March/April 2009

GEAR TECHNOLOGY

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The Journal of Gear Manufacturing

25 YEARS 1984-2009

Features

- Got Green Gears?
- Theory of Constraints—What's Holding You Back?

Technical Articles

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THE GEAR INDUSTRY'S INFORMATION SOURCE

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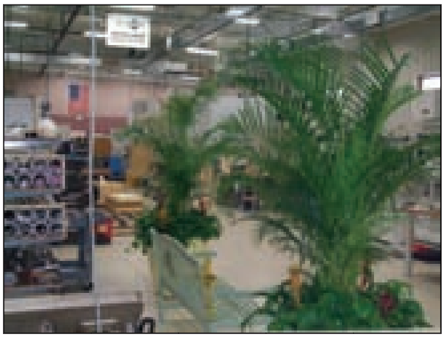

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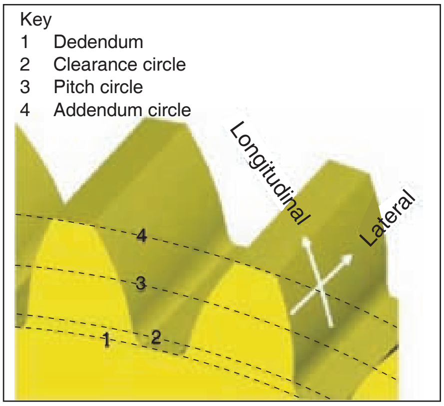

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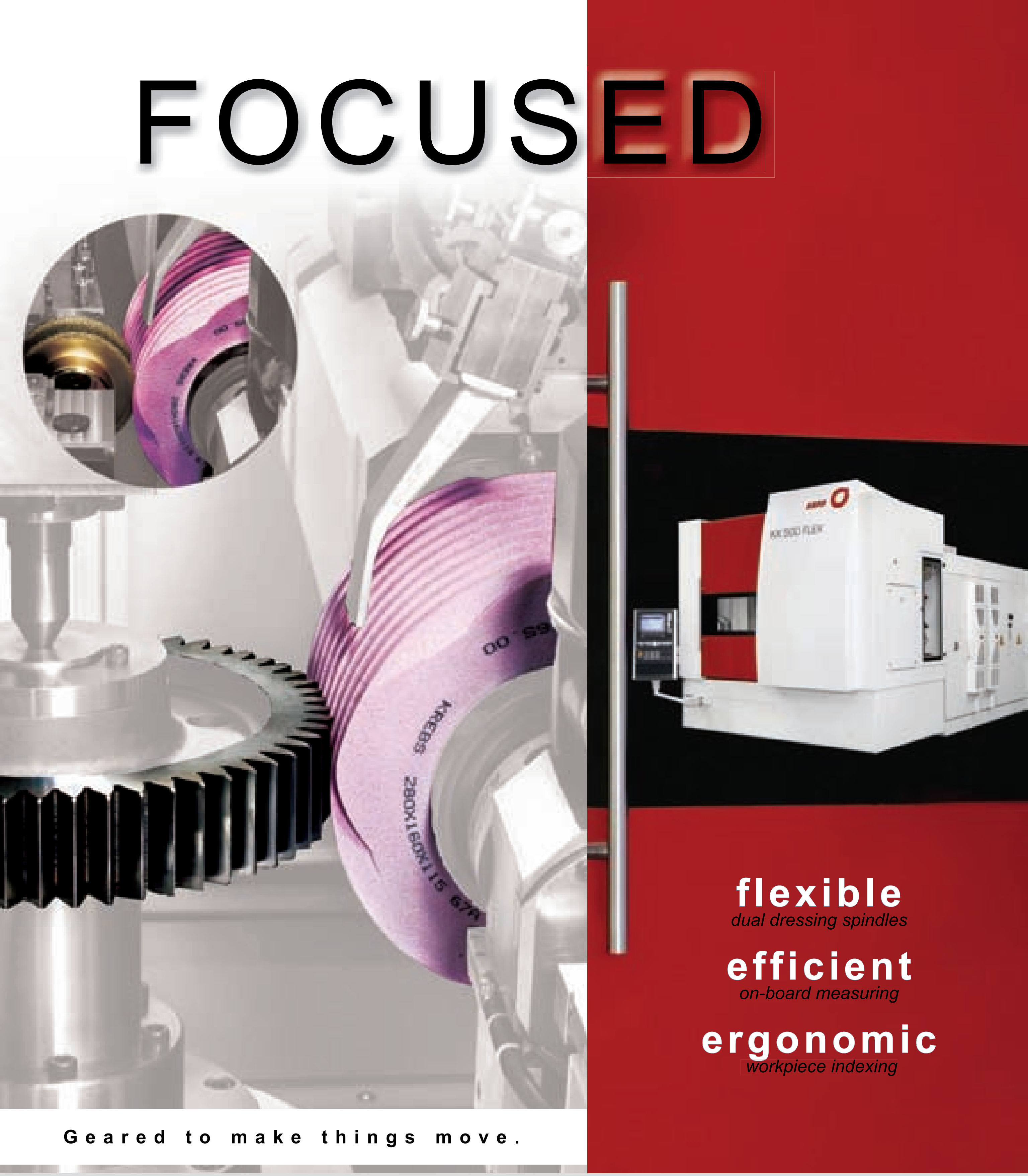
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Geared to make things move.

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GEAR TECHNOLOGY

VOL. 26, NO. 2

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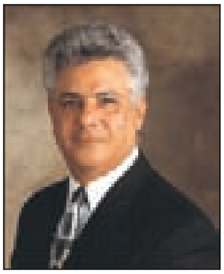
Tale of Two Gear Industries



"It was the best of times, it was the worst of times…"

Over the last couple of issues, we've happily presented you with tales of quite a few gear manufacturing companies that are thriving in these difficult times. Even though most industries are taking their lumps, these manufacturers have positioned themselves to be in the right place, with the right products, at the right time.

Many gear manufacturers we've spoken to have told us that 2008 was a very good year. "Great" was how Michael McKernin of Circle Gear described 2008 just a few months ago. "2008 is a good year," said Bipin Doshi of Schafer Gear. "My prediction is that 2008 will be our best year since 2001," said Joe Arvin of Arrow Gear in the November/December issue. Many gear manufacturers even predicted significant growth in 2009.

In our "Big Gears" issue from January/February 2009, we focused on a number of gear manufacturers who were extremely well positioned in 2008 and whose fortunes don't seem significantly diminished, even with all the bad economic news we've heard lately. Those manufacturing gears for wind turbines, oilfield operations and the mining industries seem to be not just holding their own, but thriving. "We've seen nothing but increased growth and increased demand for more and more gears for the wind industry," said Lou Ertel of Overton Chicago Gear. "I think it's about as strong as I've ever seen it," said John Schnarr of HMC. Meanwhile Nick Sudzum of B&R Gear described his company as having an 18-month backlog, and Jim Mantei of Vancouver Gear Works said, "We've never been as good as we are right now."

I have no doubt that much of the information we've presented over the past few months still holds true. There are many gear manufacturers whose business is strong and who expect it to continue to be strong throughout the economic crisis.

Now for the bad news.

On the one hand, we have companies making highly specialized gears, especially large gears, whose markets and demand seem to be growing. On the other hand, we have companies making gears for automobiles, construction equipment and other products whose demand is greatly diminished by the current economic climate. In February, Magna Powertrain announced it would be closing the New Process Gear plant in Syracuse, NY. Although there's still a chance that plant will stay open, that's 1,400 gear industry employees potentially out of work. American Axle CEO Richard Dauch called 2008 "brutally difficult." American Axle lost $1.2 billion last year. We've heard rumors of temporary closings, layoffs and even shutdowns at companies both large and small. Virtually every big company that mass-produces gears has had some kind of negative announcement over the past couple of months: GM, Caterpillar, John Deere, Eaton and the list goes on. We've also heard about layoffs, bankruptcies and plant closures at a number of much smaller companies—gear job shops and machine shops like the ones where many of you work.

In the early part of this decade, the gear industry went through a similar downturn. Many manufacturers used that slow time to look at ways to improve their operations. For example, instead of waiting for things to get better, Gear Motions turned to lean manufacturing principles to find ways of making things better on their own. One team at Gear Motions reduced customer lead time by 33 percent and setup times by as much as 30 minutes, according to the Gear Motions website. Another Gear Motions team was able to cut inventory in half.

Similarly, Micron Manufacturing of Grand Rapids, MI, won a 2008 Shingo Silver Medallion for Operational Excellence, based largely on its efforts begun during the last manufacturing slump. By implementing lean practices, Micron reduced lead time from 49 days to 12. It reduced setup times by as much as 37 percent. According to a recent article in *Cutting Tool Engineering*, Micron's Acme-Gridley department went from doing 96 setups in 3,100 hours to 285 setups in just over 1,000 hours.

Whether your company is thriving or preparing for the worst (or both), now is the right time to implement the ideas that can make you faster, more productive and more efficient. You're probably looking for ways to cut costs, save money and get more out of what you've got. That's lean manufacturing. You can't just do less of everything to effectively downsize; you need to do things differently: better and more efficiently. If you haven't begun lean initiatives, now is the time to start. If you have begun, now might be the time to reevaluate your goals and set the bar higher. Include lean thinking in your maintenance operations, your engineering department and the front office, not just your manufacturing. If you are experiencing down time, don't lay off workers. Teach them how to be more productive.

You can start by reading our article on the theory of constraints (p. 33), a tool that can help companies focus their efforts with lean manufacturing, six sigma and other continuous improvement methods.

Most companies found after the last downturn (2000-2001) that the people they let go had the skills and knowledge they needed most—and were unable to replace—when business came back. Redirect your people now so they can learn these methods. Gear Motions and Micron Manufacturing have shown that enormous improvements can be made if the bar you set is high enough, no matter if your company is prospering or struggling. Machine time is machine time, no matter where you are in the world. Being better, faster and more productive, while still retaining your quality, will make you a world-class competitor.

Now is the best time to think and act lean. When the economy improves, you'll grow faster than your competitors, you'll enjoy better profit margins, and you'll never look back.

Michael Goldstein,
Publisher & Editor-in-Chief


Shifting into a new gear
This is no time to slow down.
We are already a world leader in machine tools — now we're shifting into a new gear. Grounded in over 74 years of history, yet building on our tradition of entirely new thought, Mitsubishi Heavy Industries America is leveraging our global network to bring advances never before seen in the gear market. Advances like new machines that benefit our customers financially by reducing waste and energy consumption. Machines that ease environmental impact by operating coolant-free. We're delivering even greater accuracy, productivity, and reliability. In these exciting times, we continue to focus on our customers. With machines that share a common user interface, we help customers flatten the learning curve and reduce setup and down times. By sharing new concepts with our customers and suppliers, we both create and support the next big idea. And with gear hobbing, shaping, shaving and grinding machines to suit your unique needs, we will help you find your new gear, too. mitsubishigearcenter.com
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Machine Tool Division • Gear Technology Center
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Cutting-Edge Grinders are Great—

BUT HOW'S YOUR WORKHOLDING?

Jack McGuinn, Senior Editor

Ok—you make big gears and you've gone out and purchased, say, a spiffy Höfler Rapid 900 or 1500, or maybe a Gleason 1600. Nice move. But some owners of such machines are finding them to be almost too much of a good thing. The problem, they say, is that while their new machine is state-of-the-art, they are finding that their workholding tooling is so last-century, particularly for large-gear production. It is somewhat like buying a complex machine and not having anyone on the floor capable of running it. Capacity is key today, and the best way to ensure that you are squeezing every dime out of that new machine is to complement it with innovative workholding.

And that is exactly what Milwaukee-based Rexnord did.

"The big thing was that we purchased a Höfler rapid 900 and we realized we bought the latest and greatest technology to grind the part, yet we were putting 1920-vintage tooling on here," says Marty Kuklinski, senior manufacturing engineer, Rexnord geared products division. "What we did in the past when we'd finish grinding the gear teeth geometry, we sat them on a thrust plate or thrust ring. We would have hundreds of these different plates because the OD of the plates would have to be less than the root diameter of the part that we're finishing.

"We approached Drewco and said 'Setup is killing us, because every time we go from one part to another we have to take this plate off, put another plate on; we've got to bolt the plates in place, which is standard throughout the

Top: Drewco's workholding system in action. Bottom: The part is held in place by the activation of three pedestals (Courtesy of Rexnord).

industry."

Drewco, of Franksville, WI, had the answer.

"They asked us if we had an idea for shortening their setup time, so they gave us a family of 30 different gears—bore ranges of 3 to 12 inches—and we came up with a center pedestal setup. Because of the large range we came up with three different series of mandrills or extending collets," says Jeff Moczynski, Drewco engineer/engineering manager. "They initially wanted a big ring that the gear would rest on way out towards the root diameter of the gear. Some of these gears were six feet across and larger—for all these gears you'd have to have a bicycle rack for storing all those plates. I suggested that we use these pedestals that would be precision-ground and move them in and out on the keyways of the table. They weren't real comfortable with it at first, and the other thing they were concerned about was that with the weight of these gears, would our collet be able to center the gear to overcome the weight of it—one gear was 1,700 lbs. But manually, with just a wrench and a flange nut, we were able to turn the gears within a half-thousandth every time."

Moczynski goes on to explain that "The activation of the collet was done by means of a custom-built hydraulic nut. This was done for two reasons—one, it provided direct axial force to expand the collet as opposed to the rotating/axial force a standard nut would provide; two, due to the depth or hub width on some of the larger gears, the activating nut was deep inside the bore, thus not allowing the use of a standard wrench. Operators activate the nut by use of a T-handle allen wrench—no big wrenches or extensions required."

Rexnord was thrilled with the results—and the system's simplicity.

"These uprights (pedestals) are in key slots, and what they did was make little spacer blocks for us that located off of a central pilot," says Kuklinski. "And we just put these blocks in and slide these three uprights in place, and that positions the part like the thrust plate would under the root diameter. So now we're not changing any of these plates. We have these uprights on a fixture and, based on the root diameter, they gave us gage blocks and we just set them in, and we bump up those three uprights, bolt them down and we're ready to go.

"So, we've cut our setup time by 50 percent, if not more."

Drewco has been equally effective with other gear makers as well, Milwaukee Gear among them.

"We were using a lot of traditional manual tooling—solid bushings, clamp plates—and now we use a set of six pedestals with the expanding mandrill from Drewco," says Mike Pascavis, gear supervisor. "You put the part on, clamp it up, and it holds the part very well. It works very well on our Höfler Rapid 1500 and Gleason 1600. If you make a significant investment in a gear grinding machine or hobber, why limit yourself with your table tooling? You can cut down your cycle and setup time by investing in efficient tooling. Our old way was labor-intensive; now we'll do a 50-piece run and guys are taking only 10 to 15 minutes for setup. The savings start adding up."

Drewco's Moczynski explains that both customers were given a setup sheet for each part, so they knew what mandrill was needed with which collet. He also points out a residual benefit in that the work area is much less cluttered, especially in the number of storage racks. And speaking of capacity, the new workholding system is keeping the pedal to the metal on those new machines.

"These new grinders and hobbers—they have much higher capacity. So with our short setup times, in conjunction with better grinding equipment—they (Rexnord) gave us a whole raft of parts and they ran this machine 'out of business,' " says Moczynski. "They actually started using the older hobs and grinders, and we put them out of business as well."

Rexnord's Kuklinski certainly concurs.

"It gives us a lot more flexibility to go from Part A to Part Z because with the old system we had we would load the work up so we're not changing all those thrust plates—we'd try to almost batch the work through," he says. "Now you can run one part at a time regardless of what the next part is. The setup time is so short that we can jump from one size to another and—presto—the setup is changed and we're ready to go."

Prior to taking shipment of the Höfler, Kuklinski explains, the machine builder provided cycle times based on some test parts that Rexnord sent them. And then a light bulb went off.

"Based on (the test cycle times) and based on the machine that we were taking work off of, we saw a percentage increase (in productivity). But then we started looking a bit further when the machine was in transit and we said 'We're going to make it up in the grinding time, but we're still going to lose out in setup.' So we figured at that time that we better take a hard look at our tooling and say—'Wait a minute, we need to take another step here and move into the 21st century.'"

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marty.kuklinski@rexnord.com
www.Rexnord.com

Modultherm

EXPANDS CAPACITY

ALD and ALD-Holcroft Vacuum Technologies introduced a larger size of the ModulTherm vacuum heat treating system. The ModulTherm can now process load sizes of 36" x 36" x 72" with weights up to 7,000 lbs. Previously, the ModulTherm could only accommodate load sizes of 24" x 30" x 40" and 2,200 lbs.

"We've found justification for this size system based heavily in the wind power generation, bearing and construction equipment markets," says Klaus Loeser, vice president of new technologies at ALD-Holcroft Vacuum Technologies. "Too many opportunities have had to settle for atmosphere processing but could truly benefit from the attributes of vacuum. Now that possibility is realized."

The larger version system is available with high-pressure gas quenching, oil quenching, intensive quenching and interfaces to press quenching.

"Our ModulTherm concept has now taken another 'growth step' in maturing as the industry standard for high production vacuum thermal processing. Now more than ever, the versatile nature of the ModulTherm is needed," says Bill Gornicki, vice president of sales and marketing for ALD-Holcroft. "As load sizes and part sizes increase, choices in quenching become an absolute necessity. In conjunction with last year's introduction of five separate quenching options, the ModulTherm is uniquely positioned as the standard for automated large load processing. High volume production of large components can now benefit from the significant value of low pressure carburizing."

For more information:

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49630 Pontiac Trail
Wixom, MI 48393-2009
Phone: (248) 668-4130
Fax: (248) 624-3710
sales@ald-holcroft.com

Coating Technology

EXTENDS TOOL LIFE WITHOUT OIL

Mitsubishi Heavy Industries, Ltd. has developed a thin-film coating for applying to precision cutting tool surfaces to extend tool life at more than 200 meters per minute without using cutting oil. MHI is featuring the coating on the Super Dry III hob, which was released at the Japan International Machine Tool Fair.

The Super Dry III hob plays off the success of the Super Dry II hob, but it offers an 80–100 percent longer tool life. In order to prolong tool life in high-speed dry cutting applications, MHI focused on improving the anti-oxidation and wear resistance capabilities of the coating at high temperatures. The Super Dry III's oxidation temperature is 1,300 degrees Celsius, which is 100 degrees higher than the Super Dry II. During testing, the Super Dry III demonstrated 40 percent less tool flank wear and 80 percent longer tool life at 250 m/min and double the tool life at 300 m/min.

For more information:
Mitsubishi Heavy Industries America
46992 Liberty Drive
Wixom, MI 48393
Phone: (248) 669-6136
www.mitsubishigearcenter.com

Low-Foaming Cutting Fluid

RESISTS BACTERIAL, FUNGAL GROWTH

The KoolRite 2365 semi-synthetic cutting fluid from JTM Products, Inc. was designed for high-pressure applications that typically have foam control problems. The coolant is made with mineral oil and extreme pressure additives for use on cast iron, all steels and non-ferrous metals except magnesium.

Performance on aluminum materials has exhibited the most significant performance improvements, and the coolant performs without staining non-ferrous metals while protecting ferrous metals from corrosion. It does not remove paint or damage machines or seals. Using the JTM BioArmor technology, the Koolrite 2365 resists bacterial and fungal growth resulting in long sump life and avoiding unpleasant aromas that often result from such fluids.

For more information:

JTM Products
31025 Carter Street
Solon, OH 44139
Phone: (800) 229-6744
Fax: (440) 287-3095
sales@koolrite.net
www.koolrite.net

Electrically-Heated Quench Tank

CURES PRODUCTS POST HEAT-TREAT

The Number 974 insulated quench tank from the Grieve Corporation is electrically-heated to 200 degrees for heating mineral oil to cure metal products after heat treating. The dimensions of the tank are 22" x 22" x 26" with one-inch insulated walls and an insulated, removable cover that hangs off the front of the tank. The unit is heated by 6.4 kw Incoloy-sheathed tubular immersion heaters, and a 1/3 hp motorized agitator is responsible for fluid motion in the tank.

The Number 974 has digital temperature controllers, manual reset excess

continued

temperature controllers with separate contactors and a fused disconnect switch. The tank has a type 316 stainless steel interior and exterior with a brushed finish. The Grieve quench tank includes a stainless steel workload basket with a removable handle that sits on top of the unit during quenching, and a basket support holds the basket above the quench oil for quick draining.

For more information:

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500 Hart Road
Round Lake, IL 60073-2835
Phone: (847) 546-8225
Fax: (847) 546-9210
www.grievecorp.com
sales@grievecorp.com

Slender Drive Angle Head

MACHINES BORES MORE FLEXIBLY

BIG Kaiser's Slender Drive Angle Head features a reduced body that is capable of 90-degree cutting operations inside small bores. The latest product in BIG Kaiser's Profit Maker series is offered in CAT40/50 and BT40/50 tapers standard with a dual contact interface. The angle heads change cutter angles without altering the workpiece position.

There are three small diameter and three large diameter output attachments, six total, of varying lengths. The smaller diameter outputs access bores starting at 1.181" in diameter and the larger outputs handle bores up to 1.575". Each output comes with an attachment capable of cutting a tool centerline up to 4.921".

The Slender Drive's maximum speed is 2,000 rpm, and it is designed for drilling and light milling operations.

For more information:

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641 Fargo Avenue
Elk Grove Village, IL 60007
Phone: (847) 228-7660
Fax: (847) 228-0881
bigkaiser@bigkaiser.com
www.bigkaiser.com

Face Mill

WITHSTANDS HEAVY-DUTY OPERATIONS

The CoroMill 360 from Sandvik Coromant is a 60-degree face mill constructed with through-hardened steel for strength in demanding applications. The cutter inserts are wedge clamped with a quick release for cutting to depths of .709" or 18 mm with high feed per tooth. They are housed in an exchangeable cassette system with precise location to ensure cutter accuracy. The inserts have four edges with wide parallel land and strong edge geometry for high surface finish quality, giving a light-cutting performance.

The CoroMill 360 inserts are available in 19 mm and 28 mm, and both sizes use the same cutter body to minimize tool inventory. They can be easily removed by turning a wedge screw. They come in diameters from 160–500 mm in close and extra close pitch design as well as Arbor and CIS Arbor shank styles.

For more information:

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1702 Nevins Road
Fair Lawn, NJ 07410
Phone: (201) 794-5223
Fax: (201) 94-5217
www.coromant.sandvik.com/us

End-of-Line Crankshaft Gage

INSPECTS ALL CRITICAL TOLERANCES

Adcole Corporation introduced the Model 1300 high-speed crankshaft gage, which allows the horizontal axis to help automatic loading with cycle times under a minute and sub-micron accuracy for three-micron roundness tolerances. The gage provides QS 9000 and Q1 quality verifications and allows statistical production control of journal grinders for diameter, roundness, third harmonic analysis, cylindricity, straightness, stroke and index. The gage provides 100 percent inspection of critical tolerances.

The model 1300 high-speed crankshaft gage is designed to operate two to three shifts a day; it has a granite surface and uses touch-screen control technology and optical linear scales.

For more information:
Adcole Corporation
669 Forest St.
Marlborough, MA 01752-3067
Phone: (508) 485-9100
Fax: (508) 481-6142
www.adcole.com

Cutter Inserts

GENERATE LOW PRESSURE, STRESS

The X700 milling cutter inserts from ATI Stellram are coated with TiAlN by PVD for use in milling stainless steel and titanium alloys while operating at low pressure and stress during machining. As the latest addition to the X-Grade Technology series of inserts, the X700 is suited for high cutting speed and low cutting feed.

The inserts resist thermal cracking and propagation, and they allow metal removal rates three times higher and longer tool life than traditional cutting tools. The X700 Grade inserts are available in square, round and octagonal styles.

For more information:
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1 Teledyne Place
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Fax: (800) 223-2219

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Hennig, Inc.'s mobile chip conveyor enables shops with auger chip processing machine tools to use large chip bins or 55 gallon drums instead of small chip cans. The unit helps with higher production auger fed chip loads because it can be rolled around the shop. A variable speed drive provides added efficiency to the standard 110 volt current used. The receiving chip chute can be adjusted and positioned for front, side or rear discharge.

Gleason Publishes

BILINGUAL GEAR ENCYCLOPEDIA

The 462-page *Gleason Gear Encyclopedia* is a comprehensive resource of technical terms applied to the gear engineering and manufacturing industry. Published by Gleason Corporation and written by Dr. Hermann J. Stadtfeld, vice president of research and development, the book is divided in two major sections, English/German and German/English.

Stadtfeld spent five years researching this project with the collaboration of four colleagues.

The encyclopedia includes proper technological terms, formulas, definitions and appropriate translation in both languages. Terms are complemented by corresponding color illustrations, diagrams, formulas and photographs. Two smaller volumes are also available that include conversion tables and factors and a Gleason technical poster gallery.

"The (*Gleason*) *Gear Encyclopedia* is a logical progression of one of my earlier works, the *Gleason Gear Dictionary*," Stadtfeld says. "This time, I wanted to provide the industry with a much more comprehensive and easy-to-use reference book that will be beneficial not only to gear engineers, but to the gear industry as a whole."

Stadtfeld has authored several other gear industry publications, including *Handbook of Bevel Gears* (1993), *Bevel Gear Technology* (1994), the *Gleason Gear Dictionary* (1994) and *Advanced Bevel Gear Technology* (2000).

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KAPP NILES

The ZP 40 grinding machine features the ultimate in design construction with true hydrostatic guideways and rotary table. The work table is direct drive. Nodular cast iron is used for the machine beds, columns, and all sub-assembly housings, for stability. The machine accuracy is therefore assured for a long lifetime.

The ZP40 is designed to profile grind spur and helical external and internal gears using dressable corundum or sintered grinding wheels. An integrated measuring device further increases machine's flexibility. The ZP machine can be set up to accommodate application-specific requirements for maximum flexibility, high precision and optimum productivity.

It is specifically designed to accommodate shaft pinions, mating bull gears and internal ring gears.

Extended capacity for gears and profiles is:

- External grinding capability to 50 module (0.5 DP)
- Internal grinding capability to 25 module (1.0 DP)

KAPP NILES

NILES ZP 40

Tip diameter max.	4,000 mm (157.48 in.)
Distance rotary table – grinding wheel min. /max.	435 / 2.260 mm (17.13 / 88.98 in.)
Number of teeth	any
Profile depth external	100 mm (3.94 in.)
Module-External (at tooth height 2,25 x mod. max.	50 mm (0.5 DP)
Module-Internal (at tooth height 2.25 x mod)	25 mm (1.0 DP)
Helix angle max.	40 deg.
Stroke length max.	1,550 mm (61.02 in.)
Rotary table- load max.	40,000 kg (88,000 LBS)
Table diameter	2,250 mm (88.58 in)
Bore diameter x depth	1.365 x 265 mm (53.74 x 10.43 in.)
Grinding wheel- diameter max.	500 mm (19.69 in.)
Dressable diameter min.	220 mm (8.66 in.)
Width max.	130 mm (3.94 in.)
Speed max.	2,200 RPM
Driving power max.	40 kW

The Changing Industrial Landscape

COMPANIES WEIGH IN ON GREEN TECHNOLOGY AND SUSTAINABILITY EFFORTS

Matthew Jaster, Associate Editor

Gleason Cutting Tools installed a centralized chiling system to conserve energy and reduce shop floor costs (Courtesy of Gleason).

What makes a gear green? How can energy efficiency lead to more profitable cutting tools? Why is sustainability the word of the day? These are questions that have recently been discussed in manufacturing boardrooms across the country. While green technology has been utilized to some degree by manufacturers for decades, corporate leaders are realizing its full potential in 2009. It's no longer a question of why such programs should be implemented, but how companies can most effectively practice what they preach.

In a manufacturing industry that deals with heat treating, lubrication and a plethora of waste materials, it's difficult not to be skeptical when higher-ups preach environmental awareness. However, even the most industrious tree hugger can't fault a company for doing everything it can to reduce its environmental impact. In today's economy, even the smallest contribution has remarkable results.

Facility, safety, human resource and operations personnel have added "green guru" to their growing list of day-to-day responsibilities. It's simply a sign of the times. Understanding the need for sustainability and energy efficiency has allowed these initiatives to get the boardroom face time they justifiably deserve.

Lean, Green and Remarkably Clean at Gleason

Sustainability has always been a part of Gleason's worldwide business philosophy. Each plant has an individual representative on its global sustainability team that monitors and communicates environmental issues. This team is made up of facility managers, environmental engineers, IT managers, supply chain directors, development engineers and controllers. The global team receives its strategic direction from a committee made up of Gleason senior staff members and the team regularly reports plans to the entire global staff.

Tom Sawyer, facility manager at Gleason Cutting Tools, is the designated representative at the plant in Loves Park, IL.

"Green manufacturing has different phases throughout a product's life cycle, and it takes a holistic approach," Sawyer says. "Products are evaluated not only for efficiency but the multiple reuses of the product. We then consider the types of materials and chemicals used in the manufacturing process and what impact they might have on the environment."

The non-direct aspects—building and grounds, lights, heat, air conditioning, air quality, housekeeping, transportation and packaging—are then evaluated by using the 3 Rs (reduce, reuse, recycle), according to Sawyer.

"When the product reaches its end life, we ask how we can recycle it at its highest potential," Sawyer says.

Environmentally sound manufacturing starts in the break room at Gleason, where an in-depth bulletin board focuses on issues regarding sustainability and ISO 14001, an environmental standard that is requested by many of Gleason's customers.

"ISO 14001 is recognized globally and audited by a third party registrar, showing our commitment to prevent pollution through continual improvement," Sawyer says.

The objective of the bulletin board is to keep the staff of the entire plant updated on the sustainability goals of the organization.

"Our commitment to green technology was first demonstrated in 2001 when our first facility was registered to the ISO 14001 standard," Sawyer says. "Today, we have programs in place that address operational procedures, green manufacturing, green building design, lean manufacturing, and recycling. We work with our vendors and suppliers daily to find new ways to reduce, reuse and recycle."

In addition to ISO 14001, Gleason is involved in green heat treating as well as new machine technology that produces products with less energy and waste. The company also follows

continued

Forest City Gear created a green plant area in the middle of the shop to promote green manufacturing (Courtesy Forest City Gear).

Ronson Gears has focused for many years on technology and has now also turned its attention to sustainability (Courtesy Ronson Gears).

Forest City Gear installed a *Big Ass* fan on the shop floor to assist with cooling (Courtesy FCG).

KAPP Technologies is headquartered in Boulder, CO, an eco-friendly city with several green initiatives (Courtesy KAPP Technologies).

LEED (Leadership in Energy and Environmental Design) practices, a whole building and site approach to sustainability.

Active recycling programs include scrap metal, cardboard/paper, inks, cathode ray tubes, e-waste (cell phones, printers, monitors, etc.), oil reconditioning, coolant waste water, light bulbs/lamps, batteries and ballasts, waste oil, solvents, rags, absorbent quill pads, hand towels, packaging reuse program/recyclable packaging material, sand media reclaiming for heat treating, refrigerant reclaiming and aluminum can collection.

In the case of the Gleason plant in Illinois, one can merely take a stroll through the plant's heat treating department to see how far the company has come. The heat treating today is a far cry from the methods utilized in the past. Clean floors, oil-free machines and various lean principles solidify Gleason's stance on green manufacturing.

"With the growth of alternative energy and environmental awareness, it is in our best interest to show our commitment to green technology and environmental sustainability as it makes eco-business sense," Sawyer says.

In the near future, the company plans to create a larger role for sustainability and energy efficiency on its website as well as establish a broader green strategy within the organization.

"Creating a 'green brand' is a new marketing effort that is currently the focus of senior management," Sawyer says. "As it stands now, each plant shares its best practices and ties all the resources of Gleason together, from design and purchasing to manufacturing and quality."

Ronson Gears: Sustainability at Square One

Ronson Gears began in Melbourne, Australia as a small workshop that in 1954 included a lathe and a gear hobbing machine. Through the years, the company dedicated itself to learning the latest developments and trends in gear manufacturing and has earned an impressive reputation as a leading gear manufacturer in Australia with global ties to the gear community.

Gordon New, managing director at Ronson, has recently championed the green technology movement by simply reducing as much waste as possible that affects the environment.

"If a company is known to be green, then it may be favored with orders ahead of competitors that are not," New says. "Customers may be charged less due to their supplier's reduced operating costs."

Ronson is in the early stages of green manufacturing initiatives but is focused on several key areas moving forward.

"Initiatives are in place including recycling cutting oil, scrap metal and paper. Skylights mean less reliance on artificial lighting, thereby reducing our carbon footprint," New says. "The heat generated from our shop floor is being retained within the factory area to reduce reliance on artificial heating in winter."

In the near future, the company plans to reduce the need for air conditioners in the summer by installing external sun blinds. It also plans to install water tanks to collect rainwater from the factory roof to be used for flushing toilets. The continuation of lean initiatives will reduce process times, thus saving more energy.

Ronson has dedicated many years to the most advanced technology and equipment in the gear industry. This, alone, leads to a huge energy savings and a commitment toward sustainability.

"A staff can really achieve job security by being involved with a company that follows these directives," New says. "However, some initiatives are expensive and their introduction is delayed due to lack of funds. It also takes a long time to educate the entire workforce and get their involvement. We would like to address these actions faster, but a limitation of resources means a slow but steady approach."

It's Always Green at Forest City

Forest City Gear's approach to sustainability and energy efficiency began with the realization that new equipment increased productivity and created higher quality products. Simply by purchasing the latest machine innovations, CEO Fred Young was able to make a significant energy savings.

"Fred's always been active in regards to new technology, trying to get state-of-the-art equipment that works better than the old machinery," says Larry Cass, safety manager at Forest City Gear. "These new machines today run faster and create a far cleaner working environment."

Cass, in addition to his work as a safety manager, oversees many of the green business practices that have become part of Forest City's daily operations. These include bottle and paper recycling programs, reusing packaging materials and maintaining light and heating initiatives.

"There's always a bit of skepticism at first when you try to disrupt people's daily routines," Cass says. "Anytime you impose something that's different, people seem to be less enthusiastic. But we're seeing a more conscientious push from the entire staff to follow these guidelines."

As an avid sportsman, fisherman, hunter and wildlife advocate, Young has made an effort for many years to promote sustainability at Forest City.

"We try to get everyone involved in green technology, from the top to the bottom, by creating a certain mindset," Young says. "We've been coordinating some of these green efforts here for 25-30 years. It's simply about being as efficient as you can possibly manage."

Whether it's recycling chips, changing lights or installing an

continued

obnoxiously large ceiling fan, Young notes that the small, creative steps are just as important as the larger projects. Shutting off the lights during lunch breaks, planting fruit trees behind the manufacturing plant and adding vines that assist in cooling the manufacturing floor during the summer are a few noteworthy things that Forest City has done to promote green manufacturing.

Young even created a green plant area in the middle of the shop with a park bench where employees can take a break. It was something he discovered while visiting a gear manufacturer in Italy.

"This isn't a complete solution, but it's a great start," Young says. "If everyone pitches in one way or another, even these small steps can be very significant. We want to be a good citizen as a corporate entity as well as individuals."

And what's the payback for some of these green programs?

As a result of shipping out small, recyclable containers to its customers, Forest City regularly receives new shipments in the same containers. Even customers not affiliated with Forest City have received the containers that prominently display the Forest City logo.

"You cut down on shipping costs and there's also the benefit of free advertising," Young says. "The message seems to be working."

Once employees are fully acclimated into the green culture, savings can be significant for lighting, heat and cooling expenses.

Cass adds, "Many of our employees are doing some of these green directives in their own homes, and they've begun to do the same in the office. It's as simple as turning off the bathroom lights when no one is using it."

For the record, during a recent tour of the Forest City Gear facility, the bathroom lights were, in fact, turned off and areas of the manufacturing floor not being utilized remained dark to conserve energy.

In an effort to strengthen green technology at Forest City, Young would like to install solar panels on the roof and purchase a modest-sized wind turbine.

"We fancy ourselves to be on the cutting edge, so the next step for us would ideally be in the alternative energy sector," Young says.

Both Young and Cass are in the process of going back through Forest City's history to attempt to tie in sales with these various green initiatives.

"A $16,000 savings on the electric bill gets our attention," Cass says.

Meanwhile, Young just wants to know that the efforts Forest City makes to improve sustainability and energy efficiency can be done without raising prices.

"This is the real challenge and it's what Forest City is focusing on."

continued

Sustainability: Start Small, Think Big

Companies both large and small sometimes struggle to get innovative directives in place on the manufacturing floor that promote energy efficiency and sustainability. No company can become lean and green overnight. It takes time, money and plenty of resources. Here's a quick look at some green initiatives to consider:

BUILDING & OPERATIONS

- Energy efficient lighting system
- Energy efficient heating/AC units
- Ceiling fans for cooling manufacturing floor
- Roof insulation projects
- Skylights and sun-reflecting covers
- Plant trees, shrubs and plants all around the grounds
- Tinted windows
- Centralized chilling system for machines
- LEED (Leadership in Energy and Environmental Design) practices *www.usgbc.org/DisplayPage.aspx?CMSPageID=222*
- ISO 9001:2000/ISO 14001:2004 *www.iso.org/iso/home.htm*
- New machine technology
- Green heat treating: zero waste, computerized controls
- Lean manufacturing principles: kanban, kaizen, total productive maintenance (TPM)
- Visual management for light usage (turn lights off during lunch, keep unused areas of the manufacturing floor dark)
- Adjust heat/air on weekends and major shutdowns
- Check frequently for air leaks in the building
- Replace bottled water service with filtered tap water
- Hybrid vehicles for company use
- Diesel trucks for delivery

RECYCLE

- Spin oil out of chips
- Separate various types of scrap metal
- Cardboard and mixed paper
- Aluminum cans
- Plastic bottles
- Shrink wrap
- Reuse solvents
- Reuse packaging materials
- Use absorbent quill pads, rags and hand towels
- Cell phones, printers, circuit boards, monitors, etc.
- Inks for printers
- Oil reconditioning/Waste oil
- Batteries and ballasts
- Sand media reclamation
- Refrigerant reclamation

KAPP Serves Eco Rich Community

KAPP Technologies has had environmentally safe practices in place since the Boulder, CO facility was first built in 1992. The building was designed and constructed without floor drains, eliminating the potential hazard of plating chemicals or waste getting into the local water and sewer systems. All spent chemicals are stored in double containment tanks for periodic disposal utilizing licensed waste haulers and facilities.

Along with paper products, magazines, cardboard, wood, cans and plastic, the company recycles batteries, cell phones, computers and office electronics. They have also been creative with other materials. Instead of discarding old letterhead, for example, employees converted them into office note pads. Lights are kept off in unused areas of the building including common areas.

"As sustainability practice grows, the demand for manufacturers who are part of the solution increases," says Jim Buschy, vice president and general manager at KAPP. "For example, the wind energy market is growing rapidly and many of our customers' end-users will be manufacturing more and more gearboxes. This means that we must make our customers aware that we have the ability to do this kind of work."

Last year, KAPP launched the Rocky Mountain Gear Finishing School. As part of the program, the company took the group to the National Renewable Energy Labs for a tour of the gearbox facility.

"This helped our customers identify new wind energy technologies in development and it gave us the opportunity to present our machines as a possible solution for their production needs," Buschy says.

Boulder itself has been in the business of sustainability for many years. Eco-programs offer public transportation alternatives and a drop-off site for hazardous waste materials. It was one of the first cities to offer curbside recycling back in 1976. In 2005, a zero waste resolution was passed to support the county's sustainability efforts. Carbon gas emissions released by industrial processes in Boulder represent only five percent of the city's total. The Boulder Energy Strategy Task Force oversees programs in areas of conservation and offers rebates and incentives for energy efficiency practices.

As the city continues to look for ways to participate more in sustainability efforts, KAPP follows suit.

"We are focused on what's important to our customers; machine tools that will serve their requirements and offer efficiency, time-saving technology and increased productivity. All of these factors contribute to overall green technology," Buschy says.

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Correction: In the Jan/Feb 2009 issue of *Gear Technology*, information was omitted from Table 3 (p. 66) of the technical article "Gear Failure Analysis Involving Grinding Burn," written by G. Blake, M. Margetts and W. Silverthorne (p. 62). For the full technical article please visit *www.geartechnology.com/issues/0109/*.

Table 3—DOE Test Matrix with Post Etch Results.

Test	Ammonium Persulfate %		HCl %		Detection of Etch Indications
1	18.6	Max	9.0	Max	↑
2	18.6	Max	3.0	Min	↑
3	6.0	Min	9.0	Max	→
4	6.0	Min	3.0	Min	→
5	9.1	Typical	6.0	Typical	↗
7	6.0	Min & min time	9.0	Max and max time	↘
8	6.0	Min & min time No glass bead	9.0	Max and max time	↓

Got Lean? Six Sigma?

HERE'S ANOTHER THEORY

Jack McGuinn, Senior Editor

Most readers are at least familiar with continuous improvement programs such as lean and six sigma. Perhaps your shop or company is well along in the implementation of one or the other—if not both. But what about theory of constraints (TOC), introduced in Dr. Eliyahu Goldratt's 1984 book, The Goal*? Despite its rather negative-sounding name, this continuous improvement process has much to offer manufacturers of all stripes. And when combined with lean and six sigma, the results can be dramatic. Dr. Lisa Lang, a TOC consultant and speaker, explains why and how in the following Q&A session with* Gear Technology.


Dr. Lisa Lang

How would you define the theory of constraints ?

Theory of constraints (TOC) is a holistic management process that identifies an organization's system constraint, then systematically exploits and/or elevates it to reach a higher level of goal attainment. In a for-profit business, the goal is to make more money now and in the future. The constraint (most businesses have only one at a time) is what's limiting the business from making more money. One example is market restraint. You can have plenty of capacity internally, but you don't have enough orders to use all or the majority of that capacity.

TOC advocates strategically placing your constraint (instead of chasing it around) and then focusing management attention and company resources on leveraging it. Consider that before this recession (manufacturers) would know where their bottleneck was. But because most manufacturers followed conventional wisdom—which is to balance capacity—their constraint is constantly moving. If you have balanced capacity, meaning the same average capacity at each step, and then a big slug of work comes in, the constraint then moves from one step, to the next and to the next, depending on the mix of work and what just came in. By strategically placing the constraint and unbalancing capacity, you make it easier to leverage the thing that is limiting your ability to make money. You can't leverage a moving target. If your constraint is constantly moving, it's really difficult to leverage it. Most manufacturers are more accustomed to chasing the constraint in operations, but are less experienced when it comes to leveraging market or cash constraints.

There are different ways to leverage, and the key is that the more the constraint stays in one place, the easier it's going to be to leverage. A financial example of leveraging a constraint is throughput per constraint unit—How many dollars will I generate for how much of my constraint time? We look at how much throughput will we generate with this job, and how much of my scarce resource constraint capacity will it take to do that. If the amount I can get out is dependent on my constraint, then what I want to do to maximize my profits is get the most throughput dollars per unit of constraint time.

Why isn't TOC as popular as lean?

Except for the CEO, most managers have limited spans of responsibility and control. Cost management and cost reduction are valid objectives for these managers. Lean has excellent tools to accomplish cost reductions and local process improvements; so does six sigma. This is something a manager can do within his or her own silo (e.g., operations, engineering, etc.) without the need for a lot of coordination with other silo managers.

So if you don't have involvement from the top, a manager within a silo can only go so far. Dr. Eliyahu Goldratt, the developer of TOC, wants TOC to be the main way of managing organizations. He has thought about your question for a long time. His answer is that TOC requires multiple paradigm shifts (e.g., cutting work in progress (WIP), a change in accounting practices [see below], etc.) from any person and organization that implements it. TOC has a solution for most every aspect of organization management, most of which are counterintuitive, and often require doing the opposite of what we were taught (common practice and conventional wisdom) and in coordination with other silo managers. Hence, there are multiple paradigm shifts required to *fully* implement, including:

- ***Drum-Buffer-Rope***—A scheduling system for WIP operations and/or sales processes. Drum: the rate at which the work moves through is the constraint, and sets the rate at which work can move through the system—like a drumbeat; Buffers: protect the drum from running out of work, protecting the constraint, and a shipping buffer protects our due date commitments; Rope: how new work is released into the process, because what we want to do is release new work into the process at the rate that the constraint/drum can actually consume it.
- ***Critical Chain Project Management***—The process of applying the drum-buffer-rope concepts to

continued

a project environment.

- ***Throughput Accounting vs.Cost Accounting***—Cost accounting is old technology. Throughput accounting is what TOC uses instead of cost accounting. It is used for financial decision making—"Should I take this order or not?" "Should I buy this piece of equipment or not?" Throughput is the sales dollars we generate minus what we had to pay for raw materials or outside services (heat treating, e.g.) and sales commissions. So when we talk about throughput, we're talking about dollars.
- ***Mafia Offer***—For exploiting a marketing and/or sales presentation constraint (***See below and Drewco sidebar for more on mafia offer.***)

Can TOC work with lean and six sigma?

Yes! TOC, lean and six sigma share an interest in defining and improving processes. TOC has no equivalent to the toolkits represented by lean and six sigma, and they have no equivalent to the focusing process provided by TOC. So, the initial steps are provided by TOC, meaning the definition of the organization's goal and identification of the system's constraint. Lean and six sigma help with the next step, which is exploiting the constraint. In TOC, "buffer statistics" will highlight the weak part of the process. Buffer statistics are simply regular data that are applied to the buffers in front of the constraint and at shipping. The buffer, remember, is the mechanism that ensures that the drum—or work rate—is not interrupted, thus protecting the constraint. Buffers absorb variability and are the mechanism that ensures we don't starve the constraint or miss our due dates.

Lean and six sigma usually have specific tools that will rapidly improve the weakness. Perhaps it is setup reduction on a key piece of equipment, or reduction of variability of a key step in the process. No organization has unlimited resources. Focusing where and when to apply lean and/or six sigma is high leverage.

Recently, an analysis was conducted in a large company where some plants used lean in isolation, others six sigma in isolation, and others where TOC was combined with lean and/or six sigma. The most significant improvements were with the combination of all three. You can read that article here: *http://www.scienceofbusiness.com/Portals/0/2006MayTLSArticle.pdf*.

Your "mafia offer boot camp," what is that, and how does it work?

Initially, Dr. Goldratt defined a mafia offer as "an offer so good that your customers can't refuse it." I extended the definition as follows: "An offer so good that your customers can't refuse it and your competition can't or won't offer the same." A mafia offer typically requires that you do something different (make operational improvements) to actually deliver something (that can't be refused) to your customers, and something that your competition can't or won't do because they are not willing—or don't know how—to make the same improvements. Most companies offer solutions that solve their customers various problems or symptoms. With a mafia offer, we are addressing our customers' core problem.

When most of us are presented with a concept, particularly if it is not one we developed, we have this wonderful ability to think of all the reasons why it won't work. So if you read about the process to create one (mafia offer), you would simply do what we all do—come up with all the reasons why it won't work for you. During the boot camp, you and your team build your mafia offer. You know your company, your competitors and your customers best. We combine your knowledge with a solid process to facilitate and guide you to develop the offer that will not be refused by your customers, but something your competition can't or won't do. We usually know we are on track when your team is worried about being able to deliver the offer. During a mafia offer boot camp, we start over with fresh eyes and a fresh look at your business—and this is something you can't read about or someone can't just tell you about.

One of the most difficult things about implementing lean is securing a complete buy-in from top management/ownership. How do you go about doing that with TOC?

It must be led by the CEO. A CEO that wants to dramatically increase the bottom line of the company must have the collaboration of the top management team. To gain collaboration and to communicate what must be done, we use a strategy and tactics tree. What's a strategy and tactics tree? It is a concise explanation of what needs to be done throughout the organization to meet the company's goal. And while it is concise, it is also perfectly clear what needs to be done in each silo, at each level, which is very powerful. People don't really resist change. They resist what they don't understand or what they think will have a negative effect on them personally. We don't see "resistance" to change when we use a strategy and tactics tree with strong leadership. This tool is how/why we can achieve results very quickly, even in large organizations.

Are there any start-up costs with implementing TOC?

No. TOC is about leveraging the people and resources you already have. In *The Goal*, the elevate step (the step associated with spending money) is step No. 4, and in many cases we don't need to elevate until we have substantially grown sales. TOC should be self-funding and self-resourcing if you implement it correctly. When we start working with somebody, one of the things we have them do is cut their WIP in half. As soon as they do that, there's less stuff to deal with; (clients) resist it, but that's the first step. When you do that—i.e., self-resourcing—you'll free up some time. You'll absolutely free up some cash—self-funding—and with this free time we go to the next step. And we organize the implementation in such a way that the first actions produce huge results. Getting big results quickly also helps with the buy-in. So cut the WIP in half, just focus on what's started (on the floor)—and all of a sudden you're shipping more stuff, invoicing on a regular basis, getting more cash—with the same resources.

continued

An Offer a Godfather Would Love

As mentioned in the Q&A, Drewco, a Wisconsin-based tooling company, began implementing TOC in 2006. And, as also mentioned, they started with a mafia offer to their customers. But aside from the benefits to buyers, the offer also served to focus Drewco's attention internally on identifying their constraint and doing what was necessary in order to deliver on the offer. (*For more information on how the mafia offer served as an internal, process change agent at Drewco, please see the accompanying Q&A—Ed.*)

So what was the Drewco offer that promulgated change internally and was deemed by the company as unrefusable?

Everyone knows that in this crazy economy there is a razor-thin line that separates the winners from the also-rans—everyone is looking for an advantage. Well, how about improved lead time? Drewco focused on that and implemented an on-time and rush delivery system backed up by meaningful rebates for noncompliance.

The highlights:

- All delivery times are guaranteed, backed up by a minimum 10 percent per day rebate for late shipments.
- Rush delivery is always available. Rush deliveries are backed with an even higher guaranteed on-time rebate.

In other words, if a standard order is submitted and the shipping date is one business day late, the customer then pays 90 percent of the originally quoted price. (*See the accompanying charts for more information—Ed.*)

That's a pretty nervy offer, but it's one that Drewco is comfortable in making as a result of their internal improvements via TOC implementation.

"We have found (TOC) to be a highly effective method to get fast results," says Richard Pettibone, Drewco president. "It is a more-targeted and often-counterintuitive method that can quickly yield significant benefits."

Indeed, post TOC implementation, Pettibone says Drewco "improved from accepted industry performance of 40-50 percent on-time delivery, with an average of two or three days late, to being consistently over 95 percent on-time and zero days late. This new performance gave us greater manufacturing capacity to sell."

Going forward, Pettibone says in addition to the guaranteed on-time delivery program, TOC has enabled Drewco to reduce its standard delivery lead time. It has also reduced production lead time from six to three weeks, "with the same guaranteed and rush delivery still available."

For Drewco, at least, TOC is more than a theory. It works.

— *Jack McGuinn*

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Typical quote options:

Collets			
Example: Collet Delivery Options			
	Standard Delivery	Rush Delivery	Express Delivery
Order Lead Time	3 Weeks	2 Weeks	1 Week
Selling Price	Standard	Rush	Express
Rebate	10% / day of selling price	20% / day of selling price	30% / day of selling price

Arbors, Mandrels, & Chucks			
Example: Fixture Delivery Options			
	Standard Delivery	Rush Delivery	Express Delivery
Order Lead Time	8 Weeks	5 Weeks	3 Weeks
Selling Price	Standard	Rush	Express
Rebate	10% / day of selling price	15% / day of selling price	20% / day of selling price

Tombstones & Machine Center Fixtures

- Our typical standard delivery time on these fixtures is 10 to 12 weeks.
- Our delivery on these fixtures is also guaranteed and backed by our "guaranteed on time rebate."
- Due to the varying nature and complexity of these type of fixtures, please call us for delivery options and rebate percentages.

What would you say to those who believe being lean is sufficient without TOC?

Lean tells us to reduce waste—but where?—everywhere. And an 80/20 rule is used to decide the order of this improvement. Once you understand TOC, you realize that there is one place where you should focus management time, attention and your resources to have the biggest bottom line impact. Using TOC to focus these efforts is more like using the 99/1 rule, and you can get bottom line improvement (real ones) much faster. In addition, throughput accounting will help you to make decisions that will have an incremental bottom line improvement. This is much more difficult to do with cost accounting or lean accounting. So, we use TOC, lean and six sigma in combination.

What are some of the more common constraints that affect a manufacturing organization?

Dr. Goldratt recently declared that the most common organizational constraint worldwide is management attention. Keeping management focused on doing what needs to be done—and not doing what doesn't need to be done—is a real problem. Beyond that, more than half of all manufacturing organizations are limited by sales. They could produce more, if only they could get the sales. So that's a market constraint, which we overcome with the mafia offer. The rest have some form of internal constraint which, when addressed, usually goes away quickly, and then the constraint is again lack of sales. Internal constraints are typically an overloaded department, where the demand placed on it is greater than its capacity. The challenge that many of your readers face is that they have a highly complex environment. An environment where the mix changes dramatically, and where the variability is high, usually results in a situation where the constraint moves day-to-day or week-to-week. And how do you leverage a moving target? We've worked with a number of highly custom, complex job shops and have created a TOC solution specific for these situations. We call it a velocity scheduling system (VSS). It is a system similar to drum-buffer-rope, but customized for the starting conditions of highly complex job shops. But, if you are not using VSS, it is most common for you to be chasing your ever-moving constraint around.

Please discuss your work for Drewco in implementing TOC.

We started working with Drewco at the end of November 2006. We started by creating a mafia offer, even though they had an internal constraint at that time. Why? The offer will dictate the strategy and tactics, or another way to say it: The offer will indicate where we need to improve and by how much. And by starting with the offer, the operational improvements happened much faster because we had a reason to change, and everyone was excited about the offer.

After creating the mafia offer, we developed the full strategy and tactics tree. This was communicated throughout the organization. Within one month, Drewco had improved their due date performance from 39 percent (on first date

continued

given) to 100 percent for the collet part of their business. And velocity through the shop went from 19 days to 6 days—or 217 percent.

This improvement was accomplished by doing just the first step from the strategy and tactics tree. So we accomplished the "big results, fast" idea I mentioned earlier. From there, Drewco applied the concepts to the workholding side of their business with similar results, and then continued implementing. Their velocity board (the visual scheduling component of the velocity scheduling system) went up in 2007. This approach has enhanced communication in the shop and is the key to making this approach stick. They now have a process—the velocity scheduling system—and they get better and better at it all the time. The results?—due date performance up instantly (30 days) and dramatically (156 percent). Velocity through the shop increased about 68 percent, all while sales have been increasing and have remained consistently over 95 percent since then. And the dramatic increase in velocity has led to increased profits and improved cash flow. Sales have become Drewco's constraint, and Drewco's mafia offer is a competitive weapon.

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Dr. Lisa Lang *is the president of the Science of Business, a consulting firm. She has recently served as the global marketing director for Goldratt Consulting. She has a doctorate in engineering and is a TOCICO-certified expert in Theory of Constraints. Lang is the author of two books—*Maximizing Profitability *and* Achieving a Viable Vision*. In addition, she specializes in increasing profits of job shops and applying theory of constraints, lean and six sigma to sales and marketing. Before becoming a consultant, Lang was in operations, strategic planning, purchasing, R&D and quality while working for Clorox, Anheuser-Busch and Coors Brewing. She also provides professional keynote speeches—most recently at the National Tooling and Machining Association's annual convention—and at workshops.*

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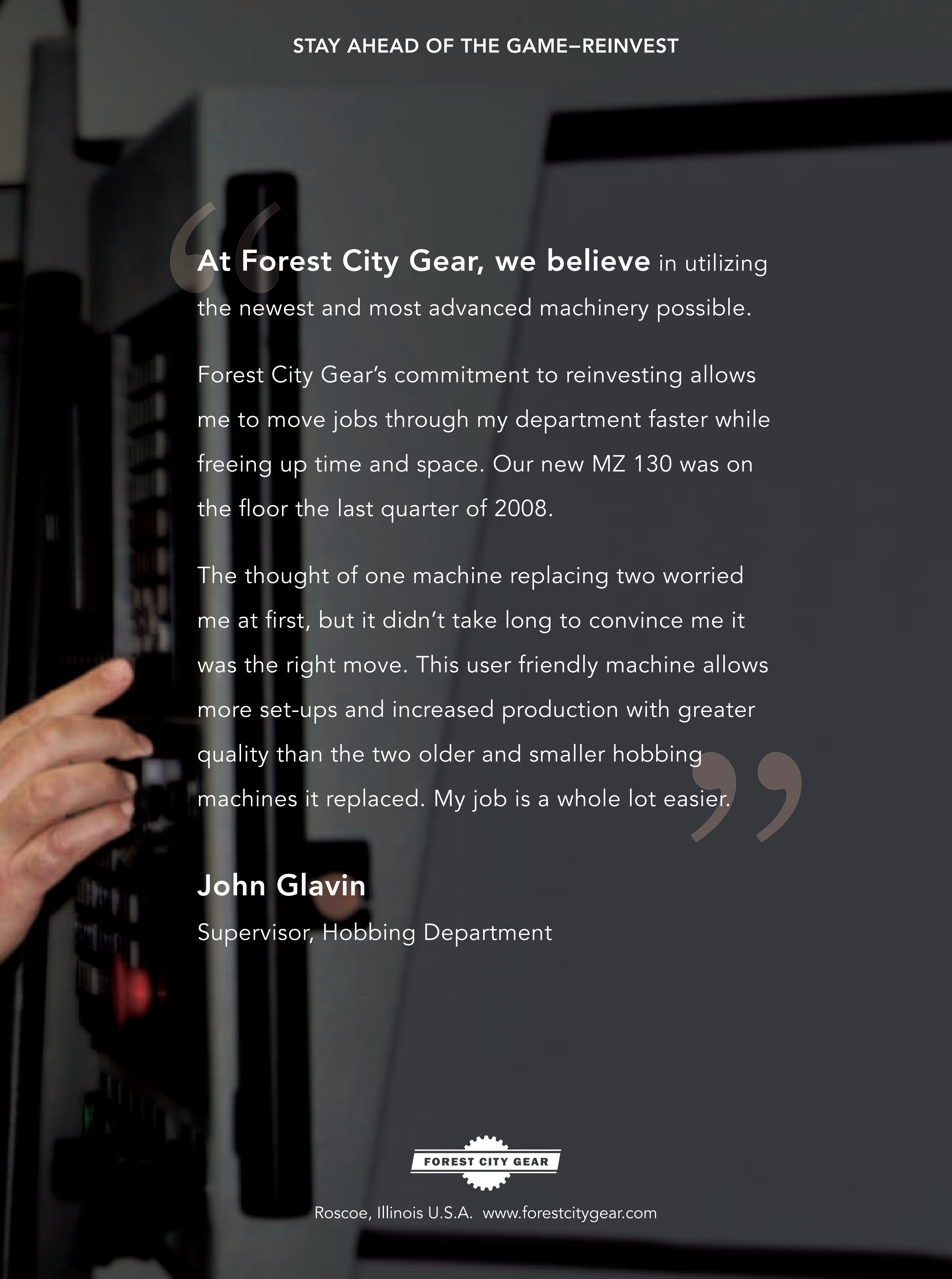
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Grinding Induced Changes in Residual Stresses of Carburized Gears

R. LeMaster, B. Boggs, J. Bunn, C. Hubbard and T. Watkins

Management Summary

This paper presents the results of a study performed to measure the change in residual stress that results from the finish grinding of carburized gears. Residual stresses were measured in five gears using the x-ray diffraction equipment in the Large Specimen Residual Stress Facility at Oak Ridge National Laboratory. Two of the gears were hobbed, carburized, quenched and tempered, but not finished. The remaining three gears were processed similarly, but were finish ground. The residual stresses were measured at 64 different locations on a tooth from each gear. Residual stresses were also measured at fewer points on other teeth to determine the tooth-to-tooth variation. Tooth profile measurements were also made of the finished and unfinished gear samples.

The results show a fairly uniform and constant compressive residual field in the non-finished gears. There was a significant reduction in the average residual stress measured in the finished gears. Additionally, there was a significant increase in the variability of the residual stress that was introduced by the grinding process. Large variations were observed in both the lateral and longitudinal directions on a tooth surface. Analysis of the data suggests a linear relationship between the change in average residual stress and the amount of material removed by the grinding process.

Introduction

Carburizing is a commonly used method for increasing the strength and wear resistance of gearing. A significant benefit of the carburization process is that compressive residual stresses are developed near the surface due to phase transformations that occur during the post carburization heat treatment steps. After carburization it is necessary to finish the gear by processes such as grinding or skiving. These finishing processes develop the precise geometric form required while improving the surface finish. Finishing processes change the residual stress imparted by carburization and subsequent heat treatment processes. These changes are due to the removal of material and the associated rebalancing of the residual stresses and the introduction of near surface residual stresses by the machining operations.

A grinding allowance is used to specify the amount of material to be left on a machined gear prior to heat treatment. This excess material and any material associated with a geometry change during heat treatment are removed by the finishing process. The magnitude of this grinding allowance will affect the strength, fatigue life and wear resistance of the finished gear because of its relationship to changes in the residual stresses. Removal of the excess material will also remove any retained austenite.

Test Gears

The three finished ground samples were designated as Finished 1, 2 and 3. The two remaining unfinished samples were designated as Unfinished 1 and 2. Each gear had 25 teeth; a diametral pitch of 4 teeth/inch; a pressure angle of 20 degrees; full radius fillets; no addendum modification; and a face width of 0.75". The gears were flat with no ribs, rims or other weight reduction features (Fig. 1).

The measurement of residual stresses in gear teeth using x-ray diffraction is complicated by the curvature of the involute and trochoid geometries, and the potential for interference of the incident or diffracted beam by adjacent teeth. The size of the gears used in this study was chosen so that the residual stresses could be measured over most of the tooth surface.

Most of the residual stresses measured were in the longitudinal direction of the gear tooth (Fig. 2). A few residual stress measurements were also made in the lateral direction. The 64 locations on a tooth from each sample where residual stresses were measured are shown in Figure 3. There are eight lateral locations associated with each radius. The lateral locations are spaced 0.079". Residual stress measurements were not made at the critical bending stress location in the fillet. This was due to the high curvature in the fillet area and interference with the incident or refracted beam path from adjacent teeth.

The gear blanks for each sample were taken from the same length of 8620H bar stock. The steps used in the fabrication of the samples are listed in Table 1. The time at temperature for the normalize, stress relief and defuse steps was based on 1-hour-per-inch of thickness. The carburization step was done using an 80–90% natural gas-derived endothermic gas atmosphere. Test slugs were pulled during the carburization step to verify an effective case depth of 0.030". The final surface hardness was determined to be within the range of 58–62 HRC. The finish grinding was done using a vitrified alumina grinding wheel on a CNC grinder.

The profiles of each sample were measured using a CMM at Oak Ridge National Laboratory. The profiles were measured at three lateral locations on each sample. There was no discernible difference between the three lateral measurements for each sample when the measurements were superimposed. The profiles measured at the first lateral location on the five samples are compared in Figure 4. There was virtually no discernible difference between the measured profiles of the samples designated Unfinished 1 and Unfinished 2. There was also little noticeable difference between the samples designated Finished 1 and Finished 2. However, the gear designated Finished 3 had noticeably more material removed at the tip than did gears Finished 1 and Finished 2. At the pitch circle, all of the finished samples were virtually the same.

Figure 5 shows the grind depth versus radius for each of the finished samples. The grind depth reported is the perpendicular distance from the unfinished profile to the finished profile (Fig. 6). The increased tip relief observed in the sample designated Finished 3 is quite noticeable. With the exception of the tip relief found in Finished 3, the grind depth is similar for all radii greater than the form radius. The material removed at the pitch circle by grinding ranged from

continued

Figure 1—A typical finished gear. This gear is designated Finished 1.

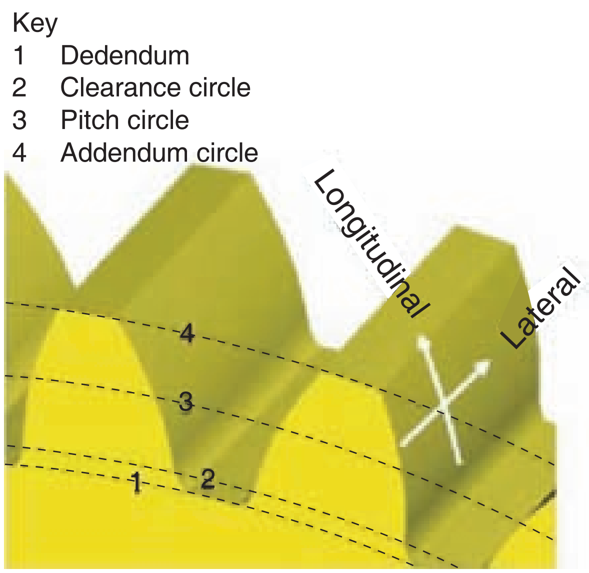

Figure 2—Longitudinal and lateral tooth directions on tooth.

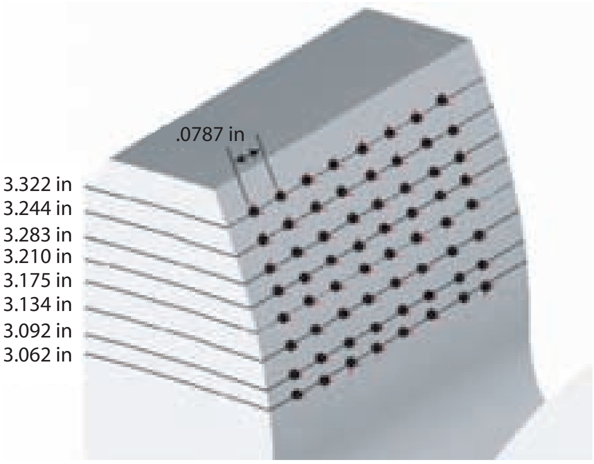

Figure 3—Radial and lateral locations where the residual stress measurements were made.

Table 1—Fabrication steps.		
1.	Rough machine	
2.	Normalize	(1,740°F)
3.	Stress relief	(1,250°F)
4.	Finish machine	
5.	Carburize	(1,650°F)
6.	Defuse	(1,550°F)
7.	Oil quench	(135°F)
8.	Temper	(450°F)
9.	Finish grind	

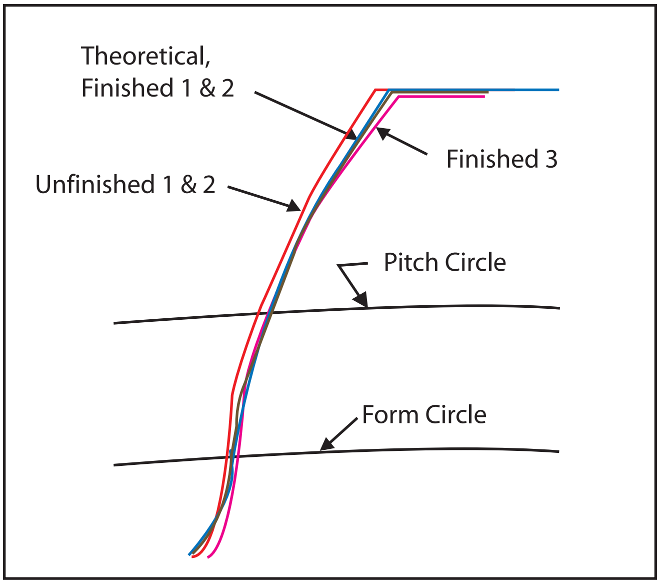

Figure 4—Comparison of the measurement profiles of the finished and unfinished gears.

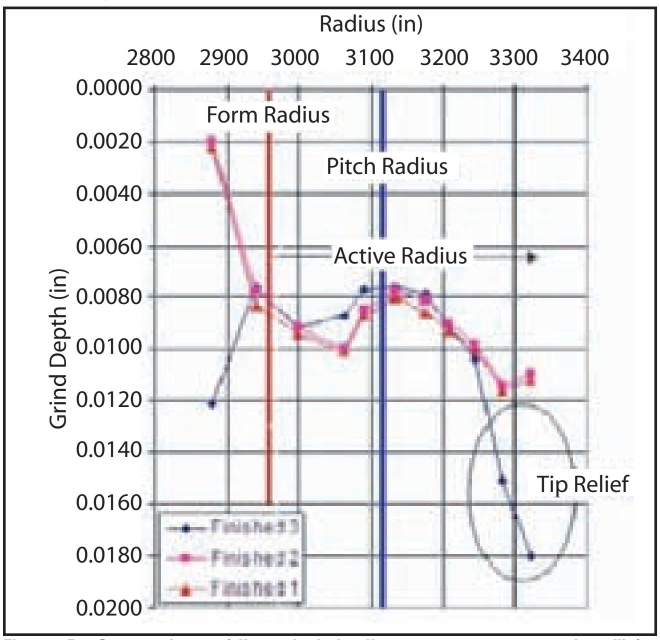

Figure 5—Comparison of the grind depth versus measurement radii for the three finished gears.

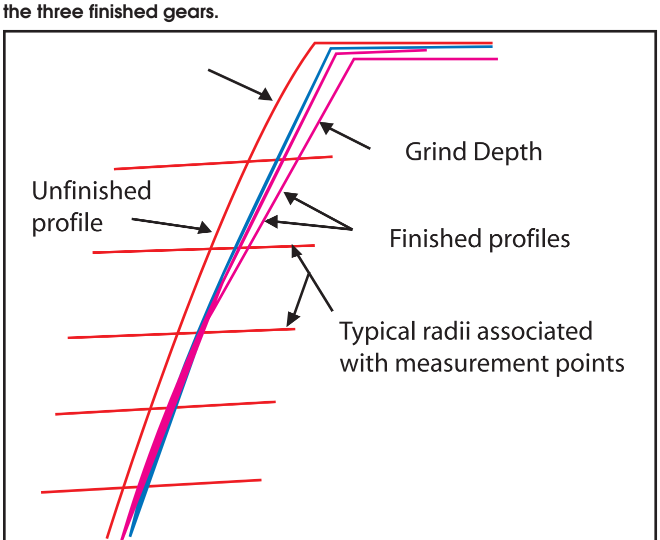

Figure 6—Grind depth is the difference between the unfinished and finished tooth surfaces measured normal to the finished gear tooth surface.

0.0082" to 0.0085" (0.208 to 0.216 mm).

X-Ray Diffraction Measurements

Residual stress measurements were made using the Model 1600 TEC diffractometer in the Residual Stress User Center at Oak Ridge National Laboratory. The residual stress measurements involved measuring the interatomic spacing (d-space) between atoms for the (211) crystal plane at different x-ray beam incident angles (ψ) (Ref.1). The measured d-space is the average value for a group of properly oriented grains near the irradiated surface. The residual stress was determined using the $\sin^2\psi$ technique (Ref. 2). In this method d-space is plotted as a function of $\sin^2\psi$. The y-intercept of the plot was taken as the unstrained d-space (d_0) with the slope being proportional to the residual stress. A 2 mm (0.079") diameter collimator, vanadium filter, and Kα radiation from a chromium x-ray target were used. Figure 7 shows a picture of a portion of the diffractometer and one of the samples mounted in the diffractometer. On average, 10 ψ-angles with a two-degree oscillation were used at each radial location. As seen in Figure 7, black electrical tape was used to cover neighboring teeth to eliminate any radiation scattered from them. Figure 8 provides an example of a typical d-space versus $\sin^2\psi$ plot.

Residual Stress Data for Unfinished Samples

The residual stress component acting in the longitudinal direction for the gears designated as Unfinished 1 and Unfinished 2 is shown in Figures 9 and 10. Each line is associated with a specific radius. There are eight data points per line. Table 2 gives the average and standard deviation of the longitudinal residual stress measured on the randomly selected tooth for each gear. The average and standard deviation values given in Table 2 are for the 64 measurement locations on the tooth.

The average residual stress for all 64 locations on the tooth from sample Unfinished 1 is 185 ksi and 150 ksi for Unfinished 2. The 35 ksi difference in the average longitudinal residual stress led to the measurement of the longitudinal residual stress at a similar location on several additional teeth of gear Unfinished 2. The tooth-to-tooth variation in the longitudinal residual stress (measured at a radius of 3.244" (82.4 mm) and lateral location of 0.315" (8 mm) is shown in Figure 11. The tooth-to-tooth variation ranges from 138 ksi to 191 ksi with an average value of 160 ksi. The average longitudinal residual stress measured on the tooth from both Unfinished 1 and Unfinished 2 fall within this tooth-to-tooth variation. Variations in residual stresses can be caused by non-homogeneous chemistry and microstructure in the material as well as non-uniform furnace heating, carbon potential and quenching rates.

The residual stress in the lateral direction was also measured at a few locations on the unfinished samples. The residual stresses were in all cases compressive and approximately equal to the residual stress measured in the longitudinal direction. This indicates a biaxial stress field in which the normal stresses were approximately equal. No

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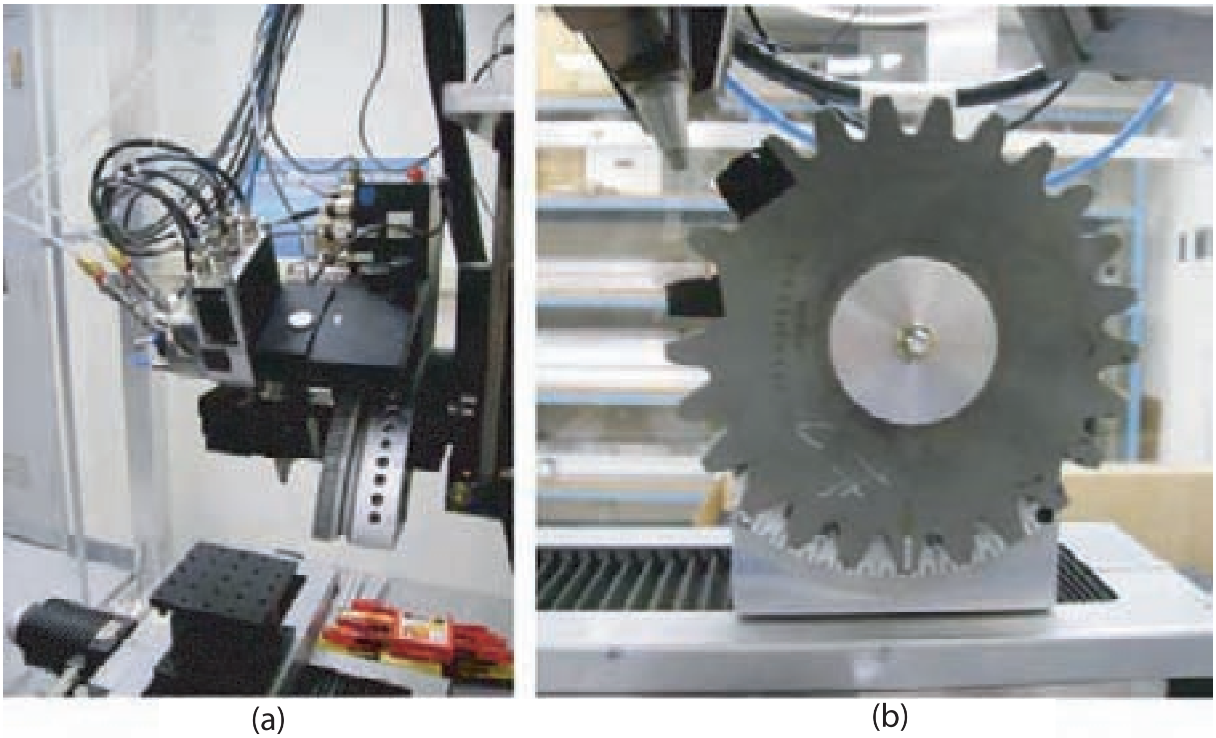

Figure 7—(a) X-ray source and detector portion of TEC model 1600 diffractometer; (b) Unfinished 2 mounted in x-ray diffractometer.

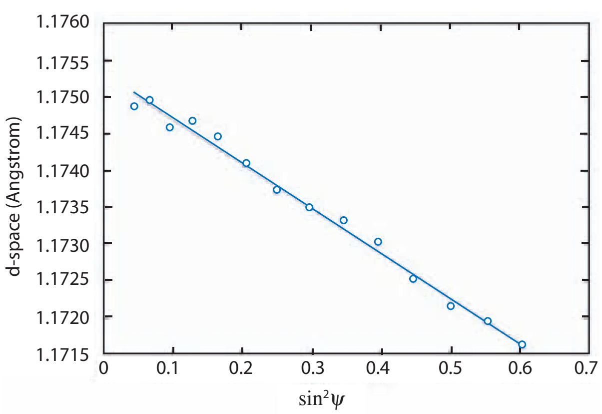

Figure 8—An example sin²ψ plot used to determine the residual stress. The slope is proportional to the residual stress.

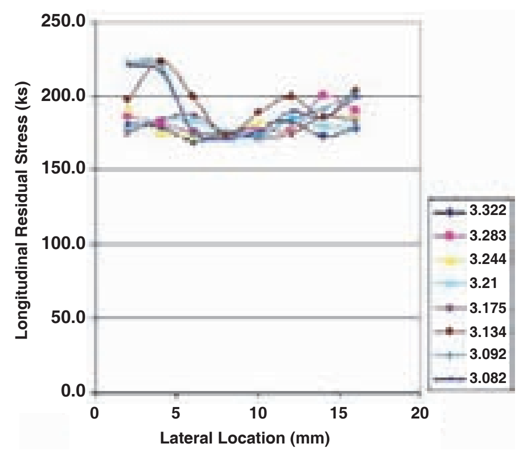

Figure 9—Longitudinal component of residual stress measured in gear Unfinished 1. Average = 185 ksi, Std. Dev. = ± 13 ksi.

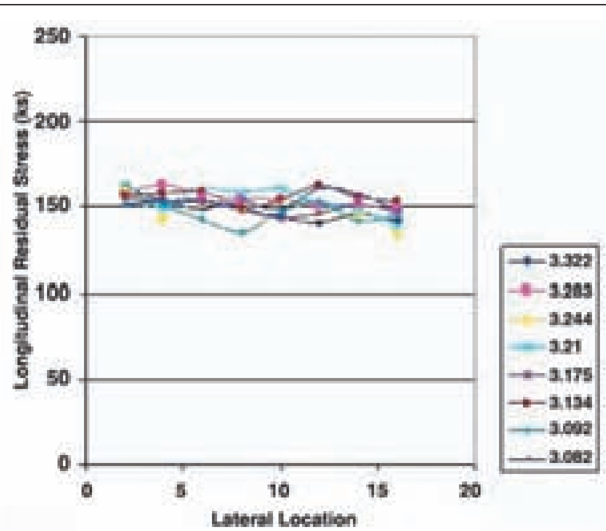

Figure 10—Longitudinal component of residual stress measured in gear Unfinished 2. Average = 150 ksi, Std. Dev. = ± 7 ksi.

Table 2—Statistical properties of longitudinal residual stress measurements.

Gear	Average longitudinal residual stress (ksi)	Standard deviation of longitudinal residual stress (ksi)
Unfinished 1	185	± 13
Unfinished 2	150	± 7
Finished 1	116	±15
Finished 2	108	±15
Finished 3	110	± 22

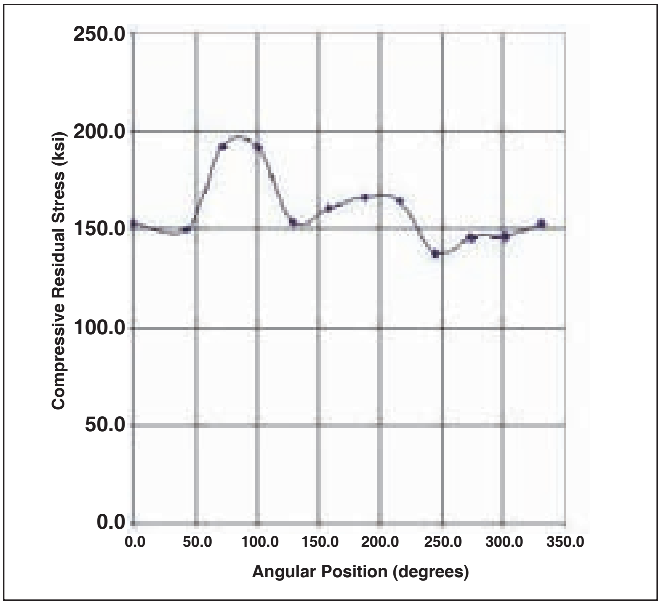

Figure 11—Tooth-to-tooth variation in the longitudinal residual stress measured at a radius of 3.244 inches and a lateral position of 0.315 inches. Average 160 ksi, Std. Dev. = ± 17 ksi.

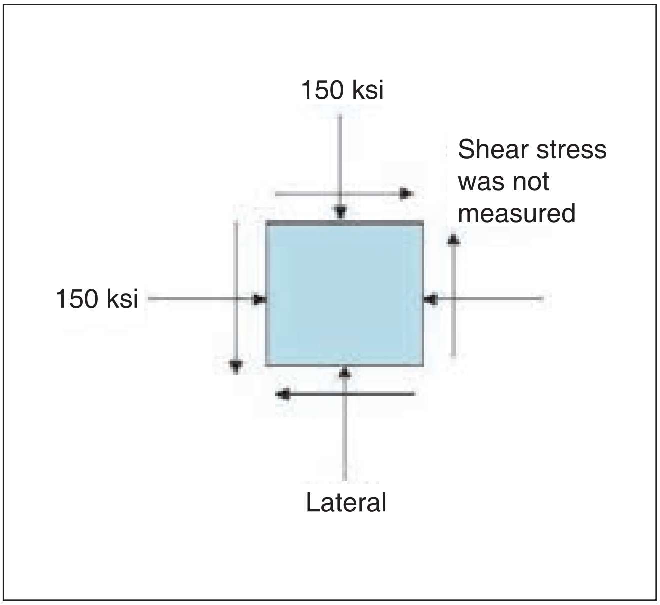

Figure 12—The unfinished gears exhibited a biaxial stress state with equal lateral and longitudinal compressive stresses.

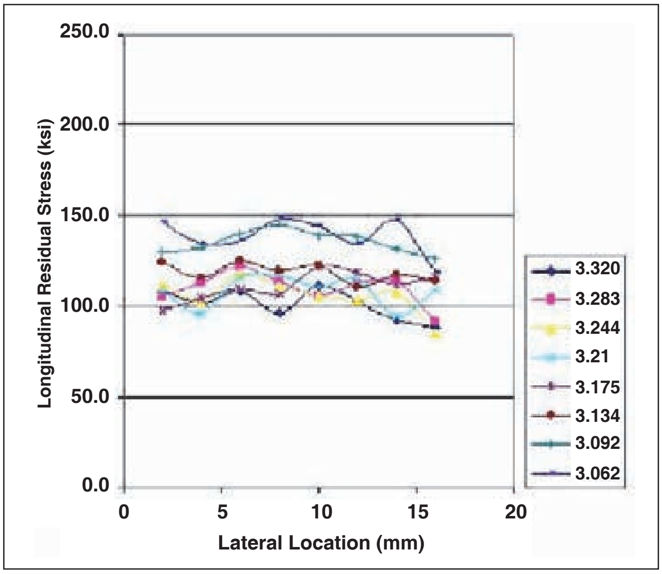

Figure 13—Longitudinal component of residual stress measured in gear Finished 1. Average = 116 ksi, Std. Dev. = ± 15 ksi.

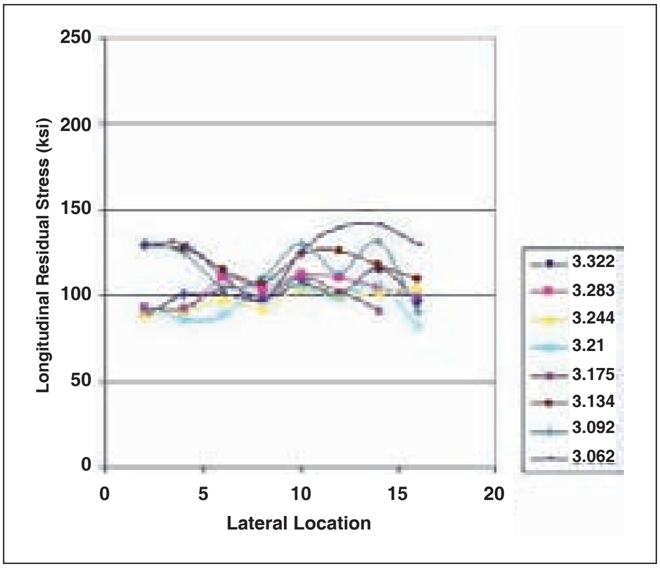

Figure 14—Longitudinal component of residual stress measured in gear Finished 2. Average = 108 ksi, Std. Dev. = ± 15 ksi.

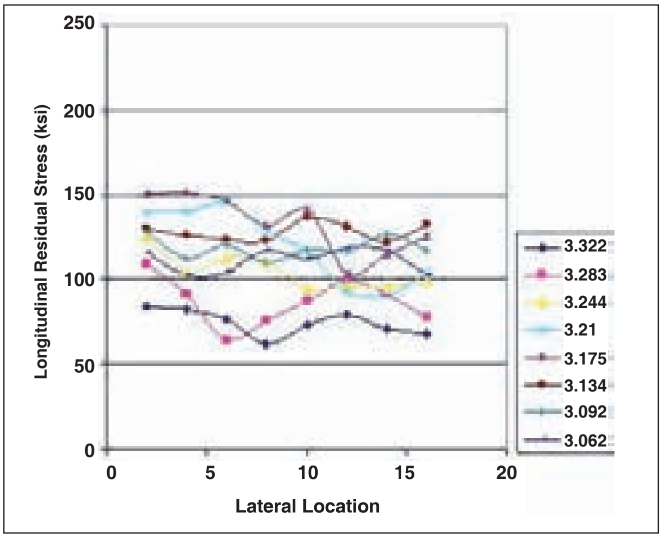

Figure 15—Longitudinal component of residual stress measured in gear Finished 3. Average = 108 ksi, Std. Dev. = ± 22 ksi.

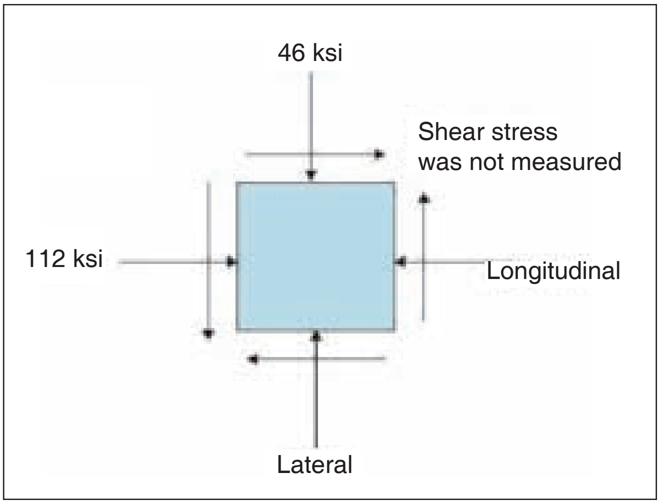

Figure 16—The finished gears exhibited a biaxial stress state with nonequal lateral and longitudinal compressive stresses. Data from gear Finished 1, tooth 1, lateral position 0.315 inch and radius of 3.244 inch.

shear stresses were measured. An example of the stress state for one of these points is shown in Figure 12.

Residual Stress Data for Finished Samples

The longitudinal residual stress measured on a randomly selected tooth on gears Finished 1, Finished 2 and Finished 3 is shown in Figures 13, 14 and 15. A comparison of these figures with Figures 9 and 10 shows that the finished gears have more variation than the unfinished gears. Table 2 gives the average and standard deviation of the longitudinal residual stress for each gear. The average longitudinal residual stress in the finished gears is approximately the same with a maximum difference of 8 ksi. The standard deviations of the data are approximately the same for gears Finished 1 and Finished 2. The standard deviation of the longitudinal residual stress in Finished 3 is ± 22 ksi, which is considerably greater than that for Finished 1 (± 15) and Finished 2 (±15). This larger standard deviation is due in large part to the lower residual stresses measured at locations having a radius of 3.322" and 3.283" (bottom two lines of data in Figure 15). These lower residual stresses are expected due to a larger amount of material having been removed at the tooth tip.

The residual stress in the lateral direction was also measured at a few locations on the finished samples. Unlike the unfinished gears, the lateral residual stresses measured in the finished gears were different than those measured in the longitudinal direction. Figure 16 shows the stress state measured at a typical point. No shear stresses were measured.

Residual Stress Change versus Grind Depth for Gears Finished 1, 2 and 3

The eight residual stress measurements taken at each radial location were used to compute an average residual stress at each radius. These average residual stresses were then plotted on the same graph (different y-axes) with the grind depth. These plots are shown in Figures 17, 18 and 19. Note that the shape of the average residual stress curves is similar for gears Finished 1 and Finished 2, and grind depths are virtually identical.

However, the grind depth curves and the average residual stress curves have different shapes. The average residual stress curves have a negative slope and slight concave up appearance. The grind depth curves have a more concave down appearance. In contrast, the shapes of the average residual stress and grind depth curves for gear Finished 3 are similar. This suggests that there is a stronger correlation between grind depth and average residual stress in Finished 3 than there is in Finished 1 and Finished 2.

An analysis of the data presented in Figures 9, 10 and 11 suggests that the average longitudinal residual stress on the teeth of the unfinished gears is around 160 ksi. This is the average residual stress for the tooth-to-tooth data shown in Figure 11. Figure 9 and particularly Figure 10 also show that most of the measured residual stresses have limited variability. The change in residual stress due to the finish grinding was

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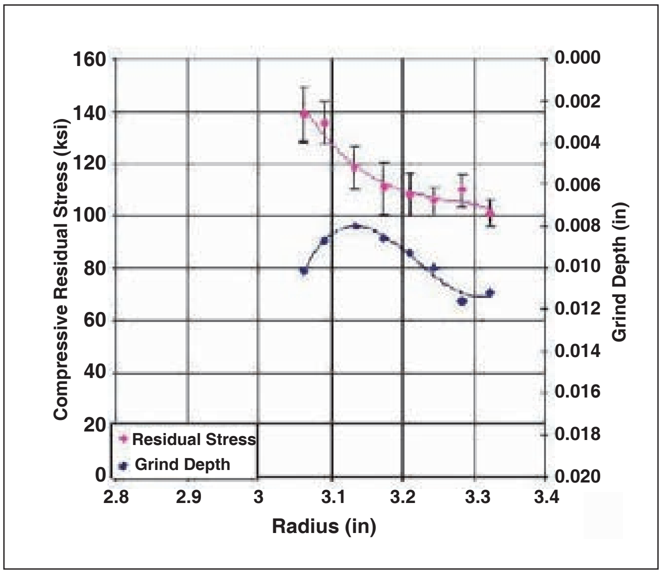

Figure 17—Average longitudinal residual stress and grind depth as a function of measurement radius for gear Finished 1.

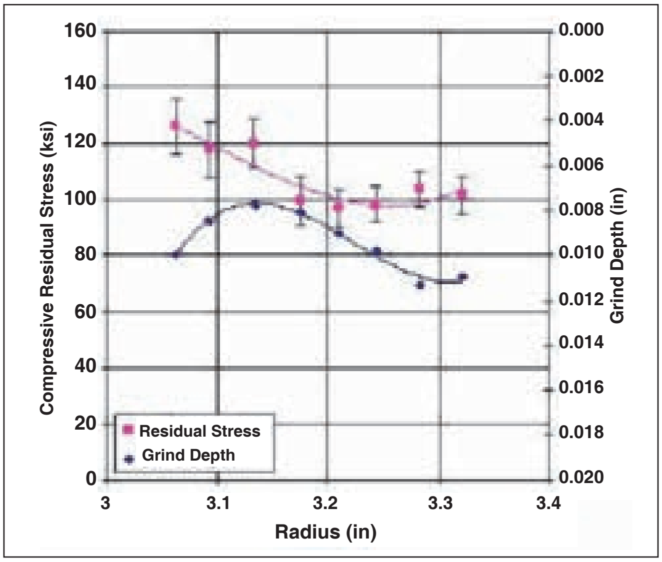

Figure 18—Average longitudinal residual stress and grind depth as a function of measurement radius for gear Finished 2.

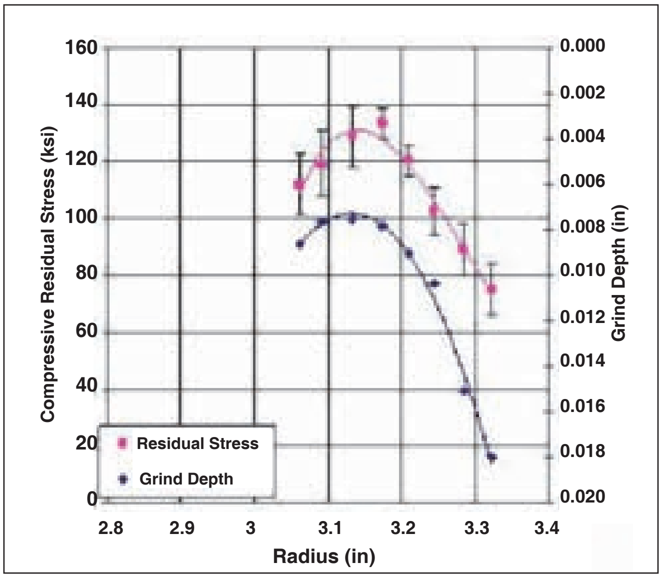

Figure 19—Average longitudinal residual stress and grind depth as a function of measurement radius for gear Finished 3.

computed as the difference between 160 ksi and the average residual stress at each radial location in the finished gears. This change in residual stress was then plotted versus grind depth and is shown in Figures 20, 21 and 22 for the three finished gears.

In each of these figures the linear curve fit is forced to pass through the origin so that at zero grind depth there is zero change in residual stress. Six of the eight data points for gear Finished 1 (Fig. 20) fall close to the linear line, which suggests a linear relationship between the change in residual stress and grind depth. There is more scatter in the data for gear Finished 2 (Fig. 21) and the linear relationship is not as evident. The data for Finished 3 (Fig. 22) also falls close to the linear line, which again suggests a linear relationship between the change in residual stress and grind depth.

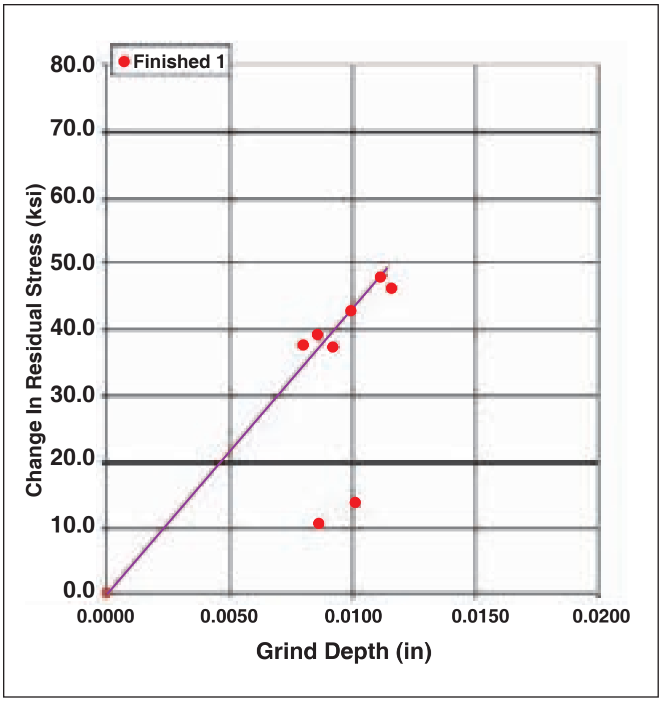

Figure 20—Change in the longitudinal component of residual stress as a function of grind depth for gear Finished 1.

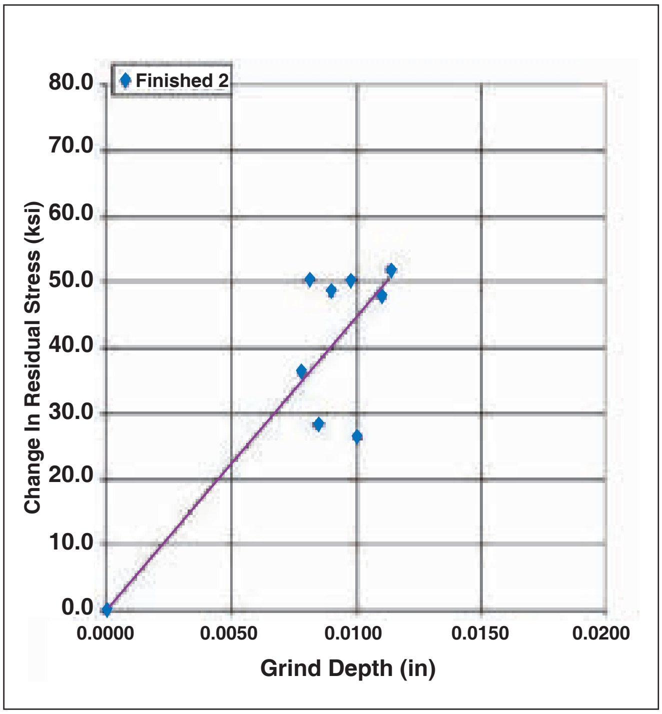

Figure 21—Change in the longitudinal component of residual stress as a function of grind depth for gear Finished 2.

Figure 23 is a composite graph that presents the change in residual stress versus grind depth data for all three of the finished gears. In this figure, 67% of the data shows good correlation with a linear relationship between change in residual stress and grind depth. 33% of the data points do not correlate as well with a linear relationship and suggest that at these locations there are other factors besides grind depth that are contributing to the change in residual stress. The equation for the linear regression line used to fit the data in Figure 23 is:

$$\Delta\sigma_R = 3{,}990 \cdot \delta,$$

where $\Delta\sigma_R$ is the change in the longitudinal component of the residual stress in ksi and δ is the grind depth in inches. As an example application of this equation, the change in residual stress due to a grind depth of 0.008" would be 32 ksi. Using 160 ksi as the initial residual stress in the unfinished gear, the residual stress in the finished gear would be reduced to 128 ksi. The applicability of this equation to gears other than the ones used in this study has not been established.

Conclusions

This paper presents the results of a study directed at measuring and quantifying the change in residual stress in carburized gears as a function of the amount of material removed during finish grinding. It is recognized that material removal is not the only mechanism by which residual stresses will change during the grinding process. Grinding itself will impose near surface residual stresses that could mask the effects of material removal. The data indicate that the grinding increased the variability in the residual stress measurements made on the finished gears as compared to the unfinished gears. The grinding also created a difference between the lateral and longitudinal components of the residual stress.

The data suggest that a linear equation may describe the relationship between change in residual stress and grind depth. The word "suggest" is used because not all of the data are served well by a linear equation. Whether the relationship between grind depth and change in residual stress is linear or not, the data show that decreasing grind depth will result in higher compressive residual stresses. The higher residual stresses should yield an increase in strength, life and wear resistance. In the specimens used in this study, an average reduction of 40 ksi was observed in the longitudinal component of residual stress. This average value is associated with a grind depth of 0.009". A maximum reduction of 75 ksi was also observed at a grind depth of 0.018", which occurred at the tip of gear Finished 3.

A large number of measurements were made in this study to determine the variation of residual stresses on the surface prior to and after finish grinding. The finished gears exhibited more variation than did the unfinished gears. As an example of the range of values that can exist, the longitudinal residual stress component ranged from 62.6 ksi to 151 ksi for gear Finished 3, and from 173 ksi to 224 ksi for Unfinished 1. Therefore, residual stresses should not be thought of as being the same at all locations on the surface of a tooth.

Acknowledgments

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References

1. Noyan, I.C. and J.B. Cohen. *Residual Stress: Measurement by Diffraction and Interpretation*, Springer-Verlag, New York, 1987.

2. Cullity, B.D. and S.R. Stock. *Elements of X-Ray Diffraction*, 3rd Ed., Prentice-Hall, 2001.

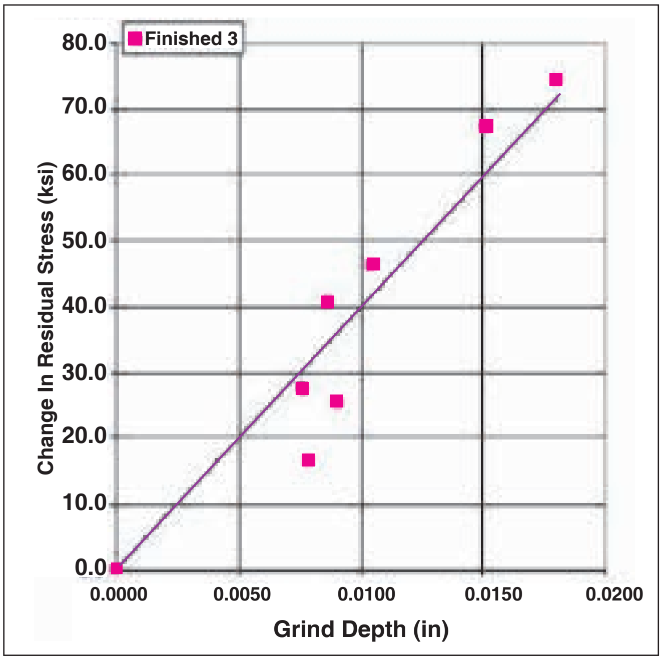

Figure 22—Change in the longitudinal component of residual stress as a function of grind depth for gear Finished 3.

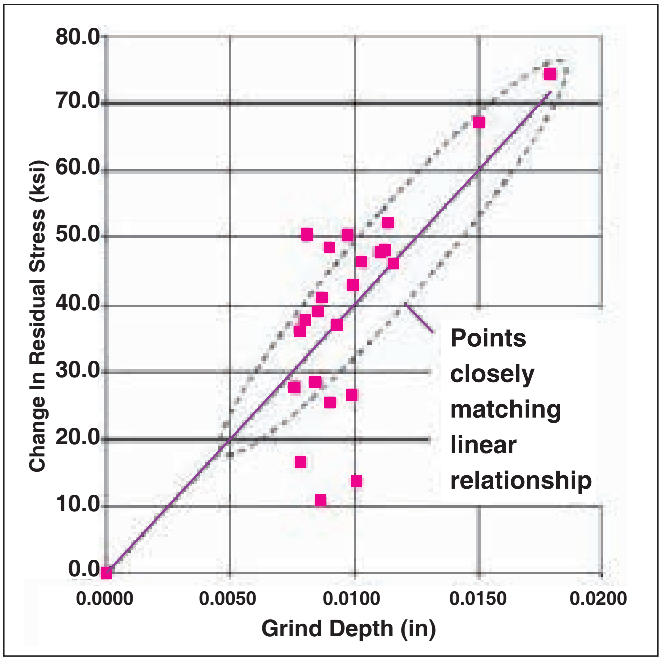

Figure 23—Composite graph showing the change in the longitudinal component of residual stress vs. grind depth for all three finished gears.

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Hob Tool Life Technology Update

By T.J. Maiuri

Management Summary

The method of cutting teeth on a cylindrical gear by the hobbing process has been in existence since the late 1800s. Advances have been made over the years in both the machines and the cutting tools used in the process. This paper will examine hob tool life and the many variables that affect it. The paper will cover the state-of-the-art cutting tool materials and coatings, hob tool design characteristics, process speeds and feeds, hob shifting strategies, wear characteristics, etc. The paper will also discuss the use of a common denominator method for evaluating hob tool life in terms of meters (or inches) per hob tooth as an alternative to tool life expressed in parts per sharpening.

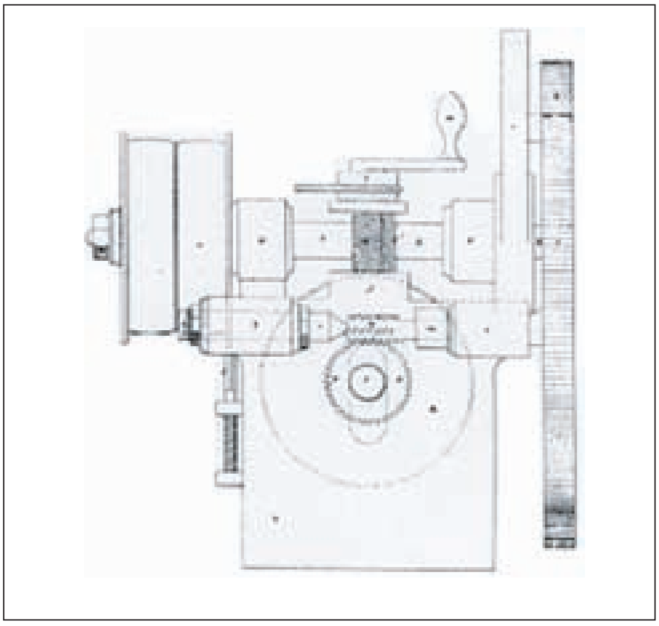

Figure 1—Whitworth's 1835 machine.

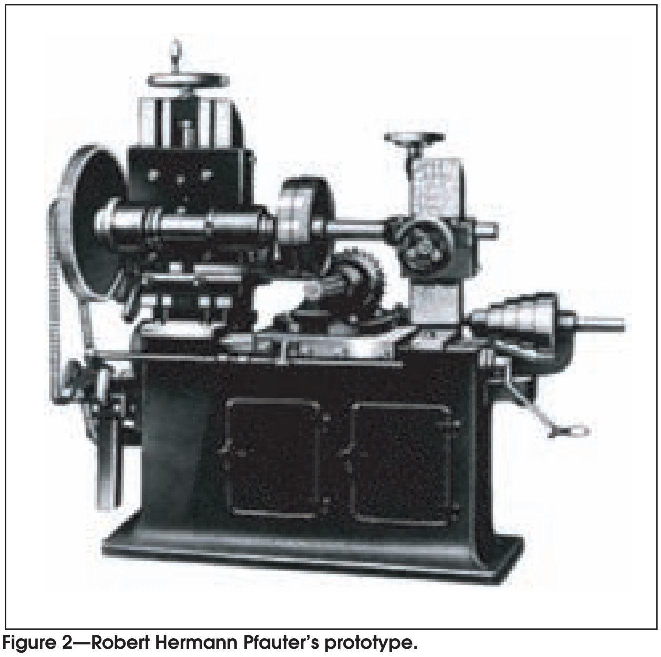

Figure 2—Robert Hermann Pfauter's prototype.

Introduction

Up until the 19th century, almost all gears were handmade and the gears were cut with form cutters shaped to correspond to the spaces between the teeth. The first known gear cutting by machine was developed by Juanelo Torrianno (1501–1575). It was recorded that he was able to produce up to three gears per day on his hand-powered machine, using cutting tools that were nothing more than rotary files (Ref. 1). Much information about the history of gears can be found in the late Darle W. Dudley's book *The Evolution of The Gear Art*. The book was sponsored by the AGMA and published in 1969.

Figure 1 is taken from the English inventor Joseph Whitworth's patent of 1835, which clearly shows a hob cutting a gear. Whitworth claimed in the patent "the construction and arrangement of a mechanism by which I give a continuous rotary motion to the wheel or disc under operation, which motion is so proportioned to the speed of the rotary cutter that by every rotation of the cutter a segment of the wheel or disc shall be advanced equal to the distance of one tooth and space." The machine shown can be "bolted on to a work bench, or placed in any other convenient situation." (Ref. 2).

It is also interesting to note that in the 1871 patent of Philadelphia's Henry Belfield, the cutting tool is referred to

Table 1—High Speed Steel Materials	C	Cr	W	Mo	V	Co	HRC
CPM M2	1.0	4.2	6.4	5.0	2.0	–	64
ASP 2023	1.3	4.2	6.4	5.0	3.1	–	64
CPM M4	1.4	4.3	5.8	4.5	3.6	–	64
CPM REX 54	1.45	4.3	5.8	4.5	3.6	5.3	65
CPM REX 45	1.3	4.1	6.3	5.0	3.1	8.3	66
ASP 2030	1.3	4.0	5.0	6.5	3.0	8.0	66
CPM T15	1.6	4.0	12.3	–	5.0	5.0	66
CPM REX 76	1.5	3.8	10.0	5.3	3.1	9.0	67
CPM REX 86	2.0	4.0	10.0	5.0	5.0	9.0	68
ASP 2060	2.3	4.0	6.5	7.0	6.5	9.0	68
CPM REX 121	3.3	3.8	10.0	5.3	9.0	9.0	70
M35V [Conventional]	1.2	4.1	6.0	5.0	3.0	5.0	66

as a "hub," not as a hob (Ref. 2). George B. Grant was issued a patent for a spur gear hobbing machine in 1889.

The first machine capable of cutting both spur and helical gears was invented by Robert Hermann Pfauter of Germany, in 1897 (Fig. 2). It included a horizontal workspindle on vertical ways, a hob swivel, a hob carriage fed along horizontal ways on the bed of the machine, and an upright outboard support of the work arbor. The hob feed was accomplished manually with a crank on the end of a feed screw (Ref. 2).

Today, most hobbing machines are full six-axis, CNC-controlled machines—capable of very high cutter and work table speeds. Many machines utilize direct drive hob and work spindles, which present an interesting scenario in which we now produce gears with machines that do not have gears in them.

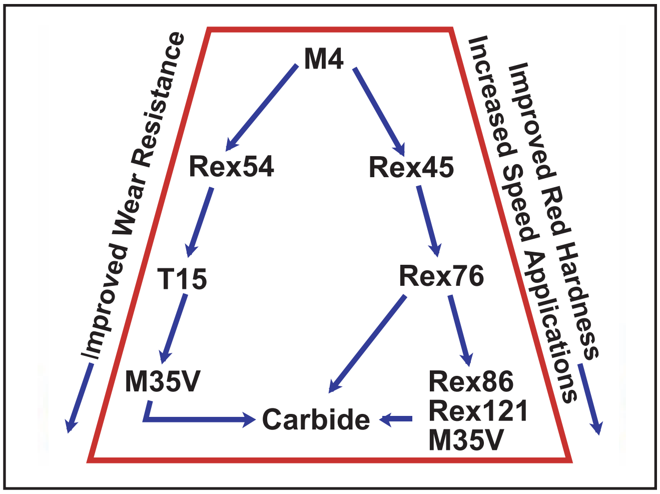

Figure 3—Material upgrade selection.

The Hobbing Process

In brief, to paraphrase what Joseph Whitworth said in his patent of 1835, hobbing is a continuous indexing process in which the cutting tool and the workpiece rotate in a constant relationship to each other while the hob tool is fed into the work. For generating helical gears, the rotation of the work is either slightly retarded or slightly advanced in relation to the rotation of the hob. As the hob is fed across the face of the work once, all the teeth in the work are completely formed. The hob can be fed axially, radially, diagonally or tangentially, depending upon the application and the machine options available.

The hobbing process can be visualized as a worm and worm wheel running together—the hob is represented by the worm and the workpiece by the worm wheel. The hob has a worm thread that has been fluted to provide cutting edges, with each tooth relieved to form clearance behind the cutting edges. It must be made from a material suitable for cutting the workpiece material.

High-speed steel (HSS) cutting tool materials. Early cutting tool materials (from the 1900s to 1940s) consisted of high-speed steels designated as 1841, which consisted of 18% tungsten, 4% chromium and 1% vanadium (Ref. 3). Today we have many materials to choose from. Table 1 lists high-speed steel materials in use today, their chemical composition and Rockwell C hardness (Ref. 4).

In the movement to cut gears without the use of coolant, carbide was initially selected as the hob tool material. Because of the expense of the carbide, the manufacturing costs and the special handling required, high-speed steel "bridge" materials were identified and have replaced the carbide in many applications. It is interesting to note this is not the case in bevel gear dry cutting production, where carbide remains the choice material for stick blades used in bevel cutter systems (Ref. 4). See below for more information on carbide material.

Figure 3 is a material selection upgrade guide based on what the desired output is: improving the red hardness (the property for retaining hardness at elevated temperatures) of the material, increasing the hob speed and/or increasing

continued

the wear resistance of the material. Rex 86, Rex 121 and M35V are grouped together on the chart, and the choice of material within the group should be based on a cost-per-piece analysis. Because of the high alloy content of REX 121, the hob sharpening technique is critical to avoid damaging the substrate material. Availability of a specific material can be a factor in your choice.

Carbide grades. Even though HSS "bridge" materials have replaced many early applications, carbide is used for applications such as steering pinions and armature shaft pinions (Fig. 4)—generally, small-diameter fine-pitch applications. Carbide is also used in hard finishing applications where gears are finish hobbed after heat treatment.

Basically, there are two classifications of carbide grades: "P" and "K". It is important to understand that the grades refer to the recommended working conditions and not the exact composition of the material.

Cemented carbides are a range of composite materials that consist of hard carbide particles bonded together by a metallic binder. The proportion of carbide phase is generally between 70–90% of the total weight of the composite.

ISO "K" grades of carbide are a simple two-phase composition consisting of tungsten carbide (WC) and cobalt (Co). A typical composition of a "K" grade carbide is 90% WC and 10% Co by weight. "K" grades have good edge stability and abrasion resistance, with a grain size range of 0.5 µm–0.9 µm.

Figure 4—Carbide shank hob.

ISO "P" grades of carbide are three-phase alloyed compositions consisting of tungsten carbide (WC), cobalt (Co) and cubic carbides. The cubic carbide binders can be titanium carbide (TiC), tantalum carbide (TaC) and niobium carbide (NbC). A typical composition of a "P" grade carbide is 73.5% WC, 8.5% TiC, 8% TaC and 10% Co by weight. The cubic carbides are softer and have larger grain size: 2 µm to 4 µm is normal for these alloy materials.

Most carbide applications in use today are ISO "K" grade. Note that traditional titanium base coatings cannot be stripped from ISO "P" grade carbides (Table 2).

The following figures show some of the relative material properties of carbide and steel.

The density of carbides (Fig. 5) is nearly twice that of steel. This means that a carbide hob with the same geometric characteristics as a high-speed steel (HSS) hob is much heavier.

Carbide is also much harder (Fig. 6) than steel, and is not as tough (Fig. 7). Think of toughness as the ability to resist fracture. This means that if you drop an HSS hob you may just put a "ding" on a couple of teeth, but if you drop a carbide hob it may shatter into pieces. Because of these properties, you must take certain precautions with the carbide hobs that you normally would not take with the conventional HSS hobs.

The linear expansion of carbide (Fig. 8) is less than half that of steel. This can be a significant characteristic due to the fact that if you are using a shell-type carbide hob with a steel hob arbor, the hob arbor will expand at a greater rate than the carbide hob, and you must account for this thermal expansion difference in the clearance between the hob bore and the steel arbor; otherwise, you may shatter the hob (Ref. 5).

Cermet. Test cutting with cermet hobs has also been conducted. The word cermet is derived from the terms ceramic and metal. A cermet is a hard material based on titanium carbide or titanium carbonitride cemented with a metal binder (Ref. 6). Cermet materials allow for higher cutting speeds over HSS tools, and even carbide tools. At this point, however, cutting with cermet tools has not proven to be cost-effective.

Table 2—Coating Re-conditioning Guidelines

Guideline	TiNite® TiN	CarboNite® TiCN	AlNite® TiAlN-S	TiAlN-X	AlCroNite® AlCrN
Strippable from HSS	Yes	Yes	Yes	Yes	Yes
Strippable from K-grade carbide	Yes	Yes	Yes	Yes	Yes
Strippable from P-grade carbide	No	No	No	No	Yes
Recoatable over itself	Yes	Not recommended	Yes	Yes	No
Number of recoatings	3 – 7	--	2 – 4	2 – 4	– –

Coatings

Tool coatings came to the market in the 1980s. The most popular at the time was titanium nitride (TiN). This coating served well for high-speed steel applications used with a coolant, and is still in use today.

Titanium aluminum nitride (TiAlN) was developed in the mid-1980s, and gained popularity in the 1990s, as a coating used in cutting hard materials and high heat applications; it has been a very popular coating for dry cutting applications.

Aluminum chromium nitride [AlCrN] coating was introduced in 2006 and is today the coating of choice for best results in dry hobbing applications.

The coatings used in gear production today are primarily AlNite (Balzers Balinit FUTURA NANO), TiAlN–X (Balzers Balinit X.TREME), and AlCroNite (Balzers Balinit ALCRONA). The performance of AlNite and TiAlN–X are about the same, although some customers prefer one over the other, and TiAlN–X is used primarily on carbide substrate material tools. AlCroNite (Balzers Balinit ALCRONA) has shown advantages for a number of applications over the other coatings.

Trials with Balinit X.CEED (a high-deposition temperature, high-aluminum single-layer coating), Balinit Hardlube (a duplex coating consisting of a wear-resistant TiAlN base layer and a high lubricity–low-friction coefficient—WC/C top layer) did not show any significant advantage over other coatings.

Nanocomposite coatings such as nACo by Platit are available. The nACo coating comprises AlTiN nano-sized particles embedded in an amorphous (non crystalline) matrix of silicon nitride (Si3N4), yielding a high oxidation resistance (Ref. 7).

The following is a brief description of coatings used in production today:

- **TiNite** (Balzers Balinit A)—TiNite is a TiN (titanium nitride) coating and is a general purpose coating for all wet oil or water soluble applications. It is not recommended for dry cutting applications.
- **CarboNite** (Balzers Balinit B)—Carbo-Nite is a TiCN (titanium carbonitride) coating recommended for wet cutting only on materials that are abrasive in nature, such as cast iron or other hard-to-machine materials that require high abrasion resistance.
- **AlNite** (Balzers Balinit FUTURA NANO)—AlNite is a single-layer TiAlN coating with a nominal 50:50 ratio of titanium to aluminum. It has high thermal stability and can be used for cutting all steels, cast iron and stainless steel, and may be used wet or dry.
- **TiAlN–X** (Balzers Balinit X.TREME)—X.TREME is a single-layer coating of TiAlN. It is specialized for carbide mills for hardened

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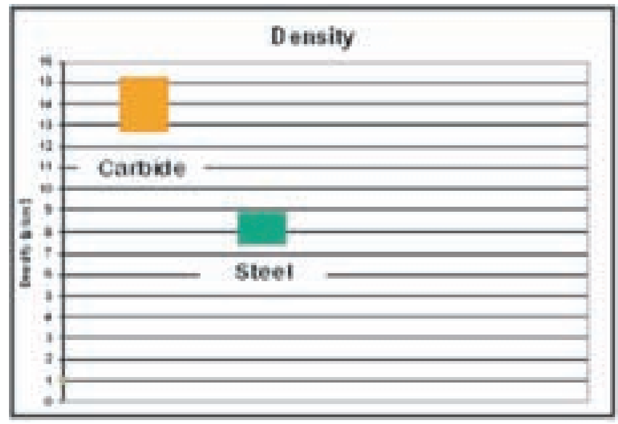

Figure 5—Density.

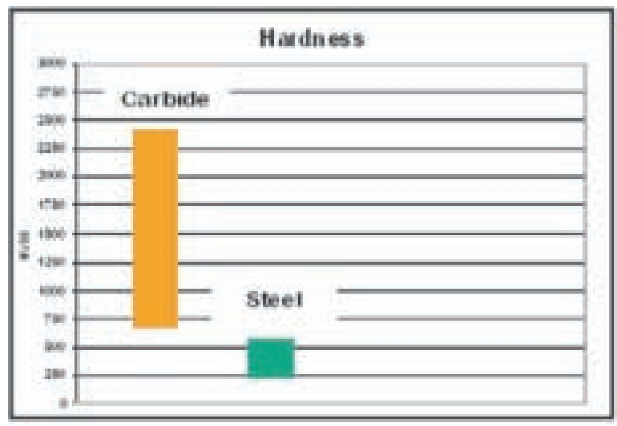

Figure 6—Hardness.

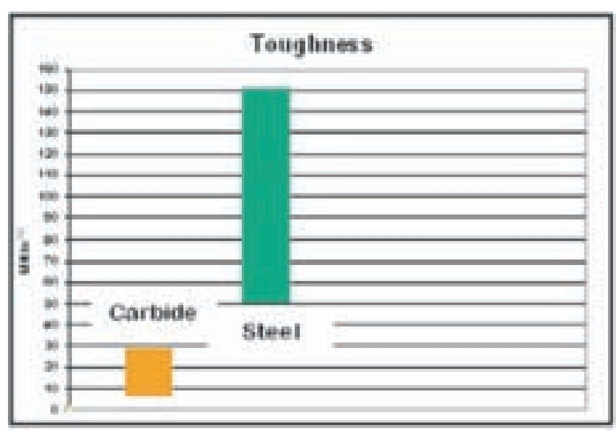

Figure 7—Toughness.

Figure 8—Linear expansion.

steel workpieces (>50 HRC). It may also be used wet or dry, and is a very popular coating today for bevel gear carbide stick blade applications.

- **AlCroNite** (Balzers Balinit ALCRONA)—ALCRONA is a high-performance, titanium-free coating (AlCrN) of the G6 generation (Ref. 8). It has exemplary wear resistance under both conventional conditions and severe mechanical stresses.

Table 3 (Ref. 8) lists some of the properties of coatings in use today.

The pie chart in Figure 9 gives an indication of how the trend in coatings has changed over the last decade. The chart represents coatings applied to all cutting tools, including bevel stick blades. You can see the increase in use of the TiAlN coatings, and now the trend to the AlCrN coating.

Tool Reconditioning Guidelines

Once the hob tool is used, it must be sharpened to remove the wear. The sharpening process will remove the coating on the face of the tool. To obtain better tool life, it is good practice to recoat the tool after sharpening. However, consideration must be given to whether the coating must be stripped off the tool before recoating, or if it can be coated over itself. Stripping the coating from a hob consists of a chemical process where the coating is removed with a peroxide base solution.

Table 2 offers guidelines for stripping and recoating of various coatings in use today.

Hob edge preparation. Tool life improvements can be made by preparing the edge of the hob tooth (Ref. 9). The process for treating the edge on HSS materials consists of removing the burr in a dry blast with an abrasive material. This process is followed by a wet blast operation to remove any residual, dry abrasive to enhance the surface for the coating application.

Treating the cutting edge of carbide tools consists of a honing process with a diamond brush. Generally, an edge radius of about 0.0004" to 0.0008" (10 to 20 μm) is desired.

Table 3—Coating Properties

	TiNite® TiN	CarboNite® TiCN	AlNite® TiAlN	AlNite®-X TiAlN-X	AlCroNite™ AlCrN
	Balzers BALINIT® A	Balzers BALINIT® B	Balzers BALINIT® Futura Nano	Balzers BALINIT® X.TREME	Balzers BALINIT® ALCRONA
Hardness (HV 0.05)	2300	3000	3300	3500	3200
Coefficient of friction	0.4	0.4	0.30 – 0.35	0.4	0.35
Max. service temp.	600°C 1112°F	400°C 752°F	900°C 1652°F	800°C 1472°F	1100°C 2012°F
Coating color	Gold	Blue-grey	Violet-grey	Violet-grey	Blue-grey
Coating structure	Monolayer	Multilayer	Nano	Monolayer	Monolayer

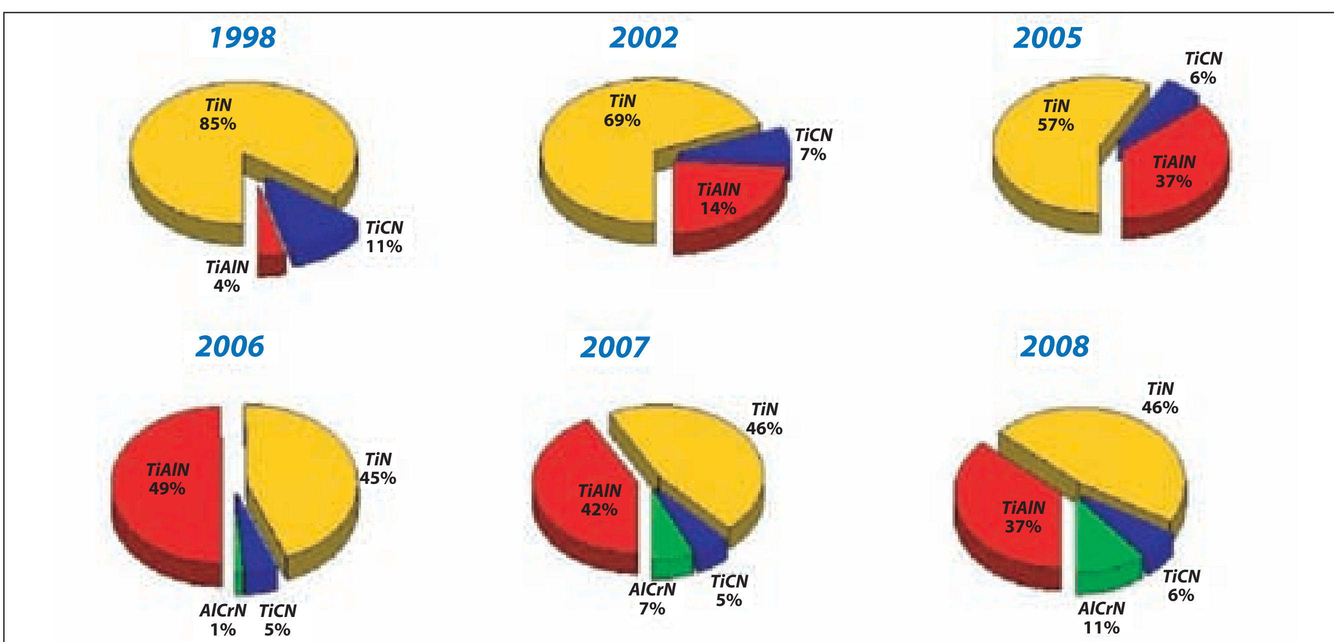

Figure 9—Coating trends.

Wear basics. Figure 10 identifies the basic types of hob wear. Tip and flank wear are normal, and eventually the wear will break through the coating and abrade the substrate material of the hob. Cratering on the face of the hob can also occur, and the tool can fail if the crater becomes too large and extends to the cutting edge of the tool. See the appendix at the end of this paper for actual photos of the different types of wear (Ref. 10).

Edge chipping on the flanks and top of the tool can occur if the tool material is too hard or brittle for the application. Edge chipping can also occur if the gear material is too hard or there is a lack of rigidity and/or vibration during the cutting process.

Another type of problem that can occur with tools is called built-up edge (BUE). BUE is a deposit of workpiece material that adheres to the face of the cutting tool. Sometimes the deposit of material can break off, taking the tool material with it. BUE is a common problem when machining ductile materials such as soft steels, aluminum and copper alloys (Ref. 11). Low cutting clearances on the tool and insufficient coolant flow or type of coolant can also cause BUE.

Hob failures can occur for other reasons besides normal wear. Chip packing can occur when the volume of material being removed is high and there is not enough room or clearance in the gash between the rows of teeth. Chip packing can often result in shelling the hob, where the hob teeth break off the hob body in the cutting zone of the hob. Grinding cracks from the sharpening operation can also lead to hob failures. Microchipping of the tool can be another mode of failure. The appendix contains photos of hobs depicting the problems described above (Ref. 11).

Indications of excessive hob wear. There are a number of indicators during the hobbing process that can be a direct result of excessive hob wear. The following are some of these indicators:

- Increase in machine power requirements
- Increase in machine vibration
- Excessive noise or chatter during the cut
- Excessive heat is generated in the cutting process; gear and/or hob tool temperatures increase
- Gear surface finish deteriorates
- Gear dimensions move out of tolerance
- Burrs that are normal get larger

If any of these indicators are observed, remove the hob from the machine and examine the tool for wear.

Hob Design Recommendations

There are a number of considerations that can be incorporated in the hob design that will help to improve tool life. In general, it is recommended to use shank type hobs, not so much for improved tool life, but for other reasons. The shank design offers several advantages. First, the hob will be mounted directly in the hob spindle, eliminating the need for premounting. Theoretically, the shank design allows the best possible hob runout on the machine. Secondly, if you are using a carbide hob, you do not have to worry about problems from the different rates of thermal expansion of the carbide and steel, which would require more clearance between the hob bore and the hob arbor diameter.

Many hob designs incorporate a positive rake angle on the face (generally 5°) to allow for better chip ejection during the hobbing operation. However, there are applications in production without the positive rake. No rake on the front face makes it easier to sharpen the hob, and the small positive rake may not be a significant factor in the overall tool life. It is very important to have a good surface finish on the hob face—5 µinch Ra or less is recommended. There should be enough clearance in the gash between the rows of teeth to lessen the effect of any chip packing. Sometimes an increased secondary cam angle can help, as well as removing the fins that may exist in the root of the gash from sharpening the hob. Hobs with longer usable face lengths are beneficial for hob shifting (more on hob shifting later). As explained earlier, edge preparation is important.

Special Considerations for Carbide Hobs

When using a carbide hob, special precautions should be taken because of their properties (and their cost—about three times the cost of a HSS hob). Because they are fragile, you should take steps to protect them in handling and transportation, etc. Also, a diamond wheel is required to sharpen the hob and you must consider special coolants for the sharpening operation to avoid any possibility of cobalt leaching.

Tool Life Variables and Meters per Hob Tooth

Below are some of the many factors that will affect the hob tool life.

- Hob tool material, its hardness specification and coating
- Workpiece material, hardness and microstructure (all affect machinability)
- Hob speeds and feeds
- Coolant type and application
- Hob shifting procedure
- Hob clamping arrangement
- Wear criteria

When asked, "What kind of tool life are you getting?" the most common response is in terms of "pieces-per-sharpening." There is a better way to think of tool life, and that is to express it in terms of a "life factor," with units of "meters-per-hob-

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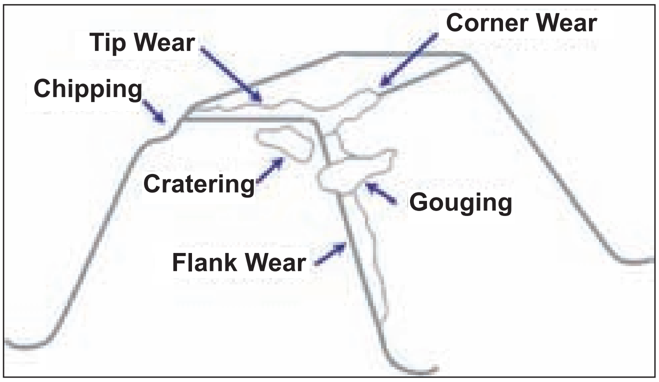

Figure 10—Types of hob tool wear.

tooth" or "inches-per-hob-tooth," instead of "pieces-per-sharpening." Here is one reason why: if the response to the tool life question is "500 pieces-per-sharpening" on an application, how do you know if that is a good number? It may be good if the hob length were 3 inches (76.2 mm) long, but would it be good if the hob were 8 inches (203.2 mm) long?

If a "life factor" in "meters/tooth" (or inches/tooth) is used, then it does not matter how long the hob is. The number of parts-per-sharpening can be calculated from the meters per hob tooth based on the hob length. Also, using a "life factor" allows us to compare tool life for different applications.

The calculation for a "life factor" is a simple one. First calculate the linear meters (or inches) of gear teeth and then calculate the number of usable hob teeth between the hob shift limits for the given application or cutting trial.

Once these simple calculations are made, the life factor for a known parts/sharpening can be determined, or the parts/sharpening for a known life factor can be determined.

The formula for linear meters (inches) of gear teeth is:

$$\text{LIN} = \text{N (NPPC)} \left(\frac{\text{FW}}{\cos(\text{HA})} \right) \quad (1)$$

The formula for the usable number of hob teeth is:

$$\text{USEN} = \text{FLUTES} \left(\frac{\text{USELEN}}{\text{NCP}} \right) \quad (2)$$

Where

LIN	Linear meters (inches)
N	Number of gear teeth
NPPC	Parts per cycle (number of parts in the stack)
FW	Face width (meters or inches)
cos (HA)	Cosine function of the gear helix angle
USEN	Usable number of hob teeth within the hob shift limits
USELEN	Usable length of the hob (length along the hob axis between the hob shift limits)
NCP	Normal circular pitch of the hob
FLUTES	Number of hob flutes or gashes

Having calculated the linear meters (inches) and the usable number of hob teeth between the shift limits, the life factor can be calculated as follows:

$$\text{LF} = \text{LIN} \frac{\text{(PARTS)}}{\text{USEN (NPPC)}} \quad (3)$$

or the parts-per-sharpening can be calculated:

$$\text{PARTS} = \text{LF (USEN)} \left(\frac{\text{NPPC}}{\text{LIN}} \right) \quad (4)$$

Where

LF	Life factor
PARTS	Parts-per-sharpening

It is important to note that the life factor method does not take into account the volume of material being removed, the rate of material removal (speeds and feeds), the machinability of the gear material or the hob material and hob coating. It is assumed that the application being evaluated is running at reasonable speeds and feeds, and the material is a typical gear material and hardness and the tool utilized has a good base material and coating. Despite these assumptions, the life factor method works very well.

When asked to estimate the parts-per-sharpening for a new application, make the calculation as described above using 3 meters per hob tooth. This is a very good starting point that can most often be met initially, and can be exceeded with development of the shifting strategy, speeds and feeds, etc.

The life factor is also very useful in setting up hob shifting strategies. See the section on "Hob Shifting Methods."

To give an idea of what type of life factor numbers to expect, 3 meters per hob tooth is a good starting point for all applications. Generally speaking, 4 to 5 meters/tooth is an achievable estimate, taking into consideration the tool life variables mentioned earlier and the application. For example, an automotive supplier in production is achieving 6 meters per hob tooth on planetary pinions, 5 meters per hob tooth on sun gears, 4 meters per hob tooth on transfer gears and 3 meters per hob tooth on final drive gears. For course pitch gears 3 NDP (8.47 Mod) or coarser, you can expect life factors of 1 to 2 meters per hob tooth.

Of course, the tool life can be increased or decreased by changing any of the parameters mentioned in the bullet items above.

Tool Wear Criteria

It is important to establish what the tool wear criteria is, and sharpen the hob when the wear limit is reached. Wear on a tool may accelerate rapidly after a certain point is reached. For carbide tools, a 0.10 mm (0.004") maximum wear limit is recommended, although there are applications using a 0.15 to 0.20 mm (0.006–0.008") wear criteria in the field. For HSS tools, a 0.30 mm (0.012") maximum wear limit is recommended; however, this also is exceeded in the field. Note that, when reporting tool life results, you should specify what your wear criteria are. For example, you can expect better tool life results (more parts/sharpening or higher life factor) if the wear criteria used were 0.15 mm (0.006") as opposed to a 0.10 mm (0.004") criteria.

Also, tool wear criteria can be based upon other parameters, not just the measured amount of wear on the hob tool. For example, the deterioration of the cut part quality, surface finish

Table 4—Hob Speeds and Hob Chip Thickness

	HSS	Carbide
Hob speed	100–180 SMPM [325–590 SFPM]	250–300 SMPM [820–985 SFPM]
Hob chip thickness	0.20 – 0.30 mm [0.008" – 0.012"]	0.15 mm [0.006"]

on the teeth being cut, heat of the workpiece after hobbing or hob spindle power draw during the cut can also be criteria for a tool change.

Hob Speeds and Feeds

Table 4 is a general guide comparing hob speeds and feeds for both HSS and carbide hobs. The chart assumes speeds and feeds for 8 normal diametral pitch (3.175 Module) gears or finer. For coarser pitch applications—harder materials and more difficult to machine—the speeds and feeds should be reduced.

Note that the table indicates hob chip thickness recommendations as opposed to specifying actual feed rates in inches/rev or mm/rev. The hob chip thickness is calculated using the formula developed by Hoffmeister that is based on the hob, gear geometry and hob feed rate. Knowing the desired hob chip thickness, the hob feed rate can then be calculated for the application. For some applications the feed rate may also be limited by the amount of allowable scallop depth.

Also note that for carbide material the hob can be run faster than that of HSS hobs; however, the maximum hob chip thickness, which determines the hob feed rate, is half that of HSS applications. This means you cannot run the carbide hobs at the same feed rates as HSS—so you gain on the speed, lose on the feed. The same speeds and feeds can be used for both wet and dry cutting, given the proper tool and coating for the application.

Hob Shifting Methods

Hob shifting methods are extremely important, fig. 11 in the hobbing process, whether it be for wet or dry applications (Fig. 11). Initially with HSS wet applications, a small incremental amount of hob shift was used after each cycle. The amount of hob shift will vary, but it is generally 0.001" (0.025 mm) to 0.050" (1.27 mm), depending on the normal diametral pitch (module), etc. Many companies have their own algorithm for calculating the starting amount of hob shift when using small, incremental shifts. The shifting strategy for small, increment shifts is set up such that after one pass over the usable length of the hob, the tool would be ready for sharpening.

With the introduction of dry hobbing, it was recommended to use larger shift increments approximately equal to the normal circular pitch of the gear or axial circular pitch of the hob, and to use multiple passes over the usable hob length. A small offset amount at the beginning of each pass is also recommended. The theory is to shift out of the "hot zone" or contact area of the hob and gear as soon as you can. The contact area on the hob consists of a roughing and finishing zone that is dependent on the geometry of the hob and gear.

As mentioned earlier, using a life factor is also very helpful in setting up your initial hob shifting strategy. For example, if the strategy is to use a large shift increment with multiple passes, start with the assumption the shift amount will be one circular pitch (or something near one circular pitch). Whatever the value chosen, the number of parts-per-pass can be calculated for the shift limits by dividing the shift amount into the usable shift distance between the shift limits. If 3 meters per hob tooth is assumed to start with (or whatever the life factor is to be used), the number of parts-per-sharpening can be calculated, and therefore the number of hob passes necessary to obtain the number of parts-per-sharpening. The amount of offset for each pass can be calculated by dividing the number of passes into the amount of hob shift.

If the hob shift strategy is to use one pass with a small, incremental amount of shift, calculate the number of parts-per-sharpening based on the life factor and divide the distance between the hob shift limits into that number, and that determines the shift amount.

Wet and Dry Hobbing

The benefits of using a coolant are well known. Coolants are used to cool and lubricate the cutting tool, as well as maintain work and workholding equipment temperatures. Coolant also aids in the chip removal during hobbing. Dry hobbing is very popular today because it eliminates the need for coolant, therefore eliminating coolant costs, disposal fees, etc. Note that dry hobbing does require the application of air to the hob tool and to the workholding equipment to aid in chip evacuation. The cost of air must be considered in the economics of the dry hobbing process. Other benefits to dry hobbing are the reduction in health hazards from the coolant, cleaner hobbed parts and a much cleaner working environment.

In the initial movement to dry hobbing, carbide tools were selected. As stated earlier, most applications today have switched to using HSS materials for the base material when dry hobbing with one of the several coatings available.

As for the end result, you will not see any difference in quality (lead, profile, pitch, size, etc.) between parts hobbed wet or dry. What you will most likely see is better tool life with coolant than you will when hobbing dry. Much has been written about the benefits of dry hobbing, including statements about obtaining better tool life. In most cases, the improved tool life came from the fact, that, when making the switch to dry hobbing, the base material of the hob and the coating were

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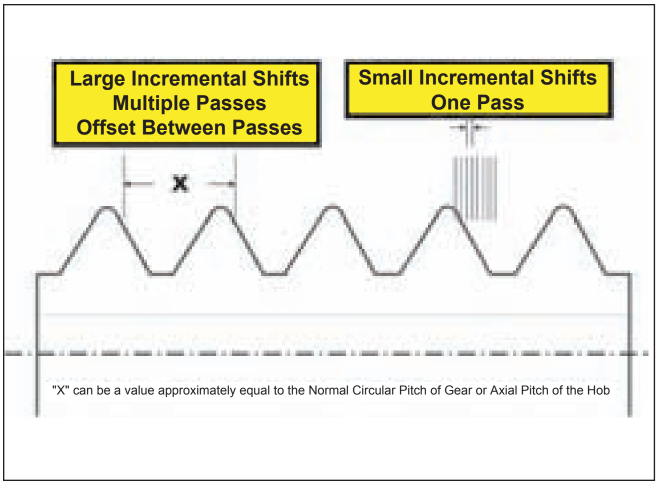


Figure 11—Hob shifting strategies.

upgraded. If the same upgraded hob tool material and coating were used in the wet application, most likely the resultant tool life would be better with the coolant application over the dry application.

Summary

There are many factors that can contribute to tool life. Start with a good base material and coating, and good hob design. Use reasonable speeds and feeds and think in terms of meters-per- hob-tooth (inches-per-hob-tooth), not in pieces-per-sharpening. Take a closer look at your current application and determine what the life factor is.

We can expect that new materials and coatings will be developed that will inherently yield better tool life, and or/ allow use of more aggressive speeds and feeds. Enhancements in the machine tools that cut the gears will also be introduced. As the new materials and coatings and machine tools are rolled out into the marketplace, they will be evaluated and recommendations will be made just as in the past.

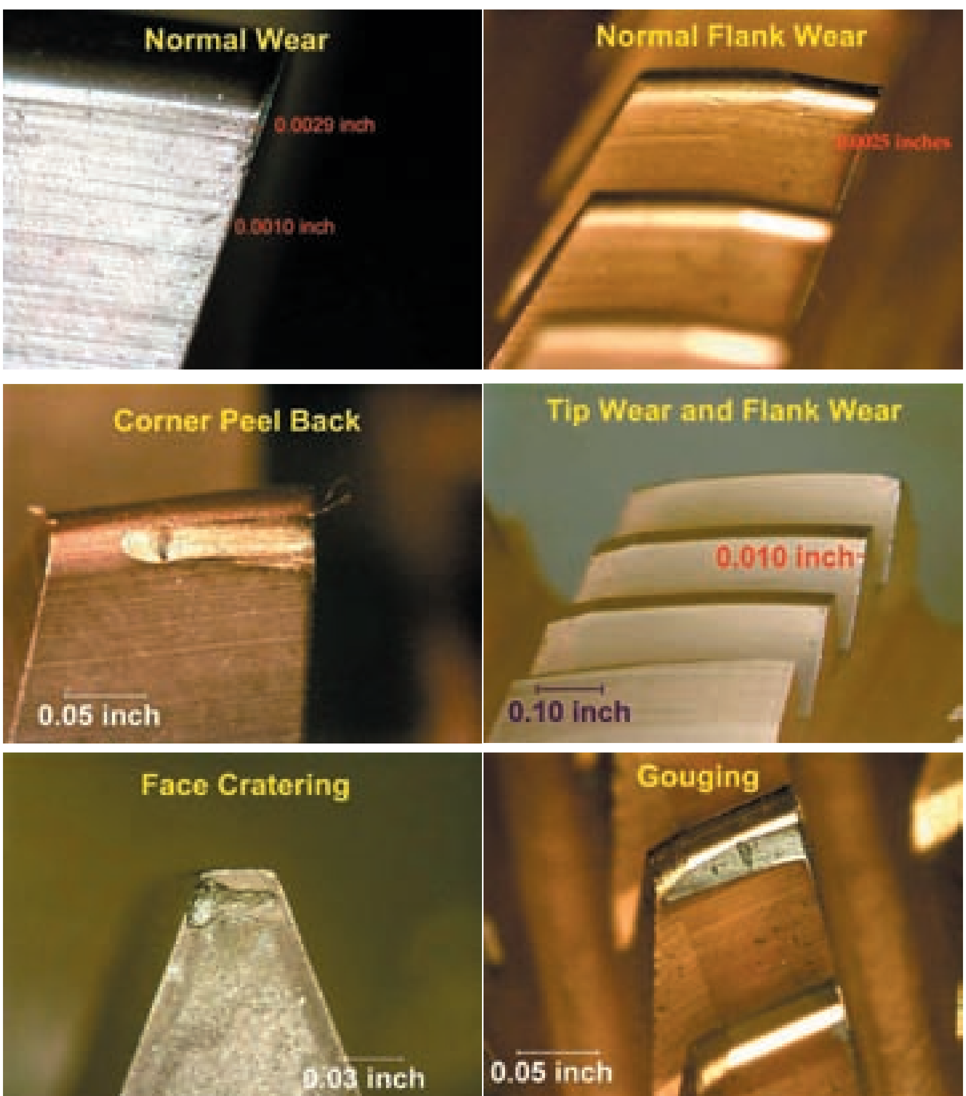
Acknowledgments

The author wishes to thank his colleagues at the Gleason Works and Gleason Cutting Tools for their contributions to this paper: Terry Blum, Peter Chapin, Glenn Schlarb, Kurt Switzer, Michael Tennutti, David Rydeberg and Kyle Puska.

References

1. Dudley, D.W. *The Evolution of the Gear Art*, American Gear Manufacturers Association, 1969.
2. Maiuri, T.J. "Synopsis of the Evolution of Gear Hobbing," The Gleason Works, Rochester, New York, May 1999.
3. Marks, L.S. *Mark's Handbook*, Fourth Edition, McGraw Hill, New York, 1941.
4. Maiuri, T.J. "Spiral Bevel and Hypoid Gear Cutting Technology Update," American Gear Manufacturers Association Fall Technical Meeting, October 2005, 05FTM07.
5. Maiuri, T.J. "Brief Synopsis of Carbide Wet and Dry

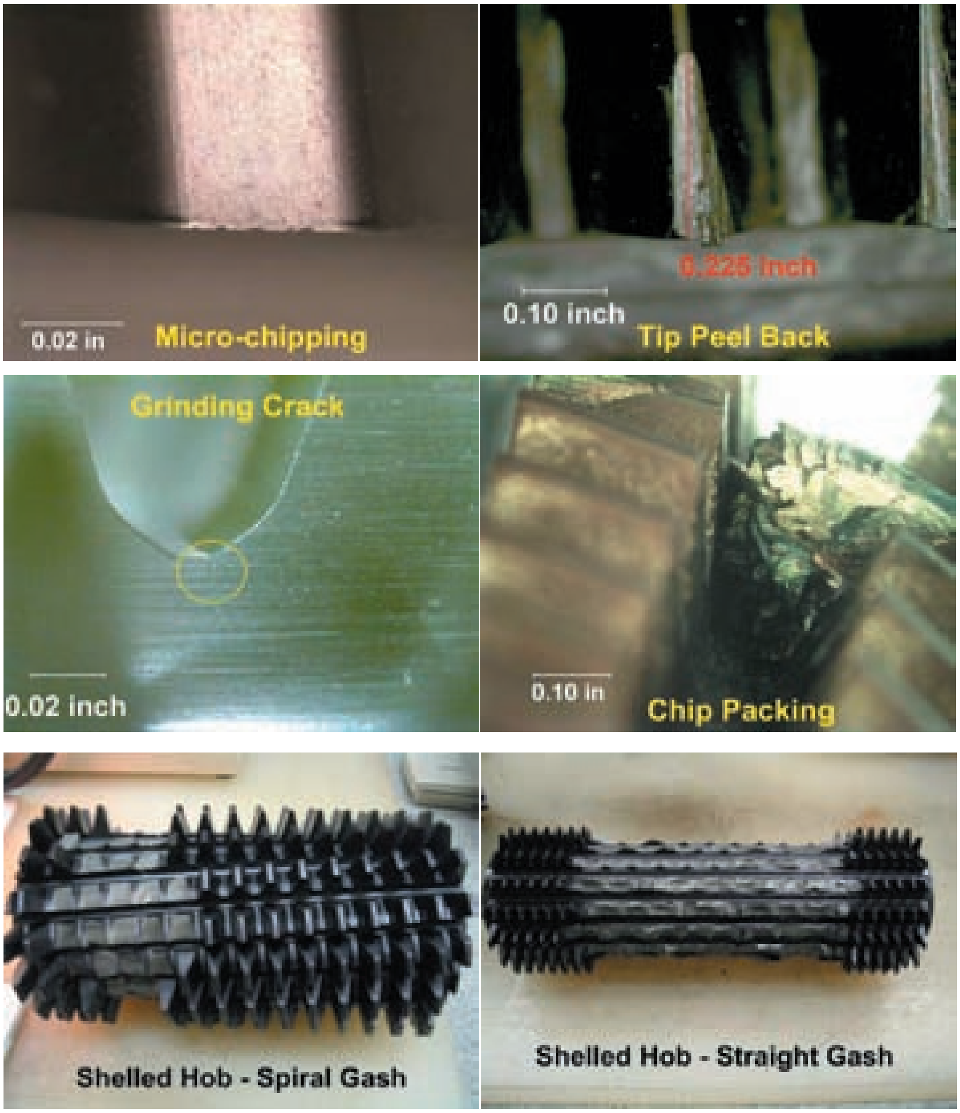
Appendix—Hob Wear Photographs



Hobbing," The Gleason Works, Rochester, New York, September 1997.
6. "Cermets: A Machinist Tooling Solution," *Mold-Making Technology* Article, *www.moldmakingtechnology.com/articles/050410.html#*.
7. Platit, AG website *www.platit.com*, May 2008.
8. Oerlikon Balzer website *www.oerlikon.com/balzers,* May 2008.
9. Rech, J., M.J. Schaff and H. Hamdi. "Influence of Cutting-Edge Preparation on the Wear Resistance in High-Speed, Dry Gear Hobbing," CPI 2005, Casablanca, Morocco.
10. Destefani, J. "Cutting Tools 101," *Manufacturing Engineering*, March 2002, Vol. 129, No. 3.
11. Appendix photos courtesy of Gleason Cutting Tools.

T.J. "Buzz" Maiuri *began his career at The Gleason Works in Rochester, NY as an engineering apprentice in 1966, and has been with Gleason ever since. He graduated from the Rochester Institute of Technology with a Bachelor of Science degree in mechanical engineering in 1974. He has held various positions in The Gleason Works organization over his 42-plus years of service, most recently as manager of application engineering and currently as product manager. Maiuri has authored technical papers, articles and recently a webinar on various gear-related subjects, and has participated in many gear seminars (SME, AGMA, etc.) speaking on various gear-related subjects. He has served on the AGMA TDEC (Technical Division Executive Committee) since 2001.*

Appendix—Hob Wear Photographs



The Effect of Superfinishing on Gear Micropitting

L. Winkelmann, O. El-Saeed and M. Bell

Management Summary

One of the most common failure mechanisms of highly stressed case-carburized gears is micropitting, or gray staining (Refs. 1–3). The standard FZG gear test (FVA Work Sheet 54) is generally used to determine the micropitting load capacity of gear lubricants. In recent years, FZG gear testing has also demonstrated its usefulness for evaluating the effect of superfinishing on increasing the micropitting load capacity of gears. Such studies, however, can only be afforded by major corporations or research consortiums, whereby the data is typically kept confidential. Results from the Technical University of Munich were presented in a previous technical article (see Ref. 4). This paper presents the results of Ruhr University Bochum. Both research groups concluded that superfinishing is one of the most powerful technologies for significantly increasing the load-carrying capacity of gear flanks.

Introduction

It should be noted from the outset that the data presented in this paper was generated by an independent laboratory. Superfinishing of the gears was the authors' sole contribution to these studies. The authors provided no input on the selection of the testing facilities, procedures or parameters. The conclusions listed at the end of this paper were solely those of the testing laboratory.

In a previous paper (Ref. 4), the authors discussed the FZG Brief Test of Gray Staining (BTGS), which was designed to quickly induce micropitting. It is an economical test in terms of cost and time to determine how lubricants, lubricant temperature, coatings and surface finishes influence micropitting. The BTGS showed that superfinishing significantly reduces micropitting, in comparison to baseline gears (Ref. 4).This finding stresses the importance of surface finish for resisting the formation of micropitting.

This paper discusses the results of a more intensive micropitting testing performed according to FVA-Information-Sheet 54/I-IV. The mineral oil used for lubrication was an ISO viscosity class 200, which contains a special additive (the nature of the additive is unknown to the authors) to reduce the micropitting carrying capacity. Baseline tests with a nonmodified standard FZG-C gear were carried out to demonstrate the micropitting properties of the oil. The test gears were standard FZG-C gears, which had the surface modified by superfinishing to a low roughness average (Ra). The pitch-line velocity during all testing was set to 8.3 m/s and the lubricant was injected at 60°C.

A brief summary of the test procedure taken from FVA-Information Sheet 54/I-IV is given below:

The micropitting test may be used to determine quantitatively the influence of lubricants (especially additives), the lubricant temperature and other influential factors on micropitting. The micropitting test differentiates between oils and thus facilitates the choice of a lubricant with sufficient micropitting load capacity.

The operating conditions (circumferential speed and lubricant temperature) may be suitably adapted for testing lubricants for a variety of applications in the micropitting test. To differentiate between the various test options, which are carried out according to the same test sequence, but with different test conditions, they are designated similarly to the FZG scuffing test by test gear type, circumferential speed and lubricant (inlet temperature in accordance with the selected test conditions (e.g., standard test: GT-Cl8.3190; GT = micropitting test).

The micropitting test consists of two parts. It comprises a load stage test followed by an endurance test. In the load stage test, the ability of the gear lubricant tribological system to resist micropitting is determined under specified operating conditions (lubricant temperature, circumferential speed) in the form of a failure load stage. The endurance test provides information on the progress of the damage after higher numbers of load cycles (Ref. 5).

Experimental Design

The gears used were the standard FZG-C type gears for micropitting testing. Table 1 gives the general data for these gears.

Baseline gears. Baseline gears were unmodified from the specifications given in the FVA Information Sheet 54.

Superfinished gears. A set of gears conforming to the specifications given in FVA Information sheet 54 were finished using chemically accelerated vibratory finishing as described in detail elsewhere (Refs. 6–7). This process utilizes high-density, nonabrasive media to enhance the performance of components that are subjected to metal-to-metal contact or bending fatigue. The Isotropic Superfinish (ISF) process generates a unique surface when compared to even the finest honing and lapping in that it has no directionality with a final surface roughness of 0.25 µm R_a or less. This ISF surface will be referred to as "superfinished" throughout this paper.

Figure 1 shows scanning electron microscope (SEM) images at 1,000X of a typical ground surface with an R_a of approximately 0.25 µm (top image) and a superfinished surface with an R_a < 0.05 µm (bottom image). Only slight scratches and small dents are visible amongst smooth plateaus of the superfinished surface.

The R_a of the baseline and superfinished gears were measured in

continued

Table 1—Specifications are given for FZG C-type gears for use in micropitting testing according to FVA Information Sheet 54 (Ref. 5)

Material	16 MnCr5 (DIN 17210)
Heat treatment	• Case carburized to 750 HV1 in the area of the tooth flank • Case depth: 0.8–1.0 mm (after grinding) • Core strength: 1,000–1,250 N/mm^2 • The zone close to the surface has no residual austenite content visible in the microscope (<20%).
Gear quality	5 according to DIN 3962, $ff_m \leq 5$ µm
	Pinion span: 34.779 mm (–0.11 to –0.135 mm) measured over 3 teeth
	Gear span: 35.252 mm (–0.11 to –0.135 mm) measured over 3 teeth
	Permissible R_w tolerance: each 0.01 mm
Roughness on tooth flanks	R_a = 0.5 ± 0.1 µm measured in the involute direction

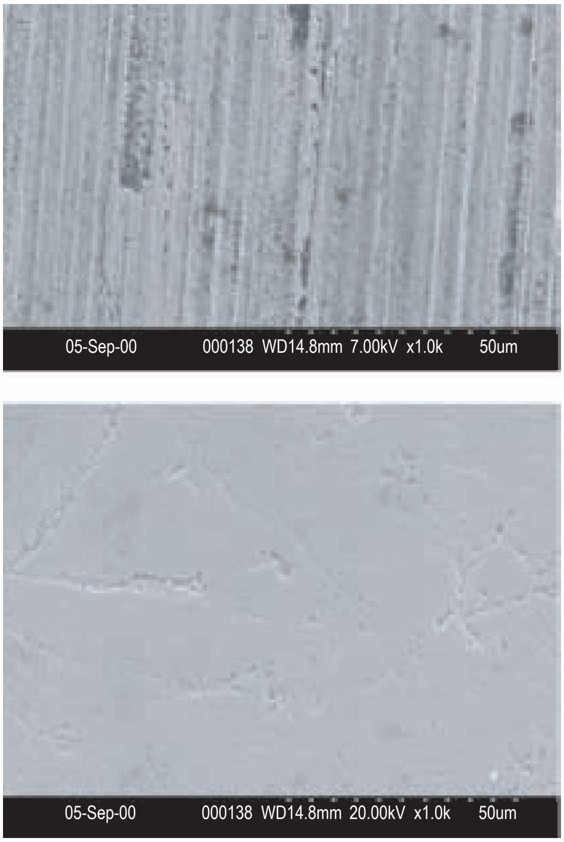


Figure 1—SEM images of a ground surface (top) and a superfinished surface (bottom).

the involute direction of the gear. The values are tabulated in Table 2.

Test rig. The test rig was the same as used in scuffing testing according to DIN 51 354 Part 1, but of reinforced construction and with spray lubrication.

Test runs description. Both the baseline gears and the superfinished gears underwent the following tests:

- Test run 1 was the load stage test in which the loading was increased every 16 hours, starting with load stage 5 and ending after load stage 10.
- Test run 2 consisted of a completed load stage test followed by an endurance test.

The endurance test starts with an 80-hour cycle at load stage 8, followed by five 80-hour cycles at load stage 10 (see Table 3).

After each 16-hour stage of the load stage test and every 80-hour cycle of the endurance test, the following inspection and measurements were made on the pinion:

- ff_m, average profile form deviation, in µm.
- *GF*, micropitting area of gear flank, in %.
- *W*, weight loss of gear, in mg.

Failure was defined by the average profile deviation (ff_m). For the load stage test, failure occurred when ff_m exceeded 7.5 µm. For the endurance test, failure occurred when ff_m exceeded 20 µm (see Table 3).

Experimental Data

Test run 1. The results of ff_m, *GF* and *W* are given in Figures 2a, 2b and 2c, for the baseline and superfinished gears, respectively. For the baseline gears, failure occurred at load stage 8, since ff_m was approximately 8.5 mm. By the end of load stage 8, approximately 30% of the gear tooth flank was covered with micropitting, which increased to 60% by the completion of test run 1 (load stage 10), with *W* at 54 mg.

The superfinished gears, however, showed no measurable variation for ff_m or *GF* at the end of load stage 10. Meanwhile, there was only approximately 8 mg of weight loss on the pinion.

Figures 3 and 4 show the presence of micropitting for the baseline pinion and its absence on the superfinished pinion.

Test run 2. Test run 2 consisted of a load stage test followed by an endurance test.

The results of ff_m, *GF* and *W* are given in Figures 5a, 5b and 5c for the baseline and superfinished gears, respectively. For the baseline gears, failure again occurred at load stage 8, since ff_m was approximately 8.5 µm. By the end of load stage 8, approximately 28% of the gear tooth flank was covered with micropitting, which increased to 60% by the end of the load stage test with W at 57 mg.

In the endurance test, the baseline pinion exceeded the 20 µm failure limit during the third 80-hour cycle at load stage 10 with an ff_m of approximately 20.2 µm. By the conclusion of testing, ff_m, *GF* and *W* reached 28 µm, 80% and 128 mg, respectively.

The superfinished gears showed no measurable change for ff_m or *GF* at the end of the load stage test. There was only approximately 6 mg of weight loss on the pinion.

Figures 6 and 7 show the presence of micropitting for the baseline pinion and its absence on the superfinished pinion.

The thin (0.5 mm) gray mark on the superfinished pinion was attributed to the lack of tip relief on the mating gear and was not a manifestation of micropitting. A better view of the gray mark is shown in Figure 8, where it was investigated under a microscope.

Table 2—Listing of the R_a values for the baseline and superfinished FZG gears.

	Baseline gears		Superfinished gears	
	Test run 1 (µm)	Test run 2 (µm)	Test run 1 (µm))	Test run 2 (µm)
R_a1 of Pinion	0.52	0.51	0.13	0.12
R_a2 of Gear	0.44	0.42	0.07	0.07
$R_a = (R_a1 + R_a2)/2$	0.48	0.47	0.10	0.095

Table 3—Contact stresses, duration, and failure limits for load stage test and endurance test.

	Load stage	Contact stress, N/mm²	Cycle duration, hours	Failure criteria
Load stage test	5	795.1	16	$ff_m > 7.5$ µm
	6	945.1	16	
	7	1093.9	16	
	8	1244.9	16	
	9	1395.4	16	
	10	1547.3	16	
Endurance test	8	1244.9	80	$ff_m > 20$ µm
	10	1547.3	80	
	10	1547.3	80	
	10	1547.3	80	
	10	1547.3	80	
	10	1547.3	80	

Conclusions

The baseline gears had a lower resistance to micropitting.

- Profile form deviation was 28 µm by the end of the endurance test.
- Micropitting coverage was 60% at the end of the load stage test and 79% at the end of the endurance test.

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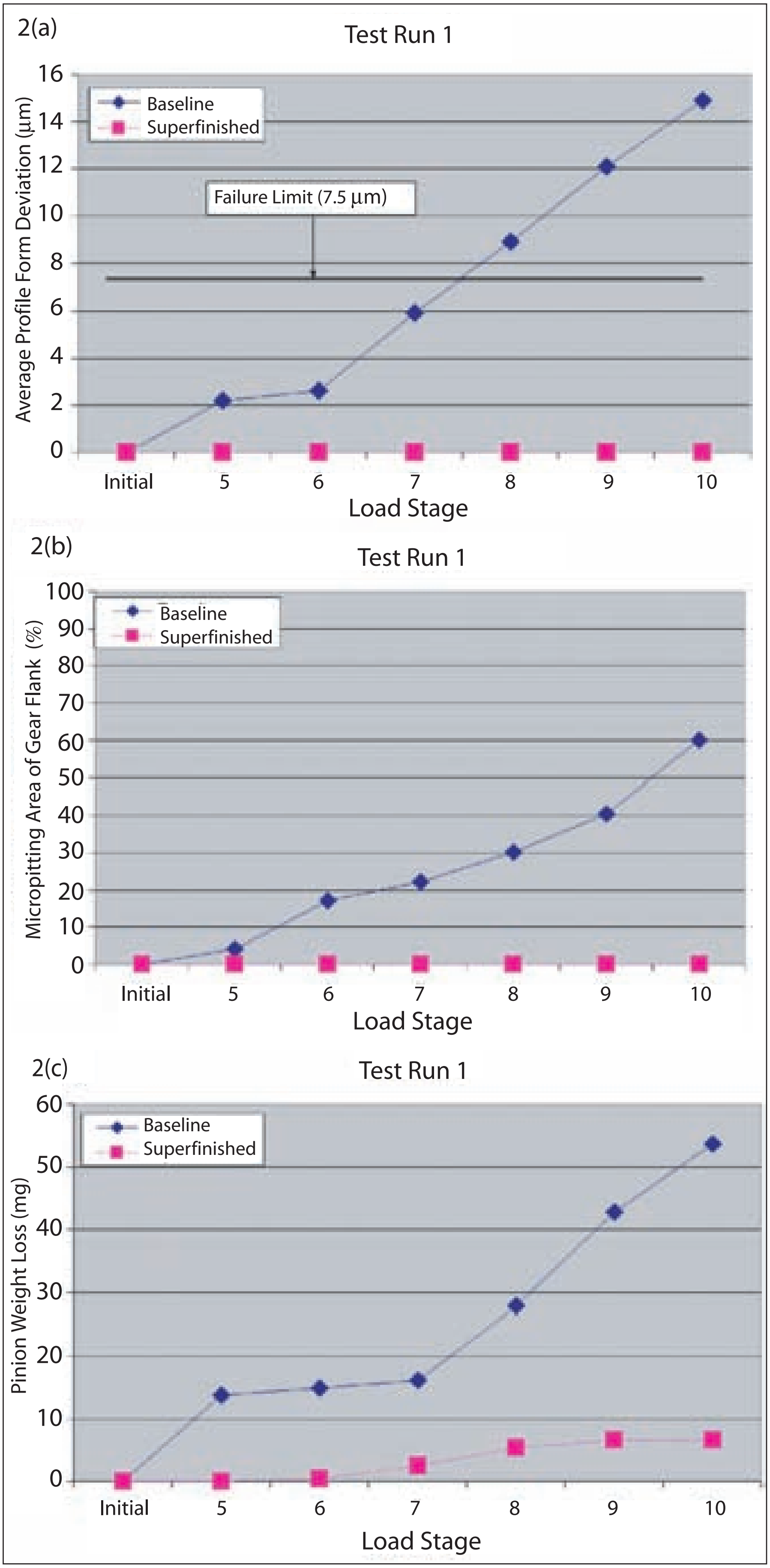

Figure 2—Measurements of test run 1 (load stage test) (a) ff_m, (b) *GF*, (c) *W* on the baseline and superfinished pinions.

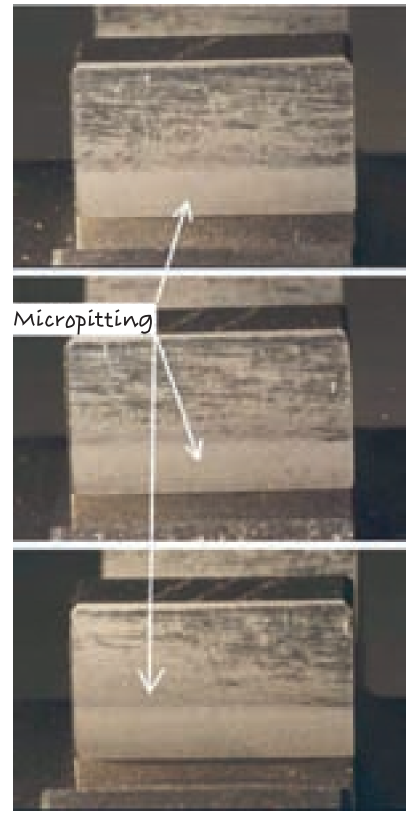

Figure 3—Pictures of three teeth on the baseline pinion after the completion of load stage 10 of test run 1 show micropitting on approximately 60% of the tooth flank.

Figure 4—Images showing the lack of micropitting on the superfinished pinion following the completion of load stage 10 of test run 1 showing no micropitting on the tooth flanks.

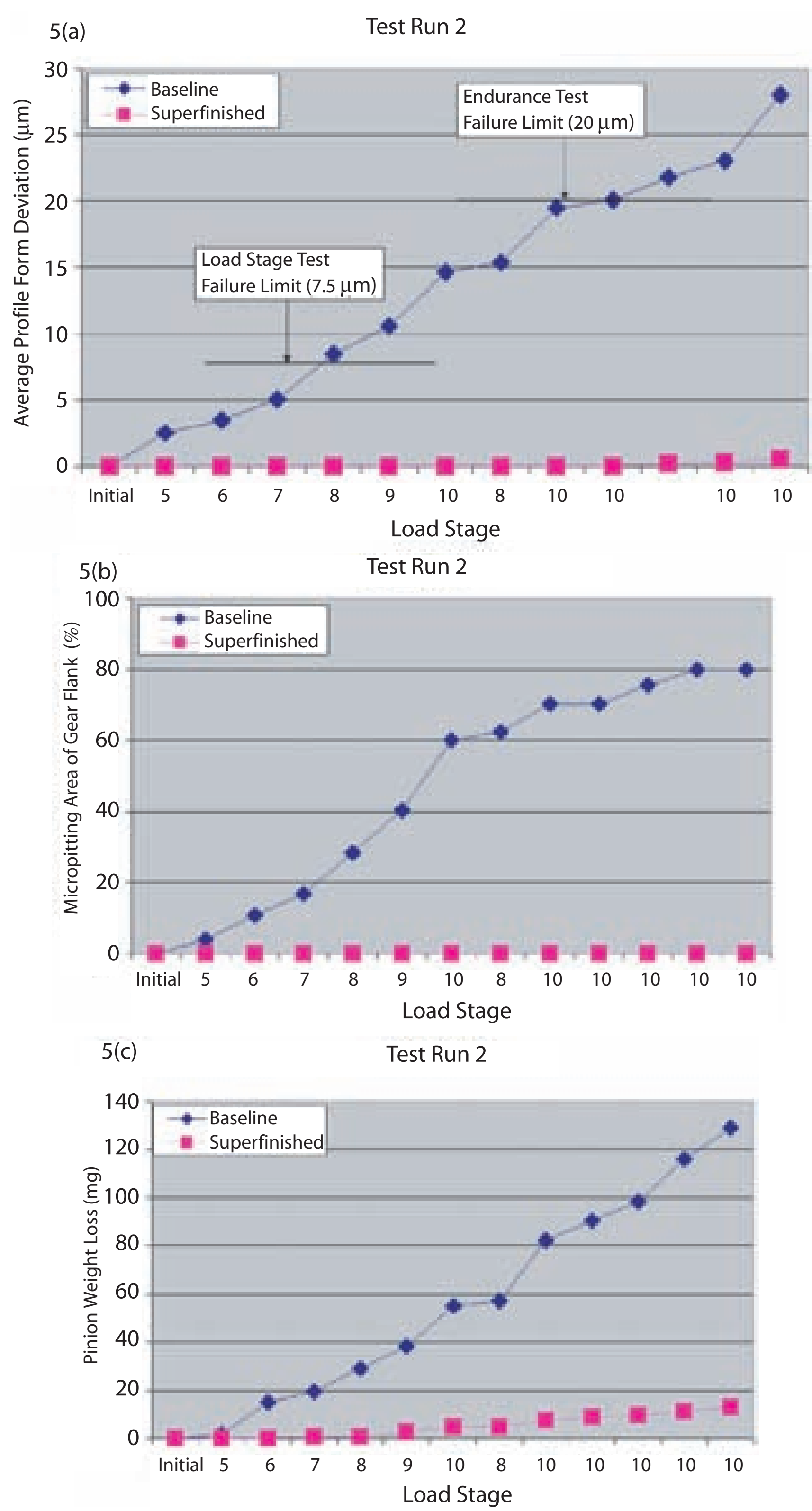

Figure 5—Measurements of test run 2 (load stage test) (a) ff_m, (b) *GF*, (c) *W* on the baseline and superfinished pinions.

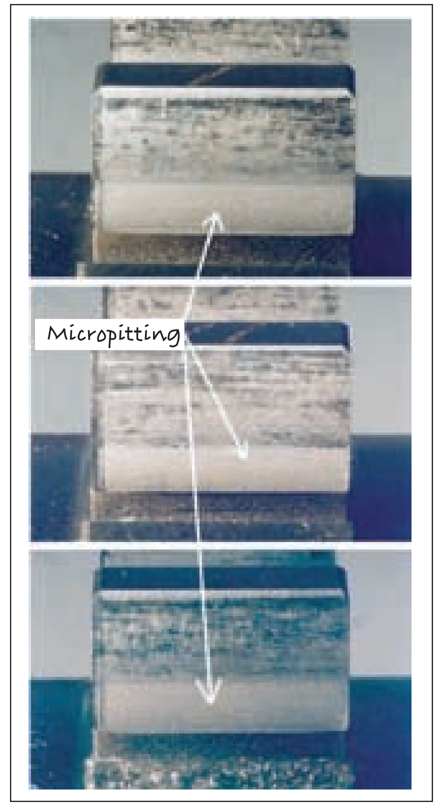

Figure 6—Three teeth on the baseline pinion after test run 2 showing 79% of the tooth flank covered in micropitting, with the band of the densest micropitting specified.

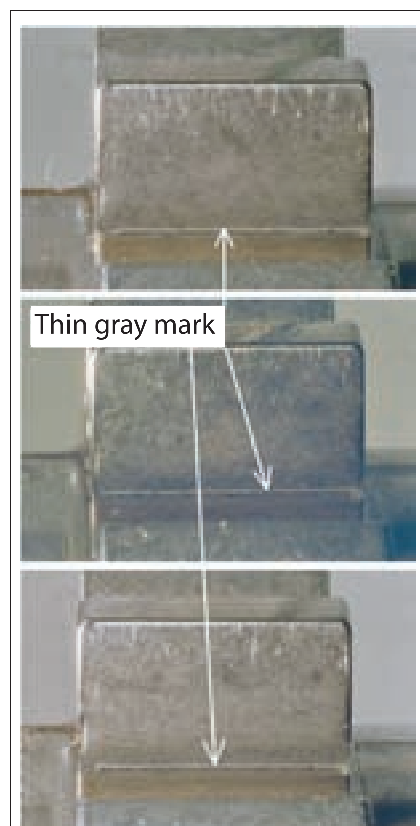

Figure 7—Picture of three teeth on the superfinished pinion after test run 2 (load stage test and endurance test) showing a thin gray mark that was attributed to the gears not having any tip relief. The gears show no micropitting.

- Weight loss was 38 mg after the load stage test, and 129 mg at the end of the endurance test.

The superfinished gears never showed micropitting nor reached any of the specified failure criteria.

- Profile form deviation was 0 μm at the end the load stage test and only 0.5 μm at the completion of the endurance test.
- Micropitting coverage at the end of both the load stage test and endurance test was nonexistent (0%).
- Weight loss was 6 mg after the load stage test, and 13 mg by the end of the endurance test.

These superfinishing results are remarkable despite the use of unfavorable oil, which showed damage at load stage 8 on the baseline gears.

Acknowledgments

The authors would like to thank Dipl.Ing. G Lützig, and Prof. Dr.Ing. W. Predki with the University of Bochum for performing the testing, along with Winergy for their part in making this information available.

References

1. Snidle, R.W., H.P. Evans, M.P. Alanou and M.J.A. Holmes. "Understanding Scuffing and Micropitting of Gears," RTO-AVT Specialists Meeting, Williamsburg, VA, June 7–9, 2003, RTO-MP-AVT-109.
2. Astrene, T. "20 Minutes with Walt Musial," *Tribology & Lubrication Technology*, May 2004, p. 2,634.
3. Barnett, D., J.P. Elderkin and W. Bennett. "An Analytical Approach to the Prediction of Micropitting on Case-Carburized Gears," *Gear Industry Journal*, 4th Quarter 2006, p. 3,246.
4. Winkelmann, L., M. Bell and B. King. "The Effect of Superfinishing on Gear Micropitting, Part I," 63rd Annual STLE Meeting, Cleveland, Ohio, USA, May 21, 2008.
5. Forschungsvereinigung Antriebstechnik, E.V., "Test Procedure for the Investigation of Micropitting Capacity of Gear Lubricants," FVA Information Sheet, Research Projects Nr. 54/I-IV, 1993.
6. Arvin, J., A. Manesh, M. Michaud, G. Sroka and L. Winkelmann. "The Effect of Chemically Accelerated Vibratory Finishing on Gear Metrology," 02FTM01, AGMA Fall Technical Meeting, St. Louis, MO, October, 2002.
7. Winkelmann, L., M. Bell and O. El Saeed. "The Capacity of Superfinished Vehicle Components to Increase Fuel Economy," ASME 2007 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, September 4–7, 2007, Las Vegas, Nevada, USA, DETC2007-34860.

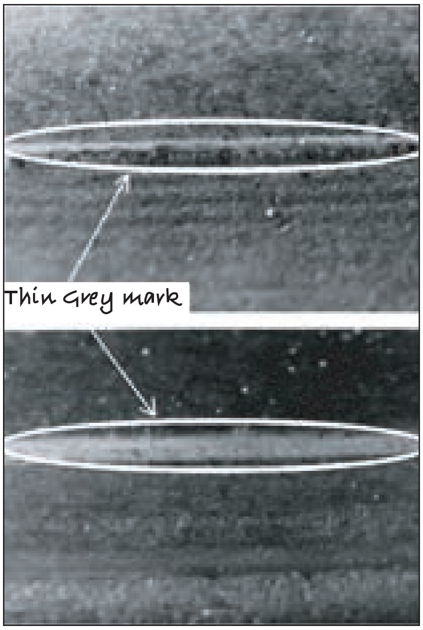

Figure 8—Microscope image of the thin gray mark of the dedendum circled on two flanks of the superfinished pinion. An investigation determined that this mark was not micropitting.

Lane Winkelmann *joined REM Chemicals, Inc. in 1996 as a senior research associate in the Research and Development Group. For the last three years, he has served as products manager. During his career, he has developed numerous products and processes for superfinishing a wide variety of alloys for both decorative and engineered surfaces. Winkelmann has co-authored several patents and has written and/or presented numerous papers on the use of superfinishing to improve gear performance. As a result of his accomplishments, this technology has been widely adopted by industries such as wind turbines, motorsports and aerospace. He received a bachelor's degree from Texas A&M University in 1991, and his master's degree at Tulane University in 2005.*

Matt Bell *joined REM Chemicals, Inc. in 2006 as a research chemist after completing a bachelor's degree in chemistry at Texas A&M with an emphasis on environmental chemistry in late 2005. Since then he has been involved in product and process development and regulatory compliance. Mr. Bell has also co-authored several articles highlighting the benefits of superfinishing gears. He is also a member of the American Chemical Society.*

Omer El-Saeed *is a Texas A&M University graduate with a degree in industrial engineering. He is currently an R&D engineer with REM Research Group in Brenham, Texas. He joined in 2005 after a stint with Alexandria Metal Finishers in Lorton, VA. As a member of the research group, he developed multiple products and processes for superfinishing various metal components such as gears and bearings. He co-authored and presented multiple technical papers for STLE, AGMA and ASME.*

Wind, Alt-Energy Themes

SWEEP THROUGH HANNOVER FAIRGROUNDS

As an indicator of what's up-and-coming in the manufacturing technology world, Hannover Messe 2009 reflects the prominence of alternative energy and efficiency. Five months prior to the show, 80 percent of exhibit space in the halls devoted to these themes was reserved, and in 2008, 1,000 exhibitors came from the energy sector, spanning over 40,000 square-meters—or 430,000 square-feet. Over 100,000 visitors, mostly trade professionals, were drawn to Hannover seeking out the energy displays, according to a Deutsche Messe press release. "In 2009, we expect to top [2008's] results—Hannover has well and truly become the world's biggest energy fair," says Oliver Frese, who is responsible for energy-sector displays at Hannover.

There are 13 flagship fairs being showcased at Hannover this year: INTERKAMA+; Factory Automation; Industrial Building Automation; Motion, Drive and Automation; Surface Technology; ComVac; Digital Factory; Subcontracting; Energy; Power Plant Technology; Micro Technology; and Research and Technology. Also this year, Hannover unveils

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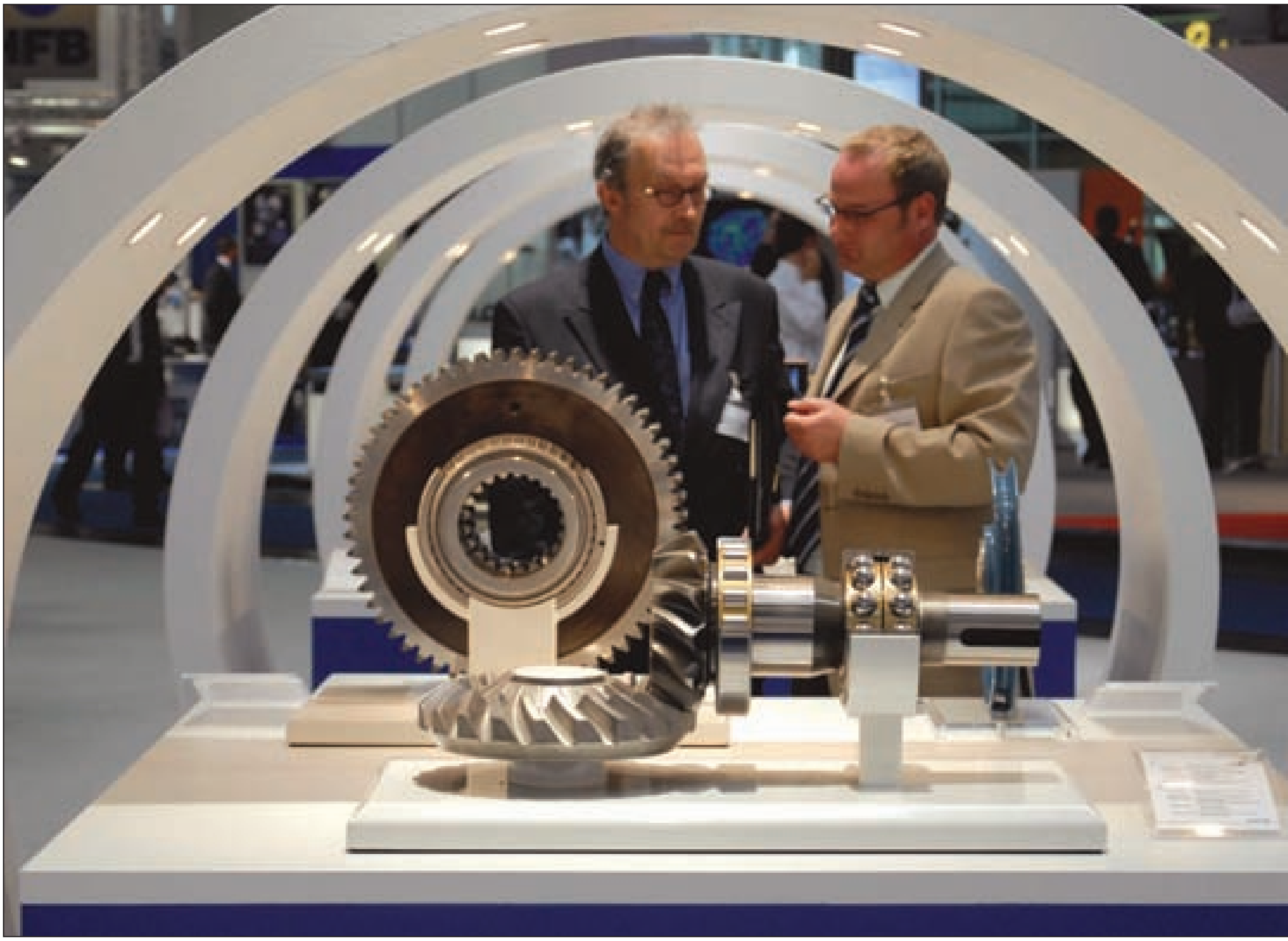


Thirteen flagship fairs make up Hannover Fair 2009, including the debut of Wind, which will be held every two years (Courtesy of Deutsche Messe).

Wind, which is set to recur once every two years. "Wind ranks among the most promising new trade shows mounted by Hannover in recent years. Staged alongside the Energy show, it is shaping up to be an absolute visitor-magnet," Frese says.

"For the first time the global wind industry can reap the benefits of a dedicated industrial fair that caters for the full spectrum of companies—from subcontractors to big name manufacturers," says Felix Losada, deputy head of corporate communications for turbine manufacturer Nordex AG.

Nordex can be found in hall 27, the place to be for the energy field featuring the Wind, Power Plant Technology and Energy shows.

The Motion, Drive and Automation show features more than 1,100 exhibitors, including many gear manufacturers (Courtesy of Deutsche Messe).

Gearmakers come to Hannover from all across the globe to grow their supply and sales networks (Courtesy of Deutsche Messe).

The Motion, Drive and Automation (MDA) show is in halls 19, 20, 21 and 23-25. Show organizers had not released an exhibitor list by press time, but the 2007 exhibitors featured many gear makers, including Hansen Transmissions, Hubei Planetary Gearboxes, IMS Gear, Italgear, Moventas, Renold and SEW Eurodrive—all found at the MDA show.

MDA is where mechanical and electric drive technology is concentrated and is the biggest hot spot to find gear manufacturers at. Along with the energy-themed shows, it is a major attraction at Hannover. "The leading trade fair for Motion, Drive & Automation will be booked solid as expected, featuring over 1,100 participating exhibitors," says Manfred Kutzinski, project manager at Deutsche Messe.

"For SEW Eurodrive, MDA is one of the most important trade fairs in the world, not least because of the high percentage of visiting professionals from outside Germany," said SEW managing director Hans Sondermann, following the 2007 show.

"The 'MDA' and 'Wind' shows supplement each other perfectly, and both will be drawing a big international audience to Germany," Kutzinski says.

Deutsche Messe looks to capitalize off of visitors' global ambitions. "We sense and are apprised by many exhibitors of the need to establish a worldwide network of trading partners and suppliers," Kutzinski says.

"The international scope of the event is what makes MDA so interesting," says Hartmut Rauen, managing director of the power transmission and fluid power sector of the German Engineering Federation (VDMA).

"Against the backdrop of this expansive internationalization of MDA, exhibitors are now in a position to make highly targeted use of their marketing budgets," Rauen says.

The World Energy Dialogue is focusing on the security of supply as its theme, demonstrating the significance of supply chain management for success in the energy field. In the fourth consecutive year at Hannover, the WED draws industry, science and political players to discuss solutions to the most pressing challenges in the world of energy today. Dr. Klaus Toepfer, formerly both the German environment minister and executive director of the United Nations Environment Programme (UNEP), is chairing the dialogue this year. Joining him as keynote speakers are Michael Glos, Germany's federal minister of economics and technology, Frank-Walter Steinmeier, Germany's foreign minister and Sergei Shmatko, Russia's energy minister. Michigan Governor Jennifer M. Granholm is one of several other speakers at the dialogue.

Hannover Messe takes place April 20–24 at the Exhibition Grounds, Hannover, Germany. For more information, visit *www.hannovermesse.de*.

March 23–25—Gear Manufacturing Troubleshooting. Star-SU, Inc., Hoffman Estates, IL. This training school for gear manufacturing is a basic course offered by the Gear Consulting Group in regional versions throughout the year to reduce the time employees spend out of the office while training. Other sessions this year will take place in Michigan, July 8–10, California, September 7–9 and Ontario, Canada, dates to be announced. Instructors Geoff Ashcroft and Ron Green teach participants both theory and practical aspects of gear manufacturing while imparting knowledge of everyday problems and understanding how to think through troubleshooting. Tuition is $750 and includes all necessary materials, as well as a reference manual and certificate of completion from AGMA. For more information, contact the Gear Consulting Group at (269) 623-4993 or e-mail *gearconsulting@aol.com.*

March 30–April 2—WESTEC. Los Angeles Convention Center, Los Angeles. More than 600 exhibitors showcase West Coast manufacturing's most advanced equipment, machine tools, knowledge and skilled professionals that will provide ideas and discuss the latest trends. According to show organizer the Society of Manufacturing Engineers, 81 percent of 2009 pre-registered attendees influence the purchase of products in their company, which is 5 percent higher than WESTEC 2008. Other statistics suggest the show will be larger than previous years, and attendance reflects California's position as the largest manufacturing state in the country. For more information, e-mail *service@sme.org* or call (800) 733-4763.

March 24–27—Detailed Gear Design: Beyond Simple Service Factors. Sheraton Premiere at Tysons Corner. Vienna, VA. AGMA and instructor Raymond Drago present this four-day course in the Washington, D.C. metro area. The seminar covers detailed gear design with hands-on *PowerGear* software training to practice the principles of gear tooth optimization presented during the first three days. Each participant receives a student version of *PowerGear* as part of the registration fee. Attendees will learn about gear design and participate in solving carefully crafted problems to demonstrate the practical application of optimization methods. Registration is limited to 40 participants on a first-come, first-served basis. For more information, contact Jennifer Cochran at (703) 684-0211.

April 20–24—Plastic Gear Design and Manufacturing. Universal Technical Systems, Inc. headquarters, Rockford, IL. This training course starts with a full day of *TK Solver* software instruction, which participants will learn to use for equation solving, manipulation of units and the creation of tables and plots in math models. Multiple topics encompassing basic and advanced gear design and theory are presented. The course concludes with an hour of gear consulting from UTS experts. Cost: $1,295. For more information, contact Kari Johnson, sales associate, at (815) 963-2220 or *sales@uts.us.com.*

April 28–30—Precision Machining Technology Show. Greater Columbus Convention Center, Columbus, OH. The Precision Machined Products Association along with *Production Machining* and *Modern Machine Shop* magazines presents the biennial PMTS, which is an international exposition attracting manufacturers, suppliers and end users of products and services completely devoted to precision machined products and turned parts' production. Several hour-long technical sessions accompany the trade show. They provide attendees with on-site expertise and the latest industry technology knowledge. Show admission and the technical sessions are free for pre-registered attendees. For more information, visit *www.pmts.com.*

May 19–21—EASTEC. Eastern States Exposition Grounds. West Springfield, MA. More than 440,000 East Coast manufacturers continue to use EASTEC as an opportunity to expand business since the show debuted in 1979. Growth industries such as medical, aerospace and defense are big ticket themes at the show this year as well as lean and green topics, which are all highlighted at official resource centers each day. EASTEC is organized into five technology buildings to help attendees navigate some 2,000 products on display. The buildings emphasize precision manufacturing equipment and systems; automation, supply chain and process improvement; plant, energy and environmental efficiency; design, engineering and rapid technologies; and tooling, workholding and machining accessories. For more information, visit *www.easteconline.com.*

June 22–26—MoldMaking Expo. McCormick Place, Chicago. The MME 2009 is co-located with NPE 2009, the International Plastics Showcase. It is an event exclusively dedicated to the moldmaking industry and the new products and processes that are helping shops increase productivity and profitability. On top of 25,000 square feet of exhibit space, the expo includes a two-day technical conference with presentations featuring end-user application approaches within case study, panel, workshop and roundtable discussion formats. The conference will focus on strategies for cutting costs and improving productivity, technological innovation and application and business and management issues. For more information, visit *www.moldmakingexpo.com.*

Howard Sanderow 1945–2009


Howard Sanderow

AGMA consulting member Howard Sanderow passed away February 2, 2009 in Columbus, OH. Sanderow was president of Management and Engineering Technologies, (MET Group, Inc.), a powder metal consulting company he founded with his wife Barbara in 1988.

Sanderow was a past president of the Powder Metallurgy Parts Association, a member of the Metal Powder Industries Federation (MPIF) Technical Board, and he was serving as chairman of the MPIF Standards Committee and executive director of the Center for Powder Metallurgy Technology. Sanderow authored more than 225 technical papers in the powder metallurgy field and a book on high temperature sintering. He held two patents, according to the AGMA.

He received a Bachelor of Science in metallurgical engineering from Rensselaer Polytechnic Institute, a Master of Science degree from the University of Pennsylvania and a Master of Business Administration from Wright State University.

In 1966 Sanderow started his career with the GE Missile and Space division. In 1970, he joined TRW, where he was appointed plant metallurgist at the Supermet division in Dayton and was promoted to general manager in 1980. He was awarded the MPIF Distinguished Service to Powder Metallurgy Award in 1995 and was named a Fellow of APMI International in 2007, according to the MPIF.

Sanderow is survived by his wife Barbara, daughter and son-in-law Meredith and James Grosser; son and daughter-in-law Lewis and Jennifer Sanderow; grandchildren Mara, Gabi and Emma Sanderow; Eli, Lindsey and Jonah Grosser; sister Sheryl Solow and brother-in-law Barry Tannebaum. Memorial contributions may be made to the Leukemia and Lymphoma Society (*www.leukemia-lymphoma.org*) or Beth Abraham Synagogue Sanderow Fund (*www.bethabrahamdayton.org*).

David Brown Gear

PURCHASED BY CLYDE BLOWERS

Textron Inc.'s entire fluid and power division was sold to Scottish-based group Clyde Blowers. The deal, worth $1 billion, included David Brown Gear Systems, Maag Pumps, David Brown Hydraulics and Union Pumps. All but the latter will remain separate portfolio companies. Union Pumps will integrate with Clyde Pumps.

"This is a very positive move for both parties, as well as a great fit for employees," says Lewis B. Campbell, Textron's chairman, president and CEO. "Clyde Blowers is gaining world-class operations with Textron's Fluid and Power group of companies, including some of the most advanced technologies, respected brands and highly talented people in their respective industries, while we continue to strategically focus our portfolio of businesses to deliver even more meaningful value growth, profitability and shareholder return."

Xspect Solutions

APPOINTS APPLICATIONS ENGINEER FOR GEAR MEASURING EQUIPMENT


Elliot Mills

Elliott Mills is now the applications engineer for Xspect Solutions/Wenzel gear measuring equipment. Mills previously worked as a manufacturing engineer, industrial engineer and production supervisor for American Axle and Manufacturing. He earned a degree in manufacturing engineering and a master's degree in operational management from Kettering University—formerly General Motors Institute—where he is currently completing an MBA.

In his new position, Mills is responsible for developing new gear measuring applications using Wenzel GMMs, Renishaw scanning probes and the *OpenDMIS* gear measuring software module.

Kleiss

EXPANDS INJECTION MOLDING CAPABILITIES

With the addition of the Microsystem 50 micro-injection molding machine from Battenfeld, Kleiss Gears is tapping into the miniature plastic gear market—with emphasis on the medical devices industry.

The Microsystem machine is a modular production cell capable of injection molding, handling, inspection and packaging within clean-room conditions. Gears weighing less than 100 mg can be molded almost void of material waste and consuming less energy than traditional injection-molding machines.

"We have been quite successful molding miniature gears with our conventional injection-molding presses," says Rod Kleiss, president of Kleiss Gears. "But we found that to produce true micro-gears on our current machines resulted in too much waste material to make the gears cost-effective for our customers.

"We are proud to be the only gear molding company in the United States using this technology to produce micro-molded precision gears, and we are in the design and tooling stages for the first scheduled production run on the new Microsystem for a major medical OEM."

Bodycote

SIGNS SUPPLY AGREEMENT WITH AFC-HOLCROFT

Bodycote's 190 commercial heat treatment facilities in 27 countries are being supplied with a common batch furnace platform supplied by AFC-Holcroft, per an agreement reached between the two companies. The purpose of the agreement is for each Bodycote plant to operate with consistency, using the same equipment.

AFC-Holcroft's Universal Batch Quench (UBQ) product family can be provided to Bodycote at a reduced cost with local service support available in all the key regions Bodycote operates in. The controls architecture will be standardized throughout the plants as another benefit to the agreement.

"This agreement represents a great alignment of AFC-Holcroft's global capabilities and products with a progressive customer that has done a tremendous amount of work in mapping their own global strategy to remain the leader in the commercial heat treatment marketplace," says William Disler, vice president of sales and engineering at AFC-Holcroft. "We are very pleased to have the opportunity to be a part of their global strategy."

"Bodycote recognized the need to buy the best equipment at the best price as a means to improve our return on investment," says John D. Hubbard, CEO/Metallurgist, P.E., Bodycote, plc. "After benchmarking the best features of each of the myriad of furnaces we have, a 'best of breed' was created. The key furnace manufacturers were given an opportunity to propose a long-term win/win approach to satisfying our batch integral quench furnace needs, and after careful review and consultation, we selected AFC-Holcroft as the best fit for our needs.

"Their commitment to open communication coupled with their desire to be the best was the deciding factor. We have now received furnaces manufactured in all their geographic facilities and have been pleased with the quality, timeliness and follow-up. We look forward to a continuously improved relationship that truly is good for both companies."

FARO

NAMES BUSINESS DEVELOPMENT DIRECTOR

Gary Telling was appointed as one of the business development directors at FARO Technologies, Inc. He began his career in the automotive industry working for General Motors as a production supervisor. In 1991, he was chosen by GM to study industrial technology at Purdue University, where he finished first in class.

Holding various engineering roles for the company over the years, Telling established GM's first modern metrology operation. He handled dimensional and quality control for eight new GM product launch sites by 2002, and he helped teams create GM's proprietary data analysis system using code he personally developed. His most recent position was as advanced global metrology lead, where he researched, benchmarked and developed business cases for GM's metrology strategies while discovering and implementing new applications for technology. Teller has been honored with the "People Make Quality Happen" and "President's Council" awards from the company.

"Gary's expertise will be crucial in helping us solve our customers' challenges not only in the automotive arena, but in other key and emerging markets as well," says David Morse, FARO SVP and managing director of the Americas. "He will help them be innovative, effective and also be their voice in our product development process."

Hexagon Metrology

ACQUIRES 3D SOFTWARE COMPANY

Technodigit SARL of Lyon, France, has been acquired by Hexagon Metrology. Technodigit develops the *3DReshaper* software, which is designed for 3D point cloud and 3D mesh manipulation for reverse engineering, rapid prototyping, product design and industrial inspection. The software helps organize and manipulate the millions of data points created by Hexagon's high-speed laser scanning systems, ScanShark laser probe and the Leica T-Scan.

"In the short run, the acquisition of Technodigit will enhance our existing portfolio of software solutions dedicated to point cloud acquisition and manipulation," says Ken Woodbine, president of Hexagon Metrology's software development group, Wilcox Associates. "*3DReshaper* already has existing interfaces to certain ROMER portable arm packages, as well as compatibility with Leica Geosystems products. The longer view is that the core technologies and algorithms can be selectively incorporated into the PC-DMIS engine to create greater flexibility and functionality in our core software package, which is the de-facto standard software for dimensional inspection at many of our worldwide customers."

Pascal Lefebvre-Albaret, president of Technodigit, says, "Hexagon metrology companies have been good customers for us for many years. Gradually this relationship has transformed into a partnership and ultimately we were asked to join the Hexagon Metrology family. We are very proud to be part of the world's leading metrology group, with the ability to offer our advanced technology as part of Hexagon's portfolio of software solutions."

Surfware

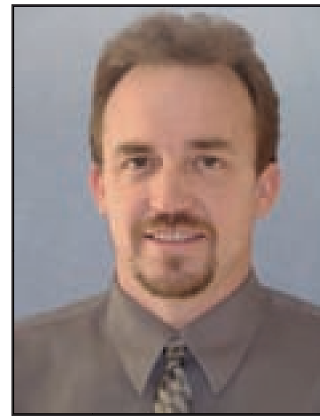
FILLS PRODUCT, SALES MANAGER POSITIONS

Greg Schils has been promoted to product manager for Surfware Inc., and Eric Brown joined the sales team as direct sales manager.

Schils is responsible for overseeing product development and expanding functionality for the *Surfcam* software and

continued

TrueMill technology. He has been with Surfware for more than 13 years in the application engineering department.



Greg Schils

"We are very pleased that Greg has accepted the position of product manager," says Stephen Diehl, president and CEO of Surfware. "His skill-set with *Surfcam* is one of the best in the market. Our products and company are growing quickly and will benefit from Greg's leadership. With his valuable combination of software knowledge and hands-on experience, Greg will provide an innovative, solutions-based approach to product development at Surfware."

Brown is responsible for creating direct sales in the Surfware Direct territories. He has more than 20 years of experience selling CAD/CAM, PLM and complementary products applications and solutions. His experience includes industries like electronics, aerospace/defense, semiconductor, medical products and other manufacturing and engineering technical sectors.

"Eric will help us continue to build our Surfware Direct customer base, both with *Surfcam Velocity* and our patented *TrueMill* technology," Diehl says. "We look forward to leveraging his skills in a variety of industries that will benefit from our high quality and innovative *Surfcam* software. Eric's insight and professionalism will also add value to our overall marketing efforts."

Eric Brown

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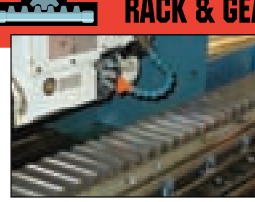

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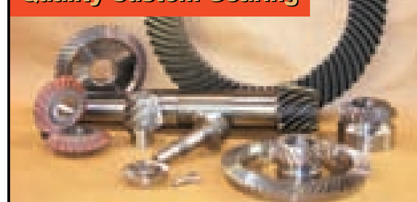

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NEXT
Gear Technology
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Honk if You Love Gears

Dear Addendum Team:

Firstly, may I congratulate you on your publication, which I have had the pleasure of reading for many years. I am a "time-served" gear cutter by trade, and I have had a good career involving gear manufacture and production.

My interest in gearing was the reason my wife surprised me many years ago with a birthday present of a personal license plate, GEARS, for my vehicle. I think my second vehicle will be "DPCPMOD," a good fit for the allowable 7 letters.

It would be interesting to see if any others have any innovative plates to advertise their interest/involvement in this fine art.

Many thanks for an excellent product.

Best wishes,

Alan Bailey, Alpek Machine Works, Calgary, AB

Alan, we like the way you think, so we're pleased to announce the establishment of the Gear Vanity Plate Hall of Fame. It's sort of like the Rock & Roll Hall of Fame, only way cooler. In order to be inducted, all you have to do is send us a photo of your plate, tell us who you are and where you live.

You drive around advertising your love of gears. We're giving you the opportunity to advertise it to the world. Inductees into the Gear Vanity Plate Hall of Fame will be publicized in a future issue of *Gear Technology*. Even more importantly, the submission materials will be permanently enshrined in the Gear Vanity Plate Hall of Fame (as soon as we find a suitable location and clear all the required building permits).

Recognizing the global appeal of gearing, our goal is to have as many U.S. states, Canadian provinces and countries represented as possible. So if you have a gear-related vanity plate, please consider submitting it for this prestigious honor.

Submit your entry today to

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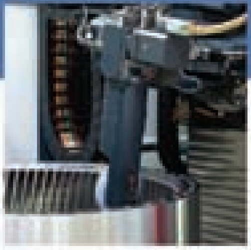

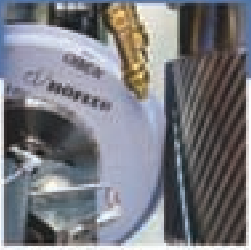

HÖFLER machine innovations not only set new standards for highest precision, dependability and profitability, but they are also helping to preserve our environment by producing our next generation of renewable energy systems and making our current power transmission equipment more efficient. However what further differentiates **HÖFLER** machines is their innovative use of environmentally friendly processes and manufacturing technologies. As an example, many machine components are made of mineral cast components, which have the highest level of dampening and thermal stability. Furthermore they are manufactured with minimal machining or other manufacturing waste products.

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