Type 3.

A full cost calculation for a representative automotive job delivers about $20 for the refurbishing of one three-face-sharpened blade and $10 for a two-face-sharpened blade.

Those calculations also considered cutter building and re-qualification of the first part. Figure 13 shows that, in cases when the two-face-sharpened blade has only half the tool life of the three-face-sharpened blade, then the tool cost per part breaks even. In case of a "two-face" tool life of only 10% compared to the "three-face" tool life, the tool cost per part of the two-face ground blade is 10 times higher than that of the three-face-ground blade.

This estimation seems to be very realistic with respect to comparisons that have been made in the automotive industry (Ref. 4).

The blade and cutter geometry proposed in this paper was the basis for cutting trials with front-face-coated blades which corresponded to Blade Type 3. The cutting trials showed tool lives that were between 40–60% of the "three-face" tool life.

The conclusion therefore is that the tool costs per part for Blade Type 3 are about identical to the tool costs of Blade Type 2. Blade Type 1 is therefore only advantageous if a specific production environment rewards the avoidance of blade sharpening and cutter building. This also explains why, in many cases of mass production, Blade Type 1 is the preferred choice.

Tool life results from conventional high-speed steel wet cutting, together with results from carbide wet and dry cutting dating back to the early days of Powercutting and the latest cutting results from blades that consisted of Style 1 and Style 3, were compiled to create the graphs in Figure 14.

The pull point of the cutter head was defined as the number of parts cut when the wear land on the side relief surface exceeded a width of 0.25 mm. Only the point on the end of the tool life was transferred from the cutting trials to the diagram of Figure 14. The rest of the graph is only of qualitative nature and is not based on measurements.

The green graph in Figure 14 corresponds to blades of Type 2 (pre-raked blade with 12° side rake in a cutter head with standard built-in hook angle). The red graph in Figure 14 results from blades of Type 3 (optimized 4° side rake angle in a prototype cutter head with 4° built-in hook angle). State-of-the-art cutting with three-face-sharpened and all-around-coated blades (Blade Type 1) resulted in the black graph in Figure 14. All graphs in Figure 14 are based on cutting results of automotive size ring gears.

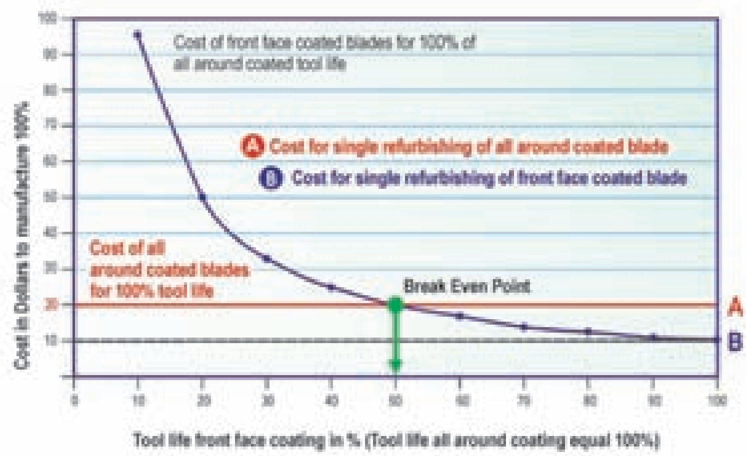

Figure 13—Tool cost per part of all-around-coated and front-face-coated blades.

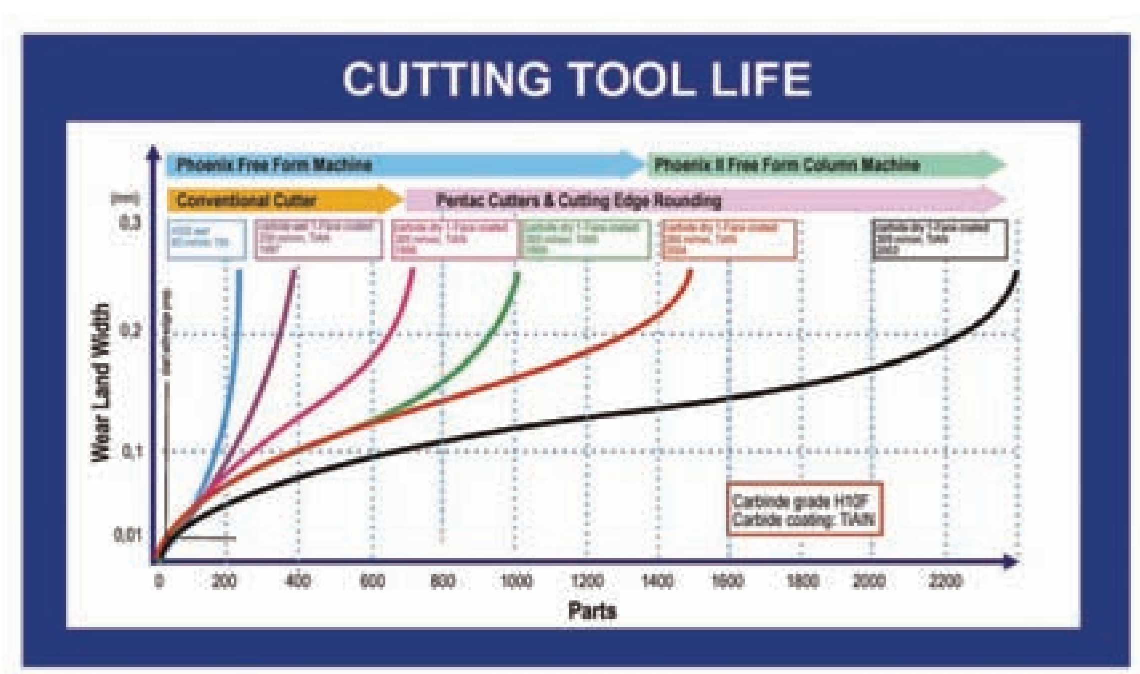

Figure 14—Tool wear as a function of chip thickness and surface speed.

Increase of Blade Point

The tips of the blades are rather sensitive parts of cutting blades. A relatively small volume of carbide material forms a considerable portion of the blade cutting edge. During a plunge cutting process of a gear, the blade tips are in contact with the workpiece material during 100% of the cutting time. The cutting edge length between the reference point and the end of a blade edge is only in contact with the work piece about 50% of the cutting time. In other words, the small blade tip area has the most cutting contact of the entire cutting edge. This also shows some potential area of improvement if it is possible to increase the ratio of (carbide volume) / (removed chip length) e.g., by increasing the blade point.

The difference between point width and blade point (Fig. 15) is the clearance between the clearance side blade edge and the material of the slot that was cut by the opposite blade (Fig. 16). To avoid chip dragging and scuffed or scratched surfaces as well as possible contact of the clearance side blade edge with the workpiece material in the slot, the clearance value needs to be 0.3 mm or larger. Subtracting a value of 0.3 mm or more from the point width delivers therefore the blade point. Optimal tool life can be expected only when a blade point is above 0.8 mm. If a blade point is below 0.8 mm, it is recommended to change the basic geometry of the job or the split between gear and pinion blade point in case only one of the two exceeds the critical width of 0.8 mm.

Besides an unacceptable tool life, the small blade point will not allow a large enough edge radius in order to form an optimal strength root fillet. This also leads to a degradation of the fillet radii as well as a degradation of the surface

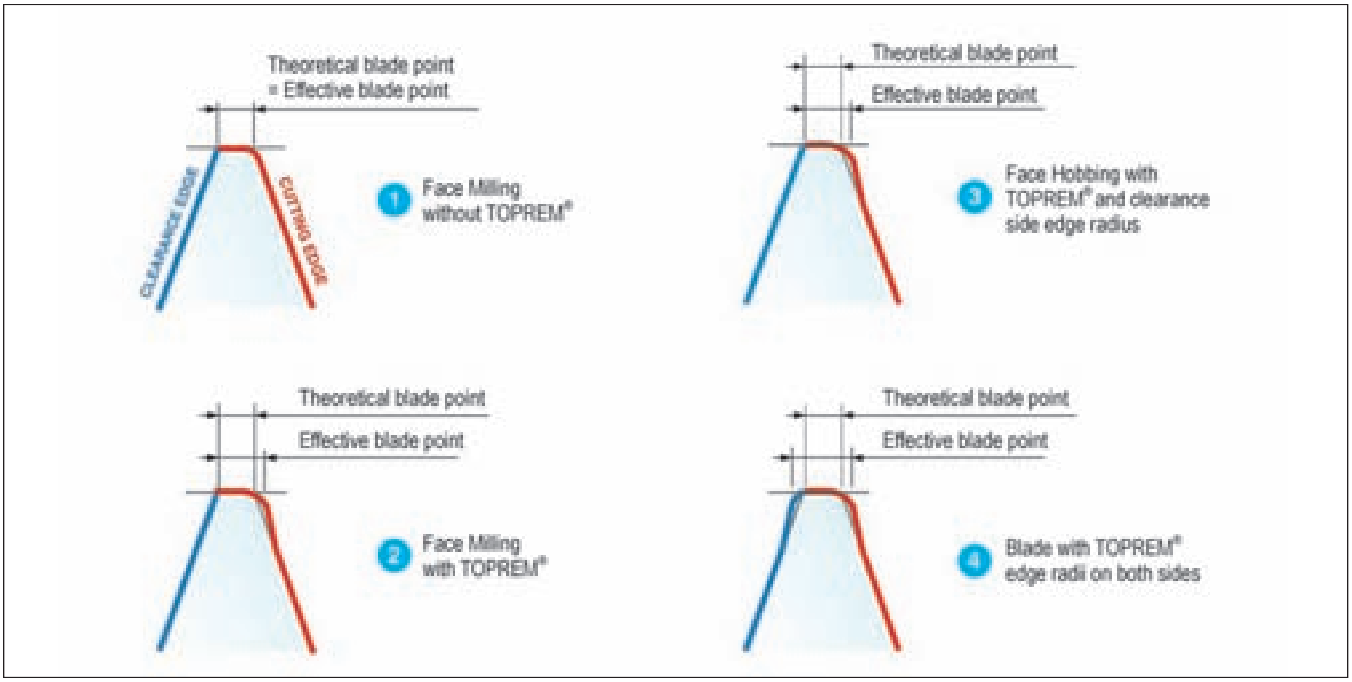

Figure 15—Artificial increase of blade point.

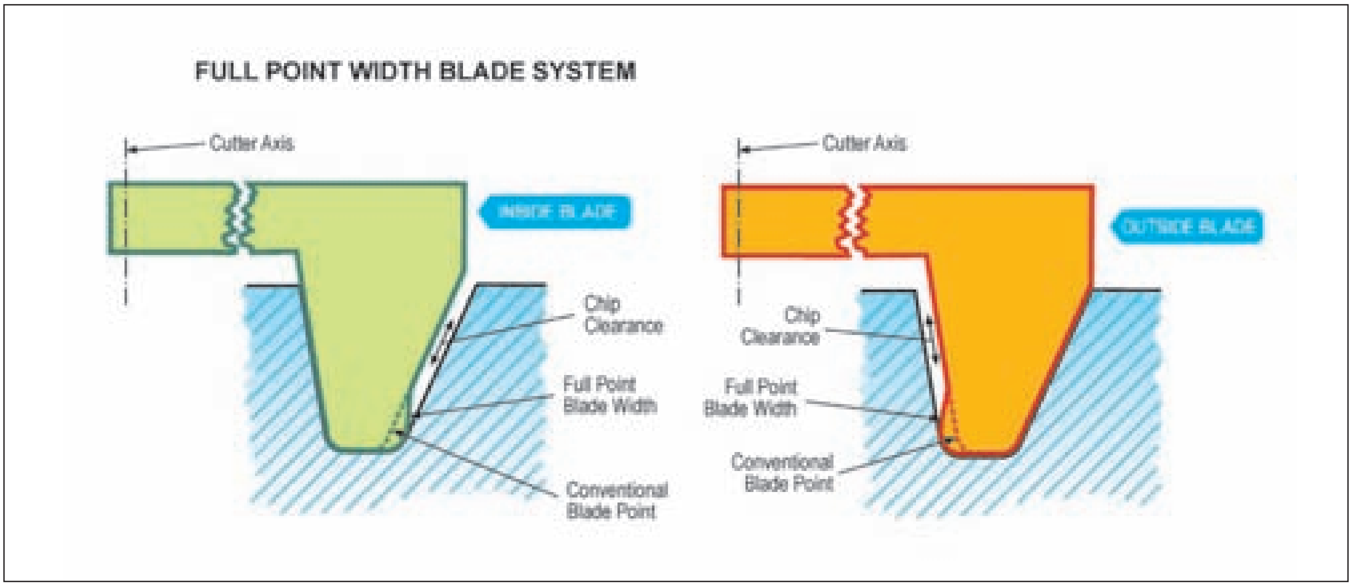

Figure 16—Full-point-width blades.

roughness in the root.

An "artificial" increase of the blade point width is possible if protuberance (TOPREM®) is used on the cutting edge and on the clearance side blade edge. The cutting edges in a face hobbing process should prepare the flank surface for the final lapping. Also, for the face-hobbed gears, a small amount of protuberance is recommended for optimized, modern developments. In most cases, when the cutting is conducted in face milling, the following hard finishing operation is grinding (which makes the soft cutting a semi-finishing process). Semi-finishing operations of pinions and gears have to be performed with blades that include an amount of protuberance that relieves at least 50% of the stock allowance in the root area. In all cases of face hobbing and face milling, protuberance zones in the blades are recommended if a material-removing hard finishing operation follows the heat treatment. This in turn justifies the application of protuberance in the blade clearance side edges. The rule is to use on the clearance side of every blade style the exact same amount of protuberance (angle and depth) that is used on the cutting edge of the opposite member (OB <-> IB) to achieve an equidistant clearance along the entire depth of the blade clearance side and yet get the largest possible effective blade point (see Figure 15, steps 1 to 4).

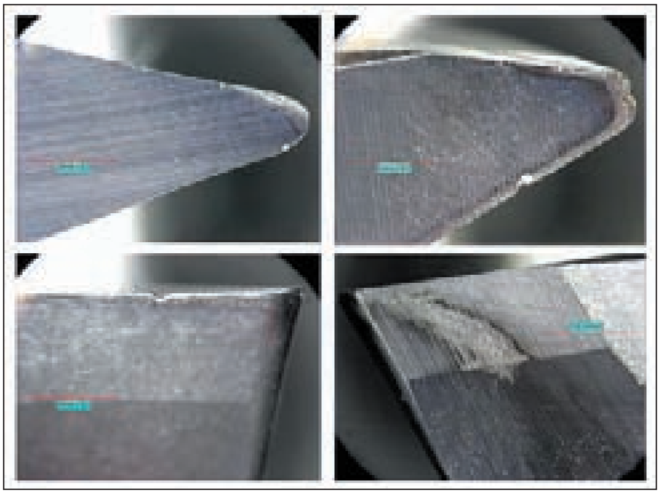

Figure 17—Different face coated blades at the end of tool life.

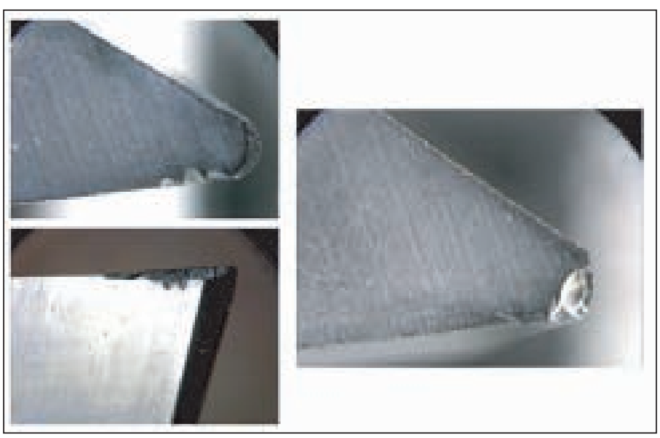

Figure 18—Blade chipping and cratering wear.

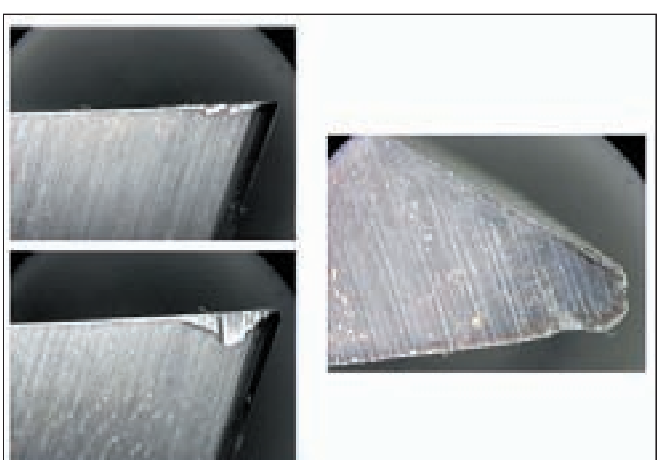

Figure 19—Abrasive wear on side relief surfaces.

Another possibility to increase the blade point is called the "full point width blade system." The blade tip geometry of this system fills out the entire reference profile. A schematic example of an inside and an outside blade is shown in Figure 16. This system was not only developed to achieve the largest possible blade point, but it realizes the idea of additional cutting action and better utilization of the blade tip region, which in most cases defined the end of a tool life because of its excessive wear. Figure 16 shows that the inside blade has cutting contact on the inside cutting edge, the inside edge radius, the flat tip region and along the entire clearance side radius, which is now also part of the active cutting process. The compound angle between side rake and hook (see also Figure 9) will provide the optimal angles only for the primary edge radius on the cutting side. The clearance side radius has the identical hook angle but is left with a non-optimal negative side rake angle. This negative side rake angle has no influence on the end chips at the bottom of the slot. The influence of the negative side rake angle is the largest where the radius begins to back away from the material to provide the chip clearance. If the full point width clearance radius is designed such that it starts to back away from the clearance side root radius at the root bottom (which is basically produced by the cutting edge radius of the opposite blade), then this newly created semi-active part of the blade works as a roughing section that prepares the clearance side root for the finishing action of the following blade. The "full point width blade system" can achieve a determined roughing-finishing split between the radii of the opposite blades. It can achieve a tremendous increase of tool life because of the consolidation of three positive effects:

- Maximum blade point for rugged and durable blade tip.
- True roughing and finishing action in tool-life-limit ing blade region.
- Consistently high root surface finish (often used as cutter pull criterion).

Typical Blade Wear

The typical "healthy" wear pattern of carbide blades is a wear land on the side relief surface as shown in Figure 17, bottom left. The small chip crater on the cutting edge did not lead to an early failure of the blade. Figure 17 shows different blades at the end of their tool life. The upper-left photo shows an abrasive wear on the front face. The upper-right photo shows abrasive wear on the top relief at the tip and a chip on the cutting edge, which most likely was caused by the blade handling. The discoloration around the cutting edge is mostly due to the abrasive removal of the decorative top layer of the coating.

The lower-right photo in Figure 17 shows a clearance side relief surface with chip scratches. This indicates that the side relief angle is too small and/or the chip clearance (see Figure 16) is not large enough. The lower two photographs in Figure 17 also show the separation of the relief surfaces in primary and secondary land. The primary land is between 1 and 2 mm wide and represents the finishing surface. The secondary land extends over the remaining side relief with a larger relief angle. The secondary land is rough ground only. It is particularly recommended to split the side relief surfaces in primary and secondary lands.

Figure 18 shows two blades at the left side with cutting-edge chipping, which could be caused by unacceptable cutting vibrations or initial micro chipping after blade sharpening and insufficient edge rounding. A blade with cratering wear is shown at the right side of Figure 18. This wear could be caused by insufficient coating protection or too high cutting surface speed.

Figure 19 shows some blades that failed due to abrasive side relief wear, which can be caused by too high cutting surface speed and too low side relief angle.

Optimal Refurbishing of Carbide Blades

The blade photos in Figure 20 show a grinding result of permanent front-face-coated blades. The surface finish of the cutting edge side relief is high and the transitions between cutting edge and edge radius are smooth. The clearance side edge radius is very small, which is not considered optimal. Surface roughness or waviness in a clearance side relief surface, as shown in the right-side photo of Figure 20, is acceptable.

To achieve optimal cutting conditions and good tool life, a number of rules have been established that can be used to judge and improve the blade-sharpening process.

- Split side relief surface in primary and secondary land.
- Primary side relief between 10 and 16°.
- Side relief angle of secondary relief surface 6°.
- Grinding direction from cutting edge into side relief.
- High surface finish without waviness (Rz = 0.4–0.6μm).
- Transitions between edge radius, protuberance and cut ting edge very smooth.
- Use roughing and finishing cycle for better transitions, higher accuracy, better surface finish and lesser risk of thermal damage.
- Sufficient grinding depth to remove destroyed carbide structure below the surface (0.3–0.8mm in shaft direc tion).
- Use grinding oils that prevent cobalt leaching.
- Avoid thermal damage.
- Possibly demagnetize blades after sharpening.
- Cutting edge rounding 5–10 μm for Blade Type 2 and 3.
- Use lowest possible blade stick out in cutter head.

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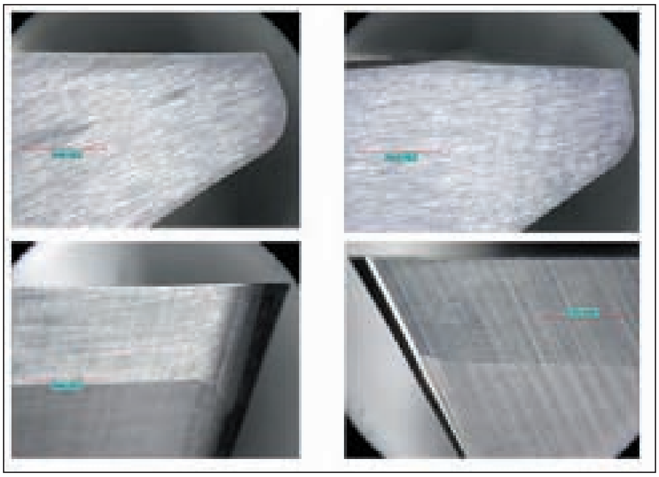

Figure 20—Carbide blades after sharpening.

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THE "TRUE" BENDING STRESS in SPUR GEARS

Edoardo Conrado and Piermaria Davoli

Management Summary

It is well known from the literature that the true bending stresses at the tooth root of spur gears are quite different from the nominal values that are utilized for the calculation of load capacity, either by standards or usual design rules.

No problems arise in using a load capacity rating when the simplified values are compared with the results of bending fatigue tests whose limits are calculated with the same schematic method.

But the "true" stress at the tooth root has different trends and values, and the designer must be aware of this difference, especially for light gears with narrow ribs and rims.

In this paper, an accurate FEM analysis has been done of the "true" stress at tooth root of spur gears in the function of the gear geometry. The obtained results confirm the importance of these differences.

Table 1- Synthesis of the cases analyzed for the full-body and the thin-rimmed gear.

	Full-Body Gears	Thin-Rimmed Gears
Model	Single Gear	Gear Pair
Load	Pinion	Pinion
Body Gear Structure	Full Rim	Rim Supported by a Web
Geometric Parameters	Module m=4.5 mm Face width b = 5, 10, 15, 20, 30 40, 50, 70, 100 mm and Plane Strain Condition.	Module m=4.5 mm Face width b=20 mm Backup ratio r = 0.5 - 0.65 - 0.75 Web ratio w = 0.2 - 0.3 - 0.4
Gear Data For Pinion		
Normal Module	m_n	
Number of Teeth	z	
Normal Pressure Angle	α_n	
Tip Diameter	d_a	
Root Diameter	d_R	
Profile Shift Coefficient	x	
Span Measurement	W	
Number of Teeth Spanned	k	
Operating Center Distance	a_w	
Tool Geometry		
Tool Normal Tooth Thickness	S_{n0}	
Tool Addendum	h_{a0}	
Tool Addendum	ρ_{a0}	
Tool Protuberance	δ_{a0}	

Introduction

In today's gear industry, designers typically utilize rating methods of gear load capacity based on standards or the customary design rules. In these methods, nominal quantities are calculated in order to characterize the stress field in the gear. These nominal quantities are compared with limit values derived from tests using gears as specimens.

In the case of tooth bending strength, a cantilever-beam model is generally used to compute the bending stress. With this approach, Lewis in 1892 first calculated the tooth root stress of spur gear teeth (W. Lewis, "Investigation of the Strength of Gear Teeth," *Proceedings of Engineers Club,* Philadelphia). This model is still the basis for standard calculation methods successfully used in gear design. However, the local stress state—the "true" stress—in the tooth root fillet may be different from the nominal values obtained by this method.

In truth, the calculation of the maximum tensile stress at the tooth root is a three-dimensional problem: The plane strain or plane stress model can be used without approximations only in the case of infinite, or infinitesimal, face width. In Reference 1, starting from the analytical solution of Jaramillo (Ref. 2), Wellauer and Seireg introduced a study of the bending stress of gear teeth based on a cantilever-plate model. This method shows clearly that a three-dimensional model must be used to evaluate the variation of the tooth root stress along the face width. Current numerical methods, FEM and BEM, for example, are available for the solution of the elasticity problem for complex domains. Thus it is possible to calculate accurately the local strain and stress state in the tooth root, taking into account the real geometry of both gear

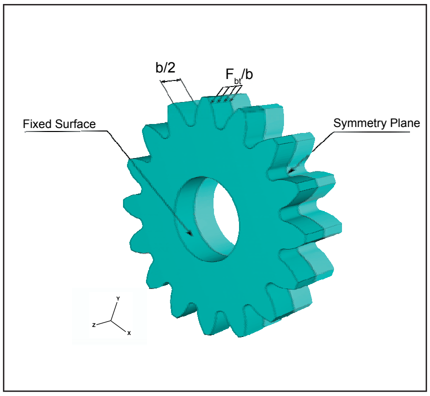

Figure 1—Geometric model and boundary conditions: Full-body gear.

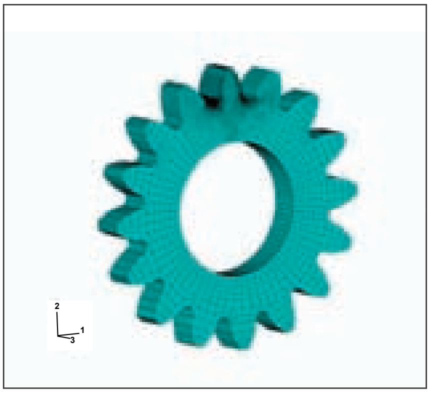

Figure 2—Finite Element Model: Full-body gear.

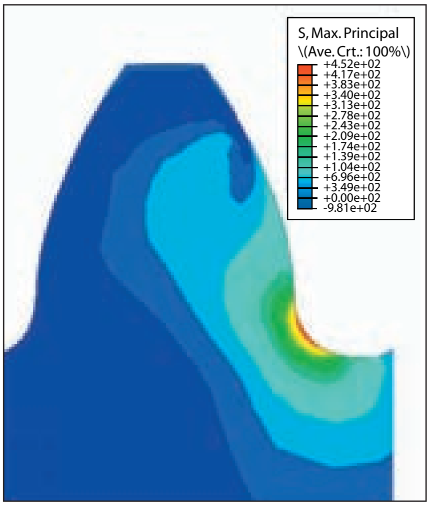

Figure 3—Maximum principal stress contour plot in the middle cross-section: Full-body gear with *b* = 20 mm.

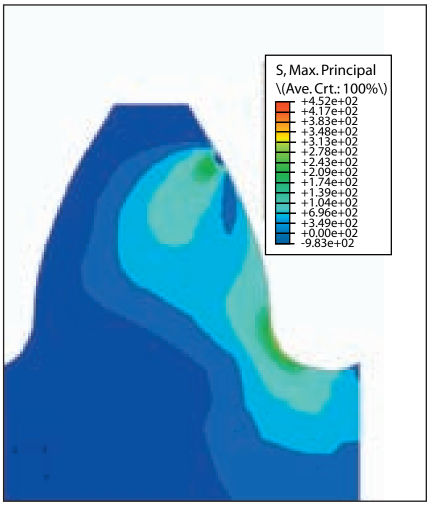

Figure 4—Maximum principal; stress contour plot in the side of the gear: Full-body gear with *b* = 20 mm

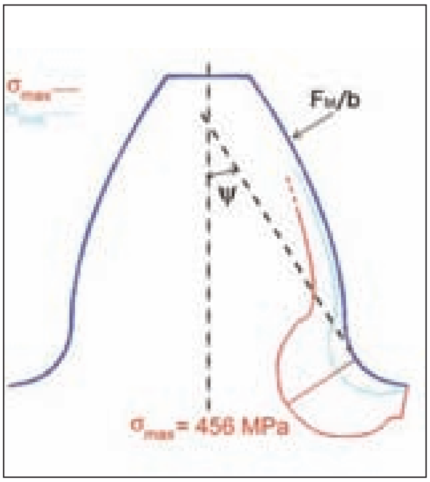

Figure 5—Maximum and intermediate principal stress distribution at the tooth root fillet in the middle cross-section: Full-body gear with *b* = 20 mm.

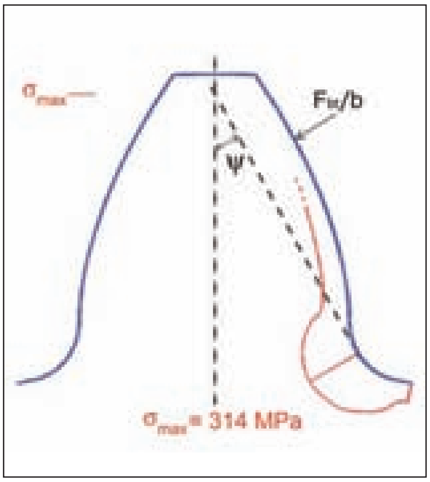

Figure 6—Maximum and intermediate principal stress distribution at the tooth root fillet in the sides of the gear: Full-body gear with *b* = 20 mm.

teeth and body (Refs. 3 and 4).

This work analyzes the stress field at the tooth root using a three-dimensional, parametric, finite element solid model. Commonly used gear geometries having full body and thin-rimmed body connected to the hub by a web are also analyzed.

Full Body Gear

The methods that are commonly used for the calculation of gear-bending strength are based on a cantilever-beam model. The maximum tensile stress in the tooth root is therefore computed in a plane strain condition for an error-free gear pair. The influence of the face width and the variation of the tooth root stress along the gear width is not taken into account.

This study examines the bending stress along the tooth width for a fixed geometry and for different values of face width (Table 1). To begin, the case of an error-free spur gear pair with full body was considered. In the FEM analyses, only half of the pinion was modeled, since loading conditions and geometry are symmetrical to the middle plane of the gear width (Fig. 1). The load, applied at the highest point of single tooth contact (HPSTC), was modeled as a linear force uniformly distributed along the face width and perpendicular to the tooth surface. The hub of the pinion was fixed (Fig. 1). An example of the FE models used in the analyses is shown in Figure 2.

Even with uniform load along the face width, numerical results show that there are areas with different stress levels at the tooth root (Figs. 3 and 4). For values of the ratio *b/m* between the face width and the module commonly used in practical gear design, the stress level is higher in the middle of the gear width than in the side areas. In the center cross-section, the magnitude of the maximum principal stress is higher than on the sides of the gear, and an intermediate principal stress is present. In addition, the location of the highest value of the maximum principal stress in each cross-section changes along the face width, but the range is small. The location varies from 30° in the middle cross-section to 34° on the sides (Figs. 5 and 6) if the position in the tooth root fillet is described by the angle ψ, the angle between the symmetry line of the tooth and the tangent to the fillet curve.

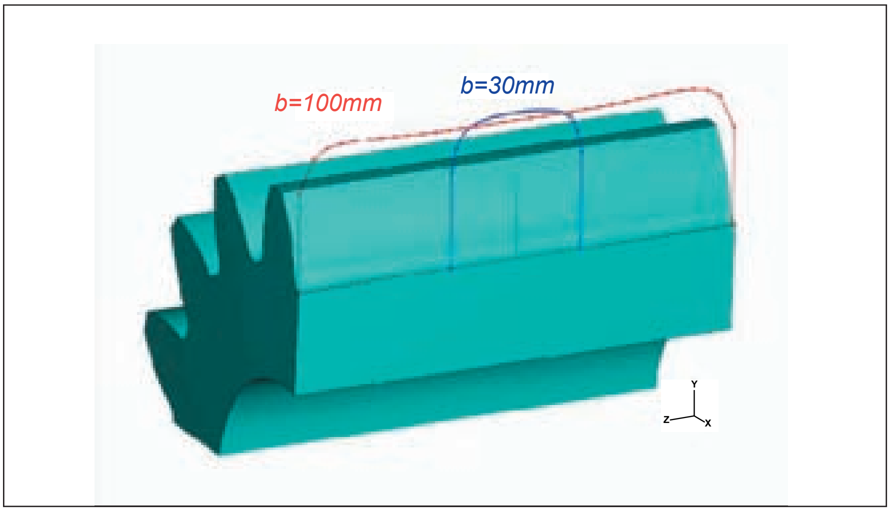

Figure 7—Bending stress distributions along the face width for full-body gears with *b* = 30 mm and *b* = 100 mm.

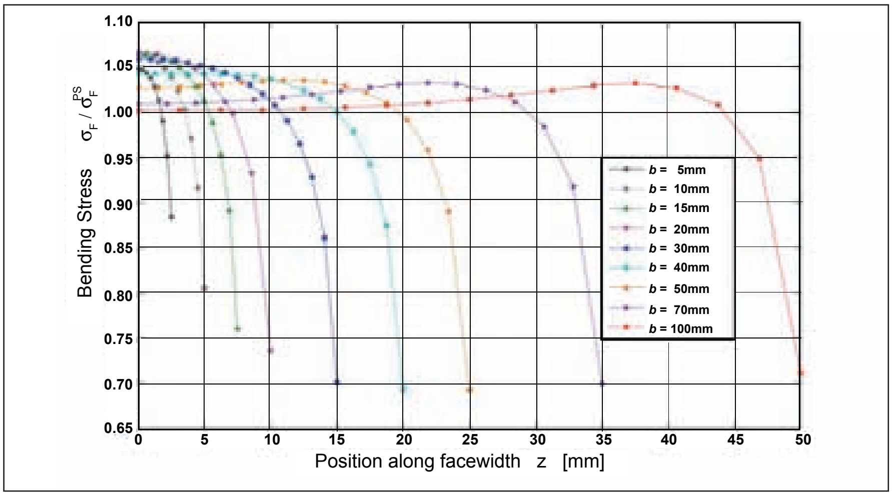

Figure 8—Bending stress distribution along the face width for different *b*: Full-body gear (σ_F is the bending stress stress and σ_F^{PS} is the bending stress in plane strain condition).

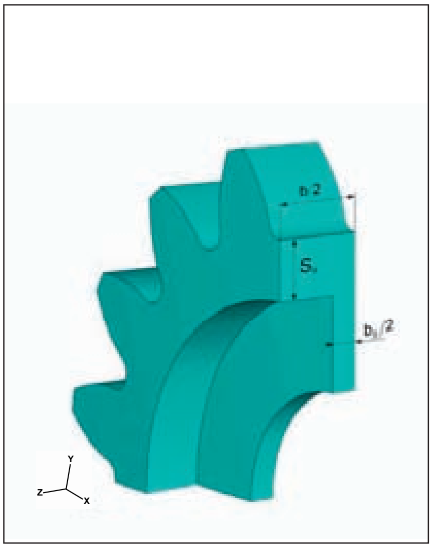

Figure 9—Thin-rimmed gear geometry.

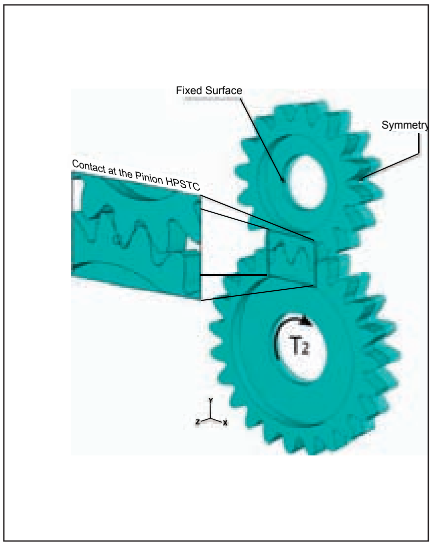

Figure 10—Geometric model and boundary conditions: Thin-rimmed gear.

The highest value of the maximum principal stress in a cross-section—herein named bending stress—may be used to characterize the stress levels along the face width. Figure 7 shows the bending stress as a function of the distance *z* from the middle plane for gears having different face width. Two types of distribution can be recognized, as shown in Figure 8. For a *b/m* ratio lower than nine, the maximum of the bending stress is in the middle section and the minimum in the sides of the gear. The maximum is higher than the bending stress calculated in plane strain condition. For a *b/m* ratio higher than nine, the minimum bending stress is again in the sides of the gear, but the maximum is close to the sides, not in the center. In the middle cross-section, the bending stress approaches the plane strain value for face width close to infinity.

Thin-Rimmed Gears

A common design goal for gears in some power transmissions (e.g., aerospace transmissions) is reduced weight. To meet this goal, thin rims are often utilized. But rims that are too thin may adversely affect the bending stress. Several researchers have employed FEA for the purpose of assessing the influence of the rim thickness on the stress behavior in thin-rimmed gears. Yet most of these 2-D and 3-D analyses do not consider a web structure of the gear body. It is therefore believed that these models cannot give an accurate evaluation of the stress field at the tooth fillet of gears having a thin rim supported by a web.

A model of a spur gear pair is used here to evaluate the influence of both the rim and web thickness. In the geometrical model, the gear bodies are modeled as a thin rim supported by a web (Fig. 9). Nine different case studies are analyzed with all geometry parameters fixed, excepting the back-up ratio and the web thickness ratio (Table 1). The first, here referred to as *r*, is the ratio between the rim thickness S_R and the tooth height. The second, referred to as *w*, is the ratio between the web thickness b_S and the face width *b*.

As opposed to the full-body gear case, the gear pair is modeled and the dry contact of the mating tooth surfaces is simulated by a numerical algorithm. The gear pair position is chosen to load the pinion tooth at the HPSTC, as in the full-body gear analyses. To impose kinematic and static boundary conditions, the pinion hub is fixed and the torque applied to the wheel hub (Fig. 10).

The contact pressure distributions obtained from the numerical simulations were similar in all cases analyzed. The contact pressure was not uniformly distributed along the face width. In the middle section, the pressure distribution is close to the Hertzian distribution for the plane strain condition (Fig. 11). In the side sections, the contact pressure distribution is again elliptical, but the maximum value is lower than in the middle section. This reduction occurs due to the free expansion of the material on the sides of gear, contrary to the middle section. The ratio between the maximum contact pressure in the side and in the middle sections can be calculated according to Johnson (Ref. 6) as $p/p_H = (1–\nu 2) = 0.91$ (considering steel gears). This value is close to that obtained from the analysis $p/p_H = 0.88$ (Fig. 11).

Considering the stress field at the tooth root, the results of the FEAs again show that the maximum bending stress is located in the central cross-section, and the minimum in the sides of the gear. But the difference between these two values is larger than in the full-body gear case. Moreover, the shapes of the maximum principal stress contour lines are different in the two positions along the gear width (Figs. 12 and 13). This is due to the differences between the stiffness of the central area—supported by the rim and the web—and the stiffness of the end areas which are supported only by the rim. As a consequence, the locations of the highest value of the maximum principal stress in the tooth fillet are also different in the two cross-sections; the location varies from 43° in the middle to 32° on the sides (Figs. 14 and 15).

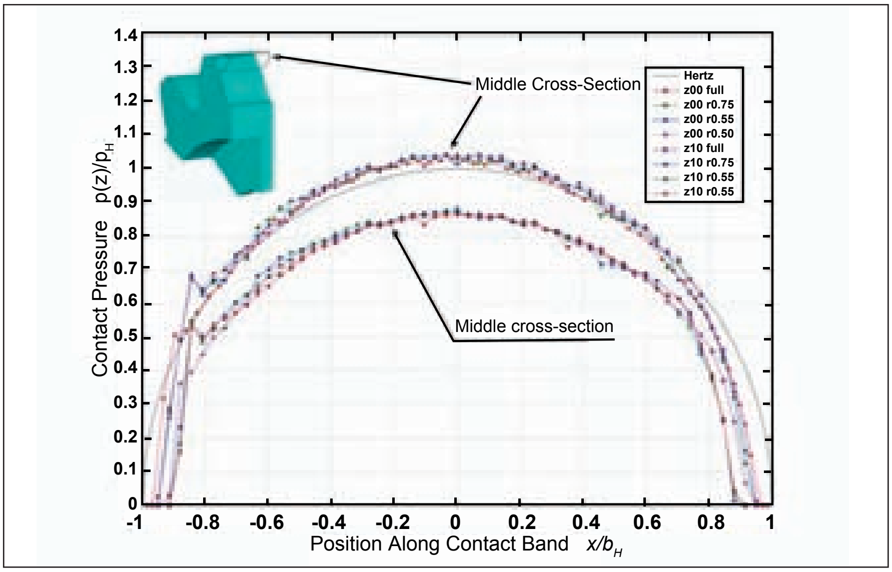

Figure 11—Contact pressure along the involute profile in the middle cross-section (*z*00) and in the sides of the gear (*z*10): Thin-rimmed gear with *b*=20 mm, *w*=0.3 and *r*=0.5, 0.65 and 0.75.

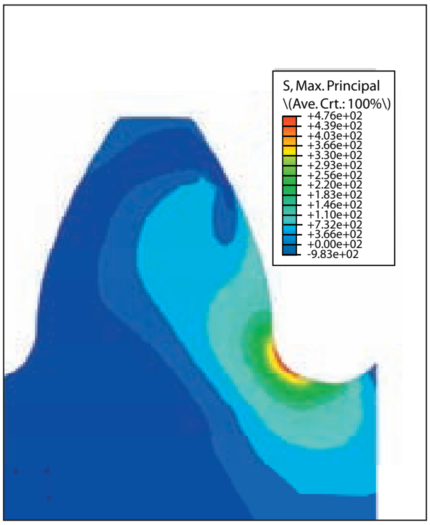

Figure 12—Maximum principal stress contour plot in the middle cross-section: Thin-rimmed gear with *b* = 20 mm, *r* = 0.65 and *w* = 0.3.

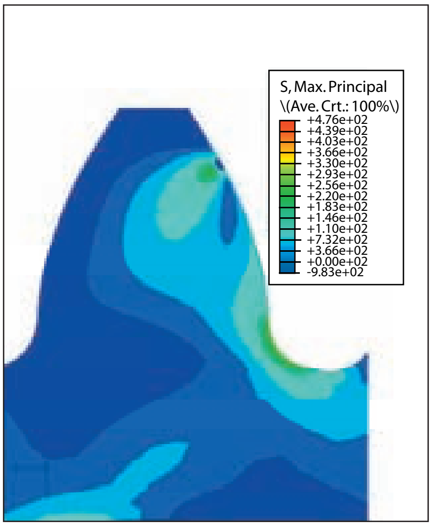

Figure 13—Maximum principal stress contour plot in the middle cross-section: Thin-rimmed gear with *b* = 20 mm, *r* = 0.65 and *w* = 0.3.

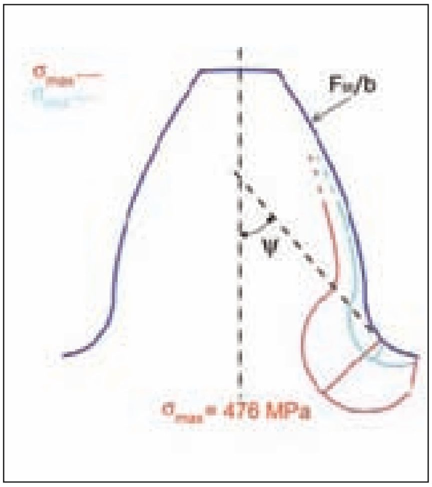

Figure 14—Maximum principal stress at the tooth root fillet in the middle cross-section: Thin-rimmed gear with *b* = 20 mm, *r* = 0.65 and *w* = 0.3.

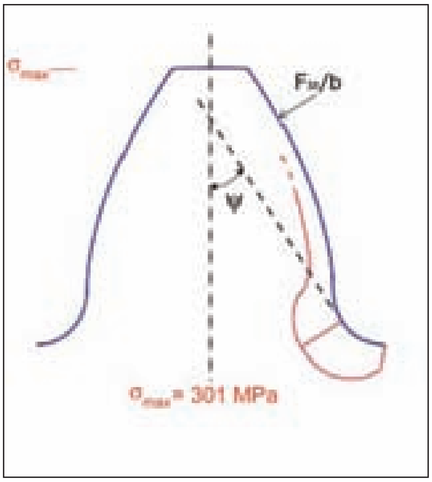

Figure 15—Maximum principal stress at the tooth root fillet in the middle cross-section: Thin-rimmed gear with *b* = 20 mm, *r* = 0.65 and *w* = 0.3.

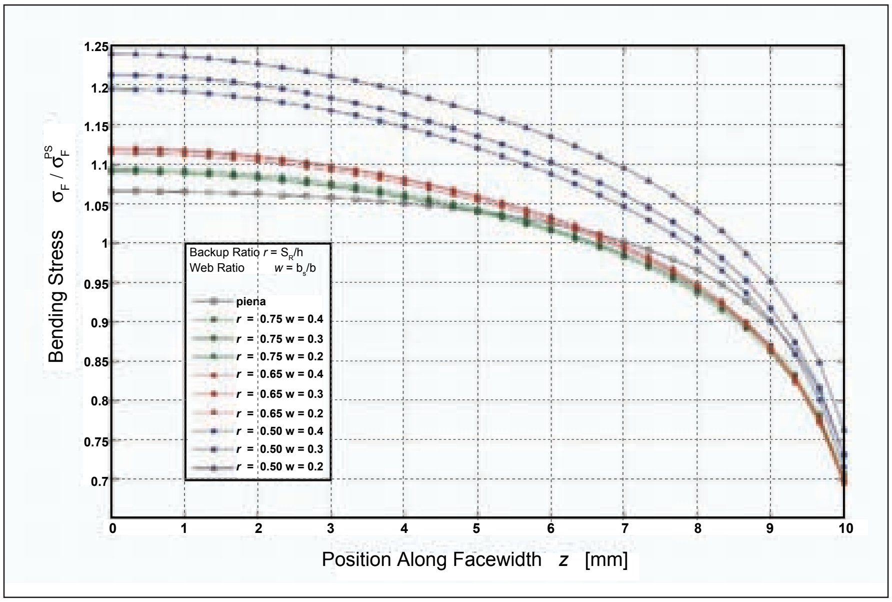

Figure 16—Bending stress distributions along the face width for different *r* and *w*: Thin-rimmed gear with *b* = 20 mm (σ_F is the bending stress and σ_F^{PS} is the bending stress in plane strain condition).

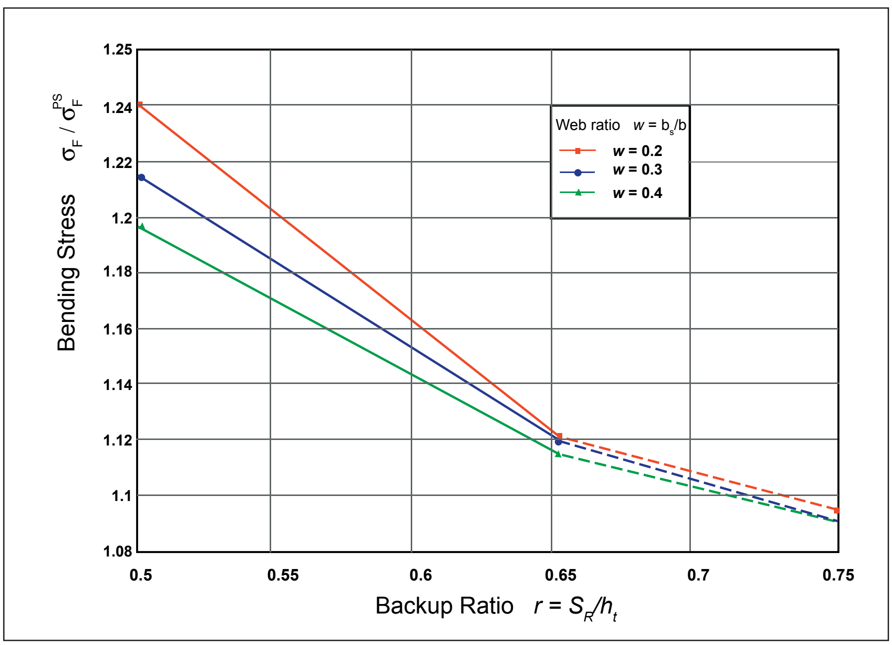

Figure 17—Ratio between the maximum bending stress and the bending stress in plane strain condition as function of the backup ratio for diffrent web thickness ratios.

In Figure 16, the bending stress is plotted as a function of the distance of the section from the middle plane for the nine case studies and for a full-body gear case. For back-up ratio equal to 0.75, the thin rim has a small influence on the bending stress, and the stress distribution is unaffected by web thickness ratio. If the back-up ratio decreases, the magnitude of the bending stress in the middle plane increases and the effect of the web thickness becomes clear—the increment of the bending stress becomes larger when the web thickness decreases (Fig. 16).

AGMA and ISO Thin-Rim Coefficients

Both the ISO and AGMA standards (Refs. 7 and 8) introduce stress-modifying factors for the bending stress calculation where the rim thickness is not sufficient to provide full support of the tooth root. The AGMA and ISO rim thickness factors *KB* and *YB* have the same meaning and same values as a function of the back-up ratio.

According to the ISO standard, the rim thickness factor should be defined as the ratio of the nominal tooth root stress for a thin-rimmed gear and for a full-body gear with the same geometry but without the back-up ratio. The magnitude of the rim thickness factor can be derived from diagrams (Fig. 17) or calculated according to the ISO standard with this formula for an assigned backup ratio: $YB = 1.6 \ln (2.242 \cdot h_t / S_R)$ per $0.5 < S_R/h_t < 1.2$

The values of the *YB* factor calculated for $r = 0.5$, 0.65 and 0.75 are listed in Table 2, while the ratio between bending stress for the full-body gear and the thin-rimmed gears investigated in this study are reported in Table 3. The differences between the values for a given *r* are large, but the effect of web is not taken into account in the *YB* factor. The values obtained have instead a good correlation with the results of numerical and experimental investigations described in Reference 5, where the effect of both the thin rim and the web thickness are considered.

Conclusions

This paper presents the results of an investigation on the variation of the tooth root stress field along the face width for full-body and thin-rimmed gears. The results of parametric, 3-D finite element analyses are used to characterize the influence of some significant geometric parameters on the bending stress distribution.

For full-body gears, the influence of the face width was investigated, showing areas with different stress levels along the tooth width. The results show that, for face width ratio close to practical gear design, most of the bending stress occurs in the center cross-section and the magnitude is higher than in the plane strain condition. The location in the tooth root fillet of the highest value of the maximum principal stress changes along the face width, but the values of the angle ψ are close to 30°.

For thin-rimmed gears, the influence of both rim and web thickness was investigated. The results show that for backup ratio values larger than 0.75, there is a very small influence on the tooth root stress, while the maximum fillet stress increases sharply as the backup ratio value is smaller than 0.75. Moreover, the more the web thickness is increased, the more the stress concentration factor decreases.

Table 2–Y_B values as a function of the backup ratios analyzed in this study.

S_R/h_t	r = 0.5	r = 0.65	r = 0.75
YB	2.40	1.98	1.75

Table 3–Ratio between the bending stresses calculated for the thin-rimmed gear and in plane strain condition as a function of the backup ratio r = S_R/h_t and the web thickness ratio $w = b_S/b$.

σ_F/σ_F^{PS}	r = 0.5	r = 0.65	r = 0.75
w = 0.2	1.24	1.12	1.09
w = 0.3	1.21	1.21	1.09
w = 0.4	1.20	1.11	1.09

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Appendix

The numerical simulations were performed using *ABAQUS* version 6.5-1 in the pre/post processing (*ABAQUS/CAE*) and in the numerical analysis (*ABAQUS*/Standard).

The material was considered homogeneous and isotropic with a linear elastic behavior. Small displacement hypothesis was assumed for the analyses. In the full body gear analyses, hexahedral quadratic elements (3D) and bilinear quadrilateral (2D) elements fully integrated (*ABAQUS* codes C3D20 and CPE8 according to Ref. 9) were used for the domain discretization in the three- and two-dimensional models. In the thin-rimmed gears analyses, hexahedral linear elements (*ABAQUS* code C3D8I according to Ref. 9) were used for the mesh. These types of elements are suggested for the convergence of the contact algorithm and the elements are enhanced by incompatible modes to improve their bending behavior. The number of elements used was varied depending upon the particular gear width being considered.

In the analyses where the gear pair was simulated, the contact between the tooth surfaces was considered as a dry frictionless contact assuming small sliding between the surfaces. The contact constraint was simulated by the LaGrange Multiplier Method (i.e. using the *ABAQUS* option "Hard contact").

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Captive Vs. Commercial Heat Treaters?

A Split Decision.

Jack McGuinn, Senior Editor


Upon completion, a heat treated wheel is pulled from the furnace at Xtek.

Heat treating is a vital step in the gear making process—that's a given. But how that step is taken can happen in a number of ways. For one, there is a goodly number of gear manufacturers that invest in keeping the heat treat process in-house, along with the not insignificant attendant overhead—i.e., equipment, trained personnel, quality control, R&D, metallurgy, environmental clean-up, etc. Then, too, there are well-respected gear makers with no heat treat capabilities that outsource the work to commercial shops.

Let's take a look at three companies—a gear manufacturer and two commercial heat treaters—that are useful examples of both captive and commercial heat treating. We'll examine the pros and cons of each scenario, as well as how our gear maker came to heat treat in-house, and what commercial heat treaters have to offer. All of which leads to the question: Who does it better?

The Short Answer: It Depends.

Captives. Cincinnati-based Xtek, Inc., since 1909 a maker of heavy equipment gears, has a long history of heat treating in-house.

"Xtek was originally founded as the Tool Steel Gear and Pinion Company back in 1909, and has roots that go back even further," says Kevin Biggers, Xtek manager for metallurgical engineering. "Heat treating was the process that the company was founded on. One of the company founders had developed a pack carburizing process prior to 1905 in Chicago in an effort to make better bicycle bearings. Carburizing process has been part of the company's core technologies ever since."

And as Biggers points out, "At that point in time, there was no commercial heat treat industry. We had no choice but to do it ourselves."

Xtek is one of many gear makers that feel keeping the process in-house is the only way to maintain strict quality control. For them, keeping the process at home is the only recourse. And given the markets served by a gear manufacturer such as Xtek, sometimes it is a matter of having little choice.

"Our decision to heat treat components is due in part to the nature of our products," says Biggers. "We tend to make very large components compared to the general industry. It is not uncommon for us to be processing a 25,000-lb., double-helical pinion. There are not many commercial heat treat shops capable of heat treating a part like that.

"We also have products where the heat treatment is vital to the performance of the part, and the heat process and equipment is very specialized just for that product. To use a commercial heat treater in such a case, we would be giving up the competitive advantage that our product has in the market." Biggers does say, however, that Xtek uses commercial heat treaters for many of their "non-critical" parts.

Larger captives such as Xtek are also in a better position

An in-process rope drum quenching at Xtek.

A tray of spiral bevel gears after vacuum carburization at Solar Atmospheres.

to possess and maintain latest-technology capabilities and processes. Xtek maintains a complete metallurgical lab to complement their heat treat operation. Add to that their inherent, collective gear knowledge and you have a combination that is very competitive in the heat treat universe.

"In the industry that Xtek supplies, it is very important to them to know that Xtek people are doing the heat treatment of their components," says Biggers. "This is one area that Xtek has proved time and again that the quality of the heat treatment is critical to the performance of a product. We view ourselves as our customers' problem solvers. Many times the solution to a customer's problem is the correct application of material and heat treatment."

Commercials. But let's say you are a gear manufacturer who has chosen not to pursue in-house heat treating. In a perfect gear world, every shop would be able to do its own heat treating. But the typical reality is that often a company's bottom line just won't justify the capital expenditure required for personnel, training, equipment, quality control, etc.

For many, the best alternative is to identify a top-flight commercial treater that will work closely with you and your manufacturing process. Also, look for a commercial house that insists that customers invest in to-the-print tooling before they'll agree to take on a job.

Bodycote, an international heat treating provider, is one of them.

"We require (dedicated) tooling for each job, and we're not going to use something that's 'close enough,'" says Don Giessel, general manager at Bodycote's New Berlin, WI plant.

"We take the stance that (the customer) must use the proper tooling for the proper job. Otherwise, they may come back to us and say 'This isn't flat enough,' etc., because of improper tooling."

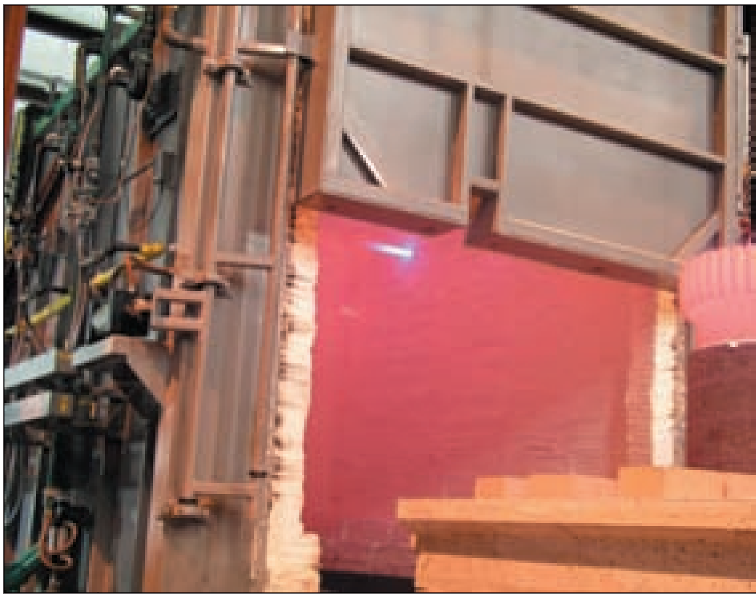
Of course, there are other considerations at play when seeking out a good commercial heat treater. Bob Lacock, marketing manager for commercial heat treater Solar Atmospheres in Souderton, PA, addresses some of the more important ones.

"The primary goal of successful outsourcing is to decrease costs (purchasing, overhead, personnel, maintenance and processing)," he says. "Complementary to reducing costs is to give management more time and resources to focus on core activities. Outsourcing also allows for production flexibility; that is, expanding without investing in capital equipment and other associated costs. Conversely, savings occur when there is no idle equipment or people during slower production times."

As mentioned, capabilities can be a huge difference maker, particularly with gear manufacture. Vacuum caburizing, for instance, is one of the newer technologies to come along. It is a much cleaner and cost-effective process in that the part comes out of the furnace in a much cleaner and finished state than with older heat treat processes. Thus with less handling and processing—less cost.

"Solar offers vacuum carburizing for optimum case-hardening results," says Lacock. "This includes a more uniform case depth, no intergranular oxidation due to the controlled vacuum environment, and minimized distortion." Bodycote is another commercial house providing this service.

That said, what should a gear maker look for if outsourcing is the process of choice?



Xtek specializes in carburizing heavy equipment gears for its customers.

"No. 1, a heat treater that's going to work with them in the gear manufacturing process," says Bodycote's Giessel. "It's very important that (the treater) ask a lot of questions; if a gear manufacturer calls up and asks someone about their heat treating their gears and all he gets is pricing, that should be a red flag. A lot of questions need to be asked upfront. No. 2, with press quenching, be adamant that proper tooling be used for that job, and don't settle for the existing tooling of another treater's customer whose tooling is just close."

As for Solar, Lacock says it's all about "Honesty, plus unique capabilities, responsive service and consistent quality. And having staff metallurgists and an R&D department as we do at Solar."

And the winner is…So who to call—captive or commercial? The fairest answer is that there is no clear-cut winner in this debate.

Commercial houses may have more equipment capabilities, metallurgical and heat treat expertise, and, depending on the project, faster turnaround.

And yet gear makers—especially those with advanced heat treat facilities—possess an understanding of gears that most, although as this article certainly demonstrates, not all, commercials can't begin to match.

But one contention can be held that is impossible to argue against: If you are a maker of highest-precision gears, you must have a trusted and experienced provider—in-house or commercial—for heat treating for gears.

Anything short of that is playing with fire.

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Power Transmission and Gearing Conference

Can Be Your Alibi

The Las Vegas strip will be home to approximately 200 gear and power transmission researchers and technologists from September 5–7 when ASME's 10th International ASME Power Transmission and Gearing Conference comes to town.

Held once every four years, chairman Dr. Ahmet Kahraman says this is the premier conference for power transmission and gearing professionals. It's held as part of the larger ASME International Design Engineering Technical Conference at the Rio All-Suite Hotel and Casino. This year's event includes 118 papers that will be presented in 26 sessions. Presenters hail from England, Japan, the Middle East, Korea and numerous other countries.

"Participation in the conference is truly international as it contains 41 papers from the European countries, 40 from the Far East and 37 papers from the U.S.," Kahraman says.


Photo is provided courtesy of Las Vegas News Bureau.


Conference Chairman and Ohio State University professor Ahmet Kahraman.

Technical paper topics are broken down as follows:

- Gear Design and Analysis (41 papers)
- Gear Dynamics and Noise (27 papers)
- Strength and Durability (14 papers)
- Gear Manufacturing (9 papers)
- Lubrication, Efficiency and Tribology (9 papers)
- Transmissions (9 papers)
- Power Transmission Components (9 papers)

For the first time this year, ASME is bestowing a Lifetime Achievement Award. Its recepient is the late Darle Dudley, author of the *Handbook of Gear Design*. Dudley was selected after a small ASME committee reviewed suggestions from an open nomination.

In addition, Bill Bradley, recently retired vice president of the technical division of the American Gear Manufacturers Association, will present the keynote address.

"For the Buckingham lecture, I will be covering three areas—standardization, testing and the qualities gear transmissions need for the future," he says. The keynote will take place Thursday, September 6 from 10:30–12:30.

Registration is available through the conference website *www.asmeptg.org* and fees range from $75–$800. A block of hotel rooms has been reserved for $159/night at the Rio All-Suite Hotel & Casino. Attendees must mention the code SRASME7 to receive the special rate.

August 21—Gear Manufacturing Technology Seminar. Lyon Oaks Golf Course Club House. Wixom, MI. Hosted by Mitsubishi Heavy Industries America Inc. Program includes seminars covering gear basics; Mitsubishi's philosophy with regard to superdry cutting tools and applications; evaluating potential errors from hobbing and shaping; and generating gear grinding. The featured guest speaker is Paul Suwjin of Gear Resource Technologies, who will present a lecture called Important Principles for Workholding Success. The free seminar runs from 7:30 to 5 and includes breakfast and lunch. A limited number of tee times have been reserved at a rate of $33 for nine holes after the seminar. For more information, contact Mitsubishi Heavy Industries by telephone at (248) 669-6136 or online at *www.mitsubishigearcenter.com*.

September 4–7—10th International Power Transmission and Gearing Conference. Rio All-Suite Hotel, Las Vegas, NV. This conference program is separated into 10 areas including gear design and analysis; gear strength and durability; gear dynamics and noise; gear diagnostics; gear manufacturing; gear lubrication and efficiency; engineered surfaces and tribology; transmissions, chains, belts and traction drives; couplings, clutches and bearings. See our extended coverage of this event on page 64. Registration fees range from $75-$800. For more information, contact the show's website at *www.asmeptg.org*.

September 10–14—AGMA Training School for Gear Manufacturing. Richard J. Daley College, Chicago, IL. The basic course offers classroom and hands-on training in gearing and nomenclature; principles of inspection; gear manufacturing methods; and hobbing and shaping. Although the course is designed primarily for newer employees with at least six months' experience in setup or machine operation, it can also benefit quality control managers, sales reps, management and executives. This course is taught by Dwight Smith, president of Cole Mfg. Systems, and Peter Grossi. $850 for AGMA members, $950 for non-members. *Note: A classroom version of this course will be offered at AGMA's Gear Expo in Detroit that will be taught by Mike Tennutti of Gleason Cutting Tools. For more info., visit AGMA website at *www.agma.org*.

September 12–14—Basic Gear Noise Short Course. Department of Mechanical Engineering, Ohio State University, Columbus, OH. Offered for gear designers and noise specialists who encounter gear noise and transmission design problems. Attendees will learn how to design gears to minimize the major excitations of gear noise—transmission error, dynamic friction and shuttling forces. Fundamentals of gear noise generation and gear noise measurement will be covered, along with topics on gear rattle, transmission dynamics and housing acoustics. Course includes extensive demonstrations of specialized gear analysis software in addition to the demonstrations of Ohio State gear test rigs. An interactive workshop session invites attendees to discuss specific gear and transmission noise concerns. $1,550. For more information, contact the GearLab by telephone at (614) 292-5860 or online at *www.gearlab.org*.

September 17–18—Advanced Gear Noise Short Course. Department of Mechanical Engineering at Ohio State University, Columbus, OH. This advanced session is an extension of the Basic Gear Noise Short Course. This advanced course will be taught through lectures on selected topics coupled with a series of hands-on workshops. Based upon their interests, the attendees may select from the following topics:

- Analytical and computer modeling (prediction of gear whine excitations, general system dynamics, bearing/casing dynamics, gear rattle models).
- Experimental and computational approaches (modal analysis of casings, acoustic radiation, advanced signal

processing, sound quality analysis, transmission error measurement). Cost to attend is $1,050. For more information, contact the GearLab online at *www.gearlab.org* or by telephone at (614) 688-3952.

September 17–20—Basics of Bevel and Hypoid Gears. Zurich, Switzerland. This Klingelnberg-sponsored course is limited to 10 participants and conducted in German. Topics include gear cutting systems, gear geometry, offset and hand of spiral, ease-off, load related deflections, bias conditions, influence of cutter diameter, example gear design calculations, and gear measurement and closed loop. 2,000 euros per person. For more information, visit Klingelnberg's website at *www.klingelnberg.com*.

September 17–22—EMO 2007. Hannover Fairground, Hannover, Germany. Featuring products and services for metalworking technology, with special emphasis on machine tools, manufacturing systems, precision tools, automated systems, computer technology, industrial electronics and accessories. Sponsored by the VDW (German Machine Tool Builders Association). For more information, visit the show's website at *www.emo-hannover.de*.

September 18–20—Great Lakes 2007 Expo and Conference. DeVos Place, Grand Rapids, MI. A new exposition and conference showcasing manufacturing innovations and emerging technologies to help advance the manufacturing community in the Great Lakes region. To request registration information, visit the show's website at *www.asme.org*.

September 25–27—Assembly Tech Expo. Donald E. Stephens Convention Center, Rosemont, IL. Co-located with Quality Expo, National Manufacturing Week, Electronic Assembly Show and PlasTec Midwest. One badge serves as admittance for all five shows. Registration is free for preregistrants or those who bring online registration materials to the show. Online registration is available throughout the show days. For more information, visit the show's website at *www.devicelink.com/expo/ateexpo2007*.

September 25–27—Makino's Tool and Die Expo. Makino Technology Center, Auburn Hills, MI. Tool, die and mold makers have the opportunity to listen to keynote speakers address customer diversification and the "new domestic OEMs." The second and third days involve a series of presentations on topics such as hardmilling and micromachining. Machine demonstrations on 16 machines under power and 20 select industry suppliers will be presented. For more information, visit *www.makino.com/expo*.

September 26-28—International Grinding Conference. Hyatt Regency Hotel, Dearborn, MI. ISAAT2007—International Symposium on Advanced Abrasive Technology—to be held in conjunction with the SME International Grinding Conference. Registration includes a hardbound copy of the conference proceedings, welcoming reception, banquet at the Henry Ford Museum, lunches, continental breakfasts, afternoon refreshments, admission to technical sessions and tours. Registration is $600 and then $650 on site. For more information, contact the Society of Manufacturing Engineers at *www.sme.org*.

October 7-10—Gear Expo 2007. Cobo Center, Detroit, MI. "The Worldwide Gear Industry Event." This year's show promises more than 150 international exhibitors. AGMA, SME and the American Bearing Manufacturing Association will conduct gear-related seminars, and the Gear Expo Solutions Center will host free presentations from more than 20 exhibiting companies. See our extended coverage on page 29. For more information, contact the AGMA online at *www.agma.org* or by telephone at (703) 684-0242.

Engesser

APPOINTED REISHAUER SALES DIRECTOR

Michael Engesser

The Reishauer AG Board of Directors, in Wallisellen, Switzerland appointed Michael Engesser as director of sales and member of the executive management group.

According to the company's press release, Engesser first joined Reishauer in 1991 as product engineer, primarily responsible for the line of thread grinding machines. He gradually assumed a leadership role in the new generation of gear grinding machines and eventual management responsibilities.

Romax Technology

SIGNS PREFERRED ENGINEERING PARTNERSHIP WITH APPLIED TECHNOLOGIES

Romax Technology, the U.S. subsidiary of U.K.-based power transmission software designer Romax Technology Ltd., has established an engineering partnership with Toledo, Ohio-based Applied Technologies, Inc.

Paul Lefief, senior sales and marketing director for Romax Technology, Inc., says, "This is an important strategic alliance for Romax here in the U.S. because it expands our business development capability by adding significant design, product development, and process engineering services from a company that has broad industry knowledge and a fine reputation in automotive, aerospace, wind energy, industrial equipment, rail and marine industries."

Craig Winn, CEO and co-owner of Applied Technologies, Inc., says, "The Romax Technology design and product development software is, without question, the world's leading power transmission design tool. We have multiple seats of our own located at our headquarter facility in Toledo, Ohio, and anticipate adding more. We can create technically superior designs in short timeframes, conduct critical NVH refinement, and even benchmark competitive products. We are a licensee for Romax Technology software and look forward to integrating the software with our engineering services and creating a worldwide sales and support structure for transmission engineering services."

According to the company's press release, Romax now offers to the North American power transmission market the option of purchasing seats of its software or letting the company provide its custom engineering services, utilizing the same software support.

AFC-Holcroft

ANNOUNCES NEW MANAGERS

Dan McMann

AFC-Holcroft announced the appointment of Dan McMann as manager of aftermarket parts and services and Tim Josephs as account manager.

McMann has more than 20 years' aftermarket experience. He started his career at AFC-Holcroft in the mechanical engineering department before moving to aftermarket sales.

Tim Josephs

Josephs will primarily be responsible for sales of CAAB (controlled atmosphere aluminum brazing) equipment with additional sales responsibility in the general market for the balance of AFC-Holcroft's North American product line.

According to the company's press release, Josephs has extensive sales experience related to thermal treatment capital equipment and was most recently employed as sales manager of a plating company.

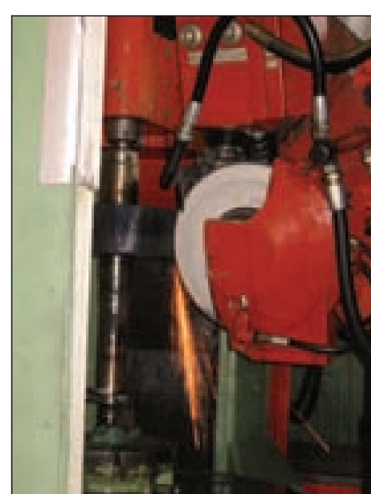
Philadelphia Gear's Birmingham Facility

INSTALLS HÖFLER GRINDER

Philadelphia Gear Corp. announced that its Birmingham Regional Service Center installed a 1.5-meter Höfler grinder. Birmingham is the fifth Philadelphia Gear Company site to obtain such operational gear cutting capability.

The grinder is typically used as reserve capacity for rapid turnaround to support the company's aftermarket value proposition of helping its customers minimize downtime. As such, Philadelphia Gear can turn and grind entire gear-sets without interrupting a normal production schedule.

Originally purchased on the used equipment market, the Höfler grinder went through several overhauls, the most substantial of which was the complete replacement of all of the electronics and installation of a PLC control system. According to Philadelphia Gear's press release, though not fully CNC, the completely refurbished Höfler grinder performs better than its purely mechanical counterparts.



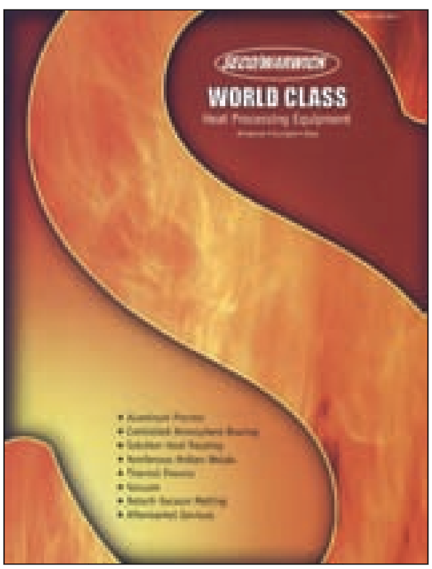
"This piece of equipment gives us a tremendous competitive advantage," said Mike Bashour, the Birmingham RSC's general manager. "It allows us to be more responsive to new customers, and to better service existing customers throughout the region."

SECO/Warwick

PUBLISHES NEW CORPORATE BROCHURE

SECO/WARWICK released the new SW-200.3 version of its corporate brochure to include new information on its Retech Vacuum Melting facilities worldwide.

According to the company's press release, SECO/WARWICK manufactures industrial heat processing equipment, including heat treat furnaces, vacuum furnace technology, atmosphere generators and aluminum reverb melting and holding systems as well as provides heat treating equipment and services.



Linamar

WINS ONTARIO BUSINESS AWARD

Linamar Corporation is a recipient of a 2007 Outstanding Business Achievement Award from the Ontario Chamber of Commerce (OCC).

According to the company's press release, Linamar was selected as one of two large business winners in the Business

continued

Excellence award category. The Guelph Chamber of Commerce nominated Linamar for the OCC Business Excellence Award early this summer and the company won in the large business category, defined as an outstanding business having more than 250 employees in Ontario.

"As we continue to hear stories about the struggling domestic automotive sector, it was a real pleasure for the Guelph Chamber of Commerce to nominate a local success story, Linamar Corp., for an Outstanding Business Achievement Award for 2007. It is important for all of us to take the time to recognize and celebrate success in our business community," said Ian Smith, president and CEO of the Guelph Chamber of Commerce.

Ontario companies were judged by a broad set of criteria. Two awards acknowledge businesses with fewer than 250 employees; two with more than 250 employees. The achievements the OCC identifies when selecting winning companies include sales and export growth, increased employment, product innovation, community initiatives, technological advancements, and general entrepreneurial skill.

Makuta

COMPLETES SECOND CLEAN ROOM

Makuta completed the addition of a second clean room at its new facility in Shelbyville, IN. According to the company's press release, the clean room houses a 30-ton, Sumitomo multi-material injection molding machine, which produces a double shot component for a major medical supplier.

The machine is equipped with a Yushin RA 30 robot with custom programming. This robotic system automatically removes the part runner and packages the parts with no human intervention. Makuta uses class 10,000 mobile clean rooms, which enhances flexibility on the production floor.

Delta Research, Tifco Gage and Gear

HIRES TONY WERSCHKY

Tony Werschky

Delta Research and TIFCO Gage & Gear announced the hiring of Tony Werschky for its sales team. With more than 12 years of sales experience, Werschky will be in charge of maintaining customer relationships, building new relationships with prospective customers and developing brand awareness for both Delta and TIFCO companies.

Delta Research, an ISO 9001: 2000 company, provides CNC prototype machining, short run production, patterns, castings, inspection services, fixtures, gages and master gears. TIFCO Gage & Gear, also in compliance with ISO 9001 & SPC, designs and manufactures precision gages, splines and gears for the aerospace and automotive industries.

Carl Zeiss

WINS BOSCH SUPPLIER AWARD

Carl Zeiss Industrial Metrology GmbH announced that it has won its third consecutive Bosch Supplier Award. The manufacturer of industrial metrology equipment was honored for its performance in areas related to quality, cost and reliability.

Werner Gerstner, vice president for sales in Germany and South America at Carl Zeiss Industrial Metrology, and Richard Gärtner, vice president and general manager of the Services Division, received the award in Stuttgart, Germany on July 4.

Gerstner says, "The fact that we have once again been honored as one of Bosch's global suppliers testifies to the continuity of our work and to the commitment of our sales and service staff. Needless to say, leading edge measuring technology is the focus of our relationship with Bosch. At the same time, however, we do everything in our power to

continued

NEWS

keep our customers completely satisfied. One aspect is not possible without the other if we are to safeguard our position in metrology in the long term."

Bosch has presented the Supplier Award 11 times (every two years) to its best suppliers around the world since 1987. This year's award was presented to 47 suppliers, including 19 from outside Germany.

McNeil Industries

BUYS OLS MACHINE

Randall J. McNeil, president and CEO of McNeil Industries announced the acquisition of OLS Inc. Terms of the agreement were not disclosed.

OLS Inc. is a privately held manufacturer of deburring, drilling, deflashing and specialty machinery and solutions that are used by global manufacturers of gears and precision parts. McNeil Industries manufactures and distributes precision products including MAXAM® Bearings, McNeil Guide Systems, and industrial seals.

Under the agreement, production, sales, and customer service operations at the OLS plant in Cleveland, which currently employs approximately 15 managers and employees, will continue without interruption.

"We welcome the addition of OLS's skilled manufacturing people and resources to the McNeil Industries team," says

McNeil. "By integrating the OLS team with our management style and administrative systems, we feel that we can together add value and achieve great things."

GW Plastics and ABA-PGT

FORM STRATEGIC ALLIANCE

GW Plastics and ABA-PGT announced the formation of a global strategic alliance for plastic gear systems and integrated motion transfer systems.

GW Plastics president and CEO Brenan Riehl says, "Working together, we bring a best-in-class solution for gears and other motion transfer applications to the world stage."

According to a GW Plastics press release, the alliance combines its global precision plastic injection molding, tooling and assembly capabilities at its six facilities in the U.S., Mexico and China with the plastic gear application development, tooling and molding technologies of ABA-PGT's facilities in Manchester and Vernon, CT.

Key advantages of the alliance include:

- Single point of responsibility for motion transfer systems including gear trains, housings and numerous manual and automated assembly capabilities.
- Shared resources including application development, tooling and injection molding.
- Combined mold making and molding capacity including three mold making facilities in the U.S. and China with more than 100 mold makers, and eight molding facilities in the U.S., Mexico and China with more than 200 molding machines.

Corrections

The article titled "Sigma Pool Hosts Gear Seminar, WZL Event" that ran in the July issue of *Gear Technology* incorrectly identified Dr.-Ing Andreas Mehr and Thierry Guertin in the photo captions. The captions should have been reversed. We apologize for the error.

—*The Editors*

A story in the July issue—"Sure, Your Quality is Tier 1. But How's Your Lead Time?"—had incorrect contact information for Precipart. Gear Technology regrets the error.

For more information:
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90 Finn Court
Farmingdale, NY 11735
Phone: (631) 694-3100
Fax: (631) 694-4016
Website: *www.precipart.com*

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Niagara Gear Co.	65, 78	(716) 874-3131	info@niagaragear.com	www.niagaragear.com
Power Transmission Engineering magazine	79	(847) 437-6604	subscribe@powertransmission.com	www.powertransmission.com
Precision Gage Co. Inc.	74	(630) 655-2121	sales@precisiongageco.com	www.precisiongageco.com
Premier Machine Tools	19	+91 22-3028-1250	shdeshpande@premier.co.in	www.premier.co.in
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Process Equipment Co.	27	(800) 998-4191, (937) 667-7105	msdsales@processeq.com	www.gearinspection.com
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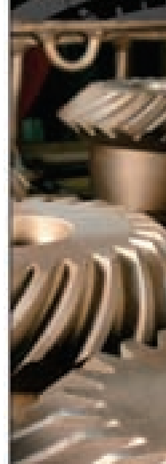

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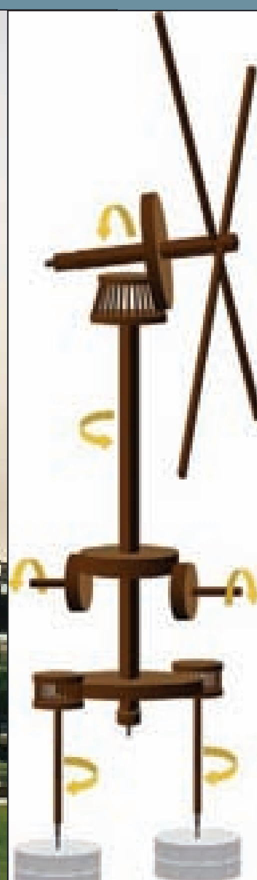
GEAR MANUFACTURING

Wind Energy Old School Style

Wind energy is 2007's gear industry buzzword, but the concept has been around for centuries.

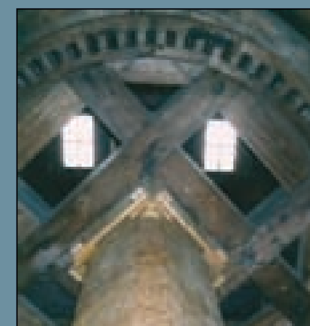
In one illustration, the Fabyan windmill in Geneva, IL, has been in operation since the nineteenth century. The mill itself was originally built by German craftsman Louis Blackhaus in collaboration with German, Dutch and Swedish mill workers between 1850–1860. Hand-cut cypress beams with hickory and maple gearing characterized the mill and its most modernized feature was a set of grain mills.

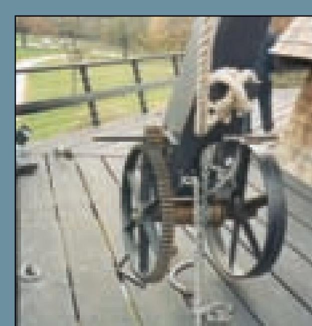


It was during its $914,000 restoration that was completed in 2005 that the local community and engineering scholars began appreciating its uniqueness.

"The Fabyan windmill is the best example of an authentic Dutch windmill in the U.S.," says Dutch windmill maker Lucas Verbij, who was contracted to oversee the restoration. "It would be the most popular windmill in the Netherlands (there are currently about 1,000)."

Roman numeral markings carved into the beams used in the original construction are still visible. It took 33 workers mixing concrete by hand to build the 42"-deep x 26"-thick foundation. Inside, beams and shafts are of cypress wood and trimmed with black walnut. New wooden gears were made. At the top, or cap, of the mill is a huge cogged wheel turned by wind blowing against the vanes (blades). The vanes are covered with canvas sails to help catch the wind. The moving cog rotates a shaft running the height of the mill.





Photos by Tom Haskell.

In its day, the Fabyan windmill housed a bakery in its basement. Its oven was rarely used, but its sharpening wheel, corn sheller and grain separator were indirectly responsible for feeding the colonel's livestock and two bears—Tom and Jerry—until the mill stopped grinding in 1919.

The Kane County Forest Preserve says the 65'-tall, five-story Fabyan windmill is one of the area's most photographed and popular attractions. It's open for weekend tours from May 15– Oct. 15. It's definitely the best way to glimpse authentic gear and timber work without buying a ticket to the Netherlands!

The Fabyan Windmill
1600 Chrissey Ave. (Rte. 25)
Geneva, IL 60134