August 2012

GEAR TECHNOLOGY®

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The Journal of Gear Manufacturing

IMTS 2012

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Powder Metal Magic

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- Ask the Expert: Profile Shift
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- How Gears and Mind Control Mesh

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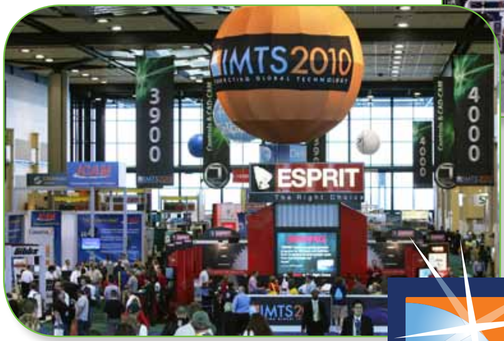

IMTS 2012
INTERNATIONAL MANUFACTURING TECHNOLOGY SHOW
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FEATURE

TECHNICAL ARTICLES

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GEAR TECHNOLOGY

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GEARTECHNOLOGY

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REMEMBERING James Cervinka

The gear industry lost one of its iconic figures in July when James Cervinka passed away at the age of 92. Jim was CEO and one of the founders of Arrow Gear. For 65 years, he was a gear man, and I can't help but feeling that his absence shrinks the gear industry by far more than the loss of just one man.

As a U.S. Navy veteran who served in WWII, Jim typified what is often called "The Greatest Generation," a different breed of men who were in many ways larger than life. Like many of his generation, he went off to war and faced situations where failure meant death. Jim, my father and much of that generation came back from World War II and applied that same "can do" attitude to their vocations, driving America forward to heights never before seen.

He was a unique man, and a character who will be missed. One of Jim's great loves was playing golf, and it is part of industry lore that Jim, every few years, had a new golf cart "enhanced" at Arrow Gear so that it drove more like a sports car than a puttering golf cart.

But I will miss Jim for far more than his personal legacy. I had known him for 48 years—my entire professional career, and—more importantly—his family and mine share a long history in the gear industry. When Jim started Arrow Gear in 1947, with his partner Frank E. Pielsticker and their extremely talented associate Ernie Kauzlarich, it was with used machinery, much of it purchased from my father, Harold, who at the time worked for *his* father, Charlie, at Machinery & Electric Motors in Chicago. Jim always specialized in Gleason bevel gearing, which was the most difficult and complex type of gears manufactured. He built the business with very hard work, ingenuity and perseverance. My father always spoke with admiration for Jim and what he accomplished professionally. This relationship between Jim and my family continued when my father started Cadillac Machinery in 1950, and continued up until his passing.

Over the last half dozen years or so, I've spent a lot of time over at Arrow Gear, whether as a machine tool dealer, as publisher of *Gear Technology*, or as a member of the board of directors for Citizens for American Manufacturing (CAM), which was started by Joe Arvin, Arrow's president.

Whenever I visited Arrow, I always made a point of stopping by Jim's office to say hello and to see how he was. Every time I saw him he would tell me how much he admired *Gear Technology*, and he would always thank me for the service we provide the industry. I guess, in many respects, we were a mutual admiration society of two.

I know that very late in his life, when most men are considering taking their chips off the table, Jim was "all in" to help Arrow Gear by investing in the latest technology and staying on the leading edge by providing the finest aircraft gearing available in the world. He was not only proud of the quality of the gears Arrow produced, but was also very proud of contributing components to some of the most memorable military and civilian aircraft produced during his career.

While he, Frank and Ernie almost literally built their business with their bare hands, he had the foresight to bring in and turn over the presidency to Joe Arvin, who has been there for 40 years. Joe brought a different skill set to Arrow and he has been an important component of Arrow's growth and success. Too often I've seen extremely talented, focused entrepreneurs drive their companies upward, only to crest and fall when they got beyond their own skills, talents and experience. This didn't happen to Jim.

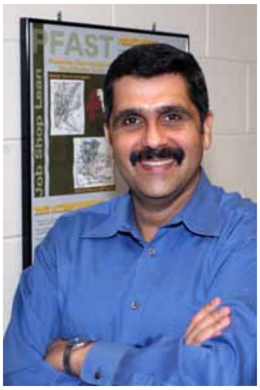
It was only 10 days before he passed away that I had the opportunity to poke my head into his office one last time, and true to form—he called me in to sit down again and thank me for what I've done with *Gear Technology* magazine. He was expansive in his interests, fiercely loyal to his family, his company and his employees and always generous with his compliments.

I was lucky enough to have been raised by a man who typified this generation, giving me his work ethic and values, but I am also grateful for the unusual and wonderful opportunity I've had to work with many other individuals like Jim Cervinka. I know how sorely we will miss them in the future. Thank you Jim, and may you rest in peace.

Michael Goldstein,
Publisher & Editor-in-Chief

P.S. Normally this editorial would have been written about IMTS, and we haven't forgotten about this very important show. With the strong manufacturing environment we've experienced over the last several years, it's more important than ever for you to consider attending IMTS (September 10–16 in Chicago). This opportunity comes only once every two years, so it's important that you see the latest technology that can help increase your productivity, flexibility, competiveness and profitability in the coming years. For more information see our show coverage on pages 22–43.

Adapting Lean for High-Mix, Low-Volume Manufacturing Facilities



Dr. Shahrukh Irani
Director, IE Research
Hoerbiger Corporation of America, Inc.

A customer has several choices when it comes to buying a service or product that he/she fancies. Boeing competes with Airbus, GM competes with Toyota and a host of other car manufacturers, and so on. Then why expect every manufacturer to pursue continuous improvement by following just the "Toyota Way" using tools pioneered by Toyota for their assembly lines? Toyota is a low-mix, high-volume manufacturer of *only* automobiles. They do not make refrigerators and bicycles on any of their assembly lines! Also, you will find that conveyors are the dominant material handling equipment used in their assembly facilities.

Now let's turn our attention to high-mix, low- or high-volume (HMLV) manufacturers of components, and oftentimes, assemblies built from those components, such as: facilities that manufacture custom configurations of assemblies, remanufacturing facilities, repair and maintenance facilities, and job shops.

Without a doubt, like Toyota, most of the above HMLV small- and medium-size manufacturers with annual sales in the $5 million to $100 million range will surely benefit tremendously by implementing lean, *even though they make hundreds of different components or assemblies*. There are savings to be gained by cutting the costs due to all forms of waste that exist in administrative and manufacturing processes. But, walk through these facilities and you will find that forklifts are the dominant material handling equipment in use. Why? Because these manufacturers have been advised (that) in order to be flexible, job shops should have process-focused facility layouts. That, unfortunately, condemns them to a batch-and-queue production system, which is the root cause of WIP, scrap, MRP-driven production control, etc. For example, Figures 1 and 2 depict the material flow in two forge shops that produce hundreds of different forgings for defense and aerospace customers. Both facilities scheduled their operations and suppliers using infinite-capacity *Material Requirements Planning (MRP)* software.

Numerous books have clearly explained the significant differences that exist between the operating conditions of any assembly production system versus those for any job shop production system when they are compared on various criteria, such as production volume, product variety, workforce skills, equipment flexibility, supplier control, production control and scheduling, etc. So, while it is imperative that HMLV manufacturers embrace lean as a philosophy, maybe they should not do it by following only what is best for an automobile manufacturer.

Unlike any low-mix, high-volume manufacturer like Toyota, job shops have to deal with: considerable volatility in demand; numerous changes in delivery dates forced upon them by customers; greater variety of manufacturing routings; high variability in setup times and cycle times across the different products they make; a diverse customer base; limited resources for workforce training (let alone even one full-time employee devoted to continuous improvement); more complex production control and scheduling; and limited clout to influence the delivery dates set by their suppliers or customers. Finally, these job shops also must deal with the tendency for their product mix to "migrate" as their customer base changes or they hire new sales and marketing staff who bring with them their past business contacts in different sectors of industry.

The popular saying is that a bad carpenter blames his tools. But what if his boss gave him bad tools that were ill-suited to the job that was assigned to him? This is exactly the case when HMLVs implement lean using only the

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popular lean tools, many of which are simply unsuitable, if not wrong, when used in non-assembly facilities.

Let's discuss the lean tools that would surely work in job shops. *Top-down leadership* and e*mployee involvement* are essential in just about any business or manufacturing facility. Even job shops need s*tandard work instructions* to minimize the impact of variability and variety on setups, tool changes, material specs, etc., although it is a non-trivial problem to actually standardize the large number of process plans, setup procedures, tooling packages, etc., that they surely have! And I know of no business that has not profited by empowering and training equipment operators to control *quality at source*. S*etup reduction* is equally important in any workplace, kitchens included. Ever seen how smoothly the professional chefs on Food Network shows glide around their kitchens to get anything they need as soon as they need it?

Next let us discuss the lean tools that may not work in job shops. I will discuss them in the context of the relevant steps of the lean thinking process pioneered by James Womack and Daniel Jones. They offered a powerful five-step thought process for guiding the implementation of lean techniques (that) is easy to remember but not always easy to achieve:

Identify value*:* Specify value from the standpoint of the end customer by product family.

Map the value stream*:* Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.

Create flow: Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer.

Establish pull: As flow is introduced, let customers pull value from the next upstream activity.

Seek perfection: As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced; begin the process

Tools that will work in any job shop	Tools that may not work in most job shops
5S	Value Stream Mapping
TPM (Total Productive Maintenance)	One-Piece Flow Cells
Setup Reduction (SMED)	Product-specific Kanbans
Error-Proofing (Poka-Yoke)	FIFO Sequencing at Workcenters
Quality At Source	Pacemaker Scheduling
Employee Involvement	Inventory Supermarkets
Strategic Planning	Takt Time/Pitch/Level Loading (Heijunka)
Visual Controls/Visual Management	Single-function Manual Machines
Standardardization of tools, processes, etc.	Assembly Line Balancing
Jidoka	
Top-Down Leadership	
Right-sized Machines	
Standard Work	

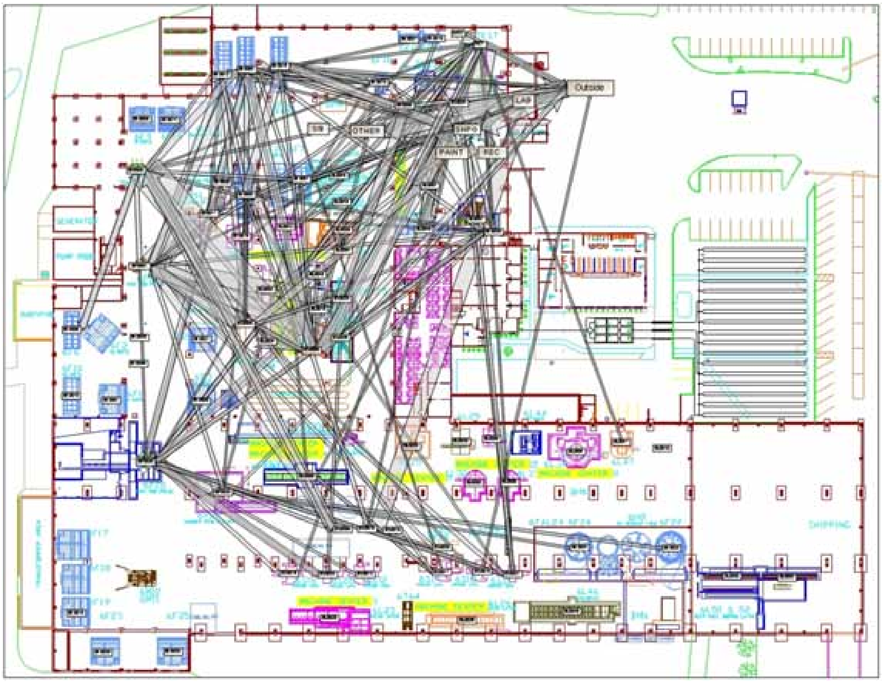


Figure 1—Material Flow Network at a Department Of Defense (DOD) Supplier

again and continue it until a state of perfection is reached in which perfect value is created with no waste.

Here is why several of these highly-popular lean tools cannot address the complexity of a job shop. Identifying value is trying to deliver to the customer what they want, when they want it at a competitive price. This is universally applicable to just about any business. But, it is not that easy to achieve *quality*, *cost* and *delivery* when the benefit of learning by repeating the same work over and over again is absent, as is the case in any job shop.

Value stream mapping (VSM) is a manual method. I have yet to see a single VSM that has mapped multiple interacting value streams that dynamically share resources. Besides, the "theory" of VSM is based on assembly line balancing. No job shop that is a multi-product remanufacturer or project-oriented custom manufacturer has a cadence (aka takt time) in their work flow. Nor does VSM have the ability to identify all the product families that may exist in any job shop's product mix.

One-piece flow cells are infeasible in job shops beyond a small portion of their product mix; instead, using group technology and production flow analysis, the job shop can be divided into two areas: One side consisting of flexible manufacturing cells ("mini-job shops") with each cell dedicated to a product family and the other side being a "remainder shop" where the spare parts, prototypes and one-off orders are produced. Flexible cells may not allow perfect one-piece flow, as in any assembly line. Still, due to increased proximity between consecutively used workstations, small batches of parts can be easily moved by hand or by using wheeled carts, short roller conveyors or Gorbel cranes.

A job shop is a make-to-order (MTO) business; i.e., orders are pulled into production based on actual demand.

In contrast, all the lean tools that suit assembly line production are based on a make-to-stock (MTS) inventory model. I see no reason to use tools for MTS production scheduling when there are tools for MTO production scheduling at our disposal, such as finite load order release, finite capacity scheduling, electronic Gantt charts, manufacturing execution systems, etc. I wholeheartedly agree that a job shop should pursue continuous improvement one part family at a time.

U.S. manufacturers are now in the 21st Century and competing against countries where manufacturers have already availed themselves of the best consultants with expertise in lean and Six Sigma. If the United States can boast of innovation-driven IT giants like Google, Apple, Microsoft, Facebook, etc., this may be a good time for the hundreds of thousands of HMLV manufacturers in the U.S. to explore a new approach that could make them not only lean, but also flexible, agile and adaptable.

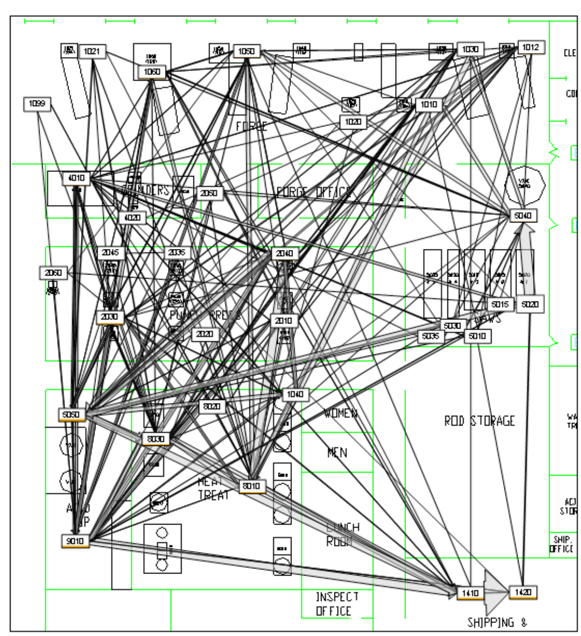


Figure 2—Material Flow Network at a Defense Logistics Agency (DLA) Supplier

New Technology for Stronger Plastic Gears

GLEASON-K2 PLASTICS ELIMINATES WELD LINES WITH NO MACHINING

With the acquisition of K2 Plastics, Gleason is now a source for strong, quiet thermoplastic gears containing no weld-lines, with a thru-hole and no secondary machining.

"Coupling Gleason's arsenal of non-linear contact FEA and advanced gear design software, with the latest engineered thermoplastics, Gleason-K2 Plastics' gears are a top choice for all demanding plastic gearing applications," says Klaus Kremmin, general manager of the Gleason-K2 Plastics division of The Gleason Works.

Weld, meld or knit lines in a molded gear are where two or more material flow fronts meet. Weld lines create a weak point in the gear, where material strength can be just a fraction of the normal material strength, particularly in fiber- or glass-filled resins. The result is that the typical 2–4 X safety factor isn't sufficient for gears with weld lines.

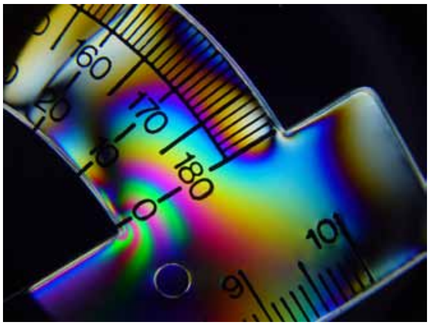
"This is also why we continually see frustrated customers who had gears designed and manufactured elsewhere upset with their cracked gears," Kremmin says. "The gears cracked at the weld line due to thermal and contact load cycling beyond the weld-line limits. As the gearing engineer, you are forced to test for weld-line strength yourself to properly select an appropriate safety factor for your design since material data sheets do not provide this information."

Gleason-K2 plastic gears can provide optimized gear designs, verified by FEA analysis. In some cases, depending on the material, an additional 1,000 percent improvement in strength can be achieved by the elimination of the weld lines. "That is an order of magnitude improvement in plastic gear strength, which is a very significant advancement in plastic gearing," says Kremmin. With Gleason gear design software, an experienced gear designer can also optimize gear profiles for increased contact ratio, reduced sliding ratio and reduced bearing loads, providing strong, silent, low-wear plastic gears.

Accuracy drops one to three AGMA levels comparing gears manufactured without weld lines to gears made with them. A weld-line-free Gleason-K2 gear can measure less than 0.0010" for TCE (total composite error) and under 0.0003" for TTE (tooth to tooth error) while the ID is kept to ±0.0005".

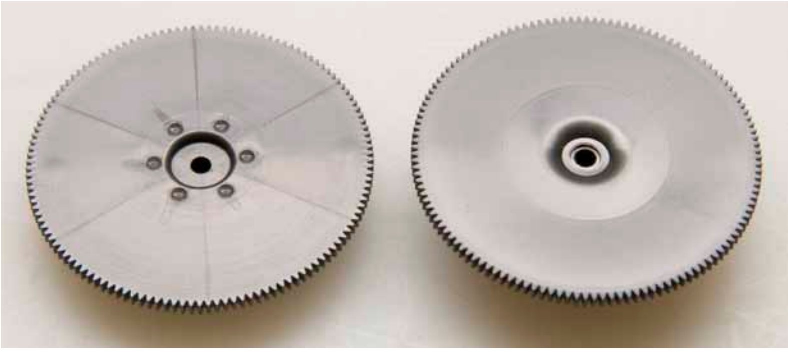
"Gleason-K2 has taken an art, reinvented the science and finally turned it into a robust, highly repeatable proprietary process vastly superior to the two approaches typically taken to address the weld-line issue," Kremmin says.

One standard "best practice" solution to the weld-line issue is to first mold the gear with a test tool of a gear containing multiple gates centered close to the ID, while maintaining strict control of the appropriate pressure and temperatures. Then, the error of the resultant gear containing weld lines is accurately measured in order to construct a second tool with the negative of the first tool's error in hopes of cancelling it out. The second tool now has negative error built into it, but still produces gears with a weld line. A second, better standard option is to disc gate the gear with a blind hole and then machine the disc gate off to achieve a thru-hole. This process, however, requires transporting the molded gear to its machining operation, precisely chucking it up to machine away the disc gate, and then de-burring it without getting any machining fines onto the electrostatically charged gear flanks.



The residual stress, caused by a poor molding process, can be seen by the colored fringes inside the part.

Example of plastic gear with cracks at the weld line due to thermal and contact load cycling beyond the weld-line limits (left) and no weld lines on the right (all photos courtesy of Gleason-K2).



A complete line of strong, quiet thermoplastic gears containing no weld-lines, with a thru-hole and no secondary machining (pictured right), is offered by Gleason-K2.

"Producing perfectly clean, 'ding free' and accurate gears, all at an economical price, from this process is very difficult," according to Kremmin. "We've found both of these solutions to be highly inferior to Gleason's no-weld-line solution. Gleason-K2's solution builds only one tool which molds plastic gears from any thermoplastic resin with a wide processing window without weld lines or any secondary machining. It does this while providing a gear with the least amount of residual stress of any competing gear molder."

Reducing the impact of residual stress. Take a polarized lens and look at a molded part made of a clear resin. The residual stress can be seen by the colored fringes inside the part. The stress is caused by a poor molding process. Cooling the molded gear too soon or constraining it in the mold because of poorly calculated part shrinkage will induce residual stress. Residual stress is also caused by poor part geometry, gating and ejection. Kremmin says that residual stress becomes particularly apparent when a gear undergoes thermal cycling either by transport to the end user or by load cycling. The stress will want to relax, resulting in gear warpage. "I have found most molders do not consider the impact of residual stress in their parts," Kremmin says. "They are having a hard enough time predicting shrink and achieving a part to print, let alone dealing with another layer of complexity to reduce the residual stress in their moldings. As long as their parts meet the print, they are OK to ship. I'm sure residual stress will be talked about now."

The no-weld-line process works for all thermoplastic resins including unfilled elastomers, acetal, nylon, urethane and filled polycarbonate, PPS, PEEK and ultra-exotic high temperature materials with melt temperatures above 800°F and heat deflection temperatures greater than 600°F. "We can even insert-mold our gears onto metal bushings, tooth plates and hubs, still producing a gear with no weld lines and no secondary machining," Kremmin adds.

Besides gears, pulleys, encoder wheels, tooth plates, bushings, sleeves, nozzles and tubes, any molded part with a hole through it that would normally be produced with weld lines can now be made weld-line free with the proprietary Gleason-K2 process.

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Bergen, NY 14416
Phone: (585) 494-2470
www.k2plasticsinc.com

Large-Gear Grinding and Gear Hobbing Machines

PROVIDE HIGH-EFFICIENCY PRODUCTION FOR LARGE-PART MANUFACTURERS

There has recently been an increased demand for machining large gears for use in wind turbine gearboxes, mining equipment, and so on. And although the world economy continues to struggle, that demand is expected to continue as wind turbine generators and construction equipment recover. While most gear machines manufactured by Mitsubishi Heavy Industries Ltd. (MHI) have been used for automotive products, the company intends to actively pursue the market for larger-gear machines in order to win more orders. Witness the large-gear grinding machine ZGA2000 and large-gear hobbing machine GEA1200 as products that provide highly efficient, highly accurate machining.

ZGA2000 Large-Gear Grinding Machine

The ZGA2000 is a gear grinding machine capable of handling workpiece diameters up to 2,000 mm. A high machining accuracy is required during the gear grinding process. In

this process, the tooth surfaces of a gear are ground after heat treatment. For highly accurate and efficient machining, the ZGA2000 uses built-in motors for the wheel and dress spindles, and a direct-drive motor and high-stiffness hydrostatic bearing for the worktable spindle. As a result, it can reduce machining time by 20 percent, compared to the existing ZG1000 model, and it has achieved a machining accuracy compliant with

Class 1 or higher, according to the new Japanese Industrial Standards (JIS). Furthermore, to reduce downtime MHI strove to increase the speed and accuracy of the on-machine gear inspection device. MHI succeeded in reducing the travel distance from the tooth root to the tip of a contact probe during tooth profile measurement, thereby improving the efficiency with which the machine can be controlled and checked.

GEA1200 Large-Gear Hobbing Machine

The GEA1200 is a gear hobbing machine capable of handling workpiece diameters up to 1,200 mm; it can also efficiently cut gears with a high degree of accuracy. The GEA1200 incorporates a motor with a rated output of 30 kW for the main spindle and a triple-lever clamping mechanism to enhance the hob clamping force, thereby improving stiffness of the hob head. Similar to the ZGA2000, MHI adopted a high-stiffness hydrostatic bearing for the worktable spindle and employed a double-worm backlash eliminator to enable stable heavy cutting. MHI also modeled the entire machine and used a static and dynamic stiffness analysis technique based on three-dimensional finite element modeling (FEM) to optimize the rib layout. This provides an optimum design with a high degree of stiffness, while reducing the component weight. As a result, the GEA1200 can reduce machining time by 30 percent compared to the existing GB100, and has achieved a machining accuracy compliant with Class 5 or higher, according to new Japanese Industrial Standards (JIS).

Future Developments

While developing these large-gear machines, MHI focused on the creation of a modular design applicable to different types of equipment, such as gear hobbing, shaping and grinding machines. MHI has adopted a basic machine structure capable of handling maximum workpiece diameters ranging from 1,200–4,000 mm, making it possible to quickly deliver a machine after an order has been placed. The large-gear grinding machine ZGA2000 and large-gear hobbing machine GEA1200 have already been delivered to users in Japan. MHI is currently manufacturing the SEA1600—a large-gear shaping machine that handles workpiece diameters up to 1,600 mm.

For more information:

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Wixom, MI 48393
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www.mitsubishigearcenter.com

Dudley's Handbook of Practical Gear Design

NOW AVAILABLE IN SECOND EDITION

The revised edition of *Dudley's Handbook of Practical Gear Design and Manufacture* is now available to order. For more than 30 years, *Practical Gear Design*, later re-titled the *Handbook of Practical Gear Design,* has been the leading engineering guide and reference on the subject. The revised edition, by Johnson Control's Stephen P. Radzevich, covers the design of all types of gears involved in practical gear manufacture, applications and problem solving. The text is well-illustrated as evidenced by the hundreds of photos and schematics that clearly illustrate designs and uses; almost 200 tables provide reference data. Selected chapters include: Gear Design Trends; Gear Types and Nomenclature; Gear Tooth Design; Preliminary Design Considerations; Design Formulas; Gear Materials; Gear Manufacturing Methods; Design of Tools to Make Gear Teeth; Kinds and Causes of Gear Failures; Special Design Problems; Gear Reactions and Mountings; Gear Vibration; Appendices; and References and Index.

Additionally, *Theory of Gearing: Kinematics, Geometry and Synthesis* is now available. This book systematically presents and develops a scientific theory of gearing, specifically for those involved in gear design, analysis, and manufacture. The author begins with a few simple postulates that form the foundation of the theory of gearing. The postulated concepts are limited just to two entities, namely to (a) rotation vectors of the driving shaft and of the driven shaft, and to (b) torque on the driving shaft.

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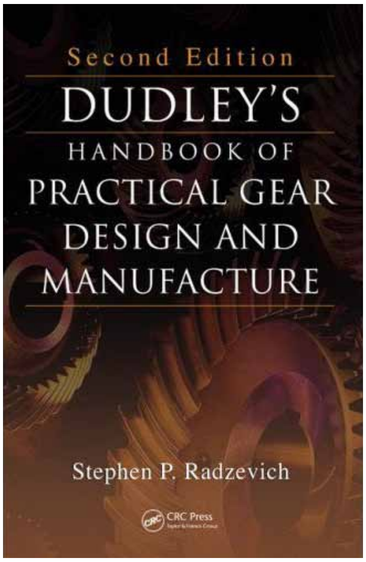

Drake

SHIPS STEERING WORM GRINDER TO EUROPE

Drake Manufacturing Services Co. has recently shipped a GS:TE-LM 200 Steering Worm Grinder to a European automotive parts supplier. The machine will finish grind the thread geometry on a steering worm shaft. It is equipped with Drake's Smart Spindle technology, which features an acoustic emis-

sions sensor mounted in the high-speed spindle. This sensor detects the sound of the wheel touching the part to within less than one micron. In effect, the wheel becomes a probe for the part, automatically equalizing stock on both sides of a thread groove. The result is a significant improvement in setup, quality and productivity. The GS:TE-LM 200 is also equipped with a part load verification system. The robot picks a part off the pallet and places it in a measuring fixture in the machine. Measurement sensors detect a particular feature on the part and determine if it is correctly oriented. Once verified, the part is placed in the collet and grinding begins.

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SKF Stroboscope
FACILITATES EASY INSPECTION

The portable SKF TKRS 10 Stroboscope facilitates easy inspection of rotating or reciprocating machinery in a "flash" without stopping the machinery or otherwise interrupting operation. The device enables the motion of machinery to appear "frozen" at the position required for visual inspection and ultimately can assist in preparing for necessary maintenance in advance of planned equipment shutdown. This tool delivers an optimum solution for inspecting and monitoring the condition of fans, gears, rolls and pulleys.

The stroboscope's phase-shift feature offers the capability to advance or retard flash timing without changing the flash rate, which allows for motion to be "frozen" at the exact position required for inspection. A bright flash rate up to 12,500 flashes-per-minute (FPM) ideally illuminates an application at a distance to cover a wide viewing area and suit a wide range of applications. Among other features, the device's flash rate can be adjusted easily and quickly using the variable dial rate and the required flash speed can be reached within seconds. The stroboscope benefits from a compact design for handheld operation and integrates an easy-to-read and user-friendly LCD display.

The stroboscope utilizes a rechargeable battery with long running time per charge (up to 2.5 hours) and includes a universal AC adaptor for use worldwide. The device is supplied in a carrying case for protection and portability. A mounting thread on the underside allows mounting on a tripod for stability and added ease of use. SKF also now offers the advanced TKRS 20, which includes all the features of the

TKRS 10 plus higher flash rate capabilities (300,000 FPM) and extended battery run time (12 hours).

For more information:
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IMTS

North America's Show of Shows

Jack McGuinn, Senior Editor

Accounts vary, but the trade show—or fair, exposition, exhibition—whatever you call it—has been around since approximately 600 B.C. The Old Testament book of Ezekiel contains many references to merchants trading, "in a multitude, riches with silver, iron, tin and lead (*Source: "History of Trade Shows & Exhibitions," by Karan Singh*, articleinspector.com)." Since the 1960s, the article continues, trade shows and exhibitions have been "extensively used as a prominent part of marketing strategy. Larger amounts are spent each year on trade exhibitions than on magazine, radio and outdoor advertising."

Some 2,600 years later, Ezekiel would be hard-pressed to recognize or understand what goes on at today's shows. Trade shows—and how they are presented—continue to evolve: new technologies in graphics, sound and lighting, booth construction and much more continue to dazzle. And yet one thing has remained constant since those B.C. days—i.e., capturing the hearts and minds of new and existing customers—and their wallets.

We talked with a number of major companies in the midst of their planning and strategizing for IMTS 2012, with the thought of determining just how much things have in fact changed for exhibitors regarding the trade show experience.

Take social media, for example. How influential is today's texting and tweeting mania on trade show planning and execution? Are customers clamoring for it, as some media accounts report?

"Social media will not play a significant role in our 2012 IMTS exhibition," says Al Finegan, Gleason Corp.'s director of marketing. "We are continuing to explore the use of social media in our marketing and promotion, but beyond our YouTube channel, the direction is not clear. And no, our customers are not clamoring for it."

"Social media 'apps' are becoming more important each year and we believe will be a significant outlet along with web, print and direct mail," Bill Miller, vice-president of sales at Kapp Technologies, allows.

And at Sandvik Coromant U.S., "Social media has been a part of (our) marketing and communications tools for the last several years," says Rick Hern, Sandvik project manager. "We are constantly releasing valuable content like application tips, events, new product news and app releases through our social media channels. At IMTS this year, we will continue to provide our followers with the latest IMTS news."

"We have not received a groundswell of requests from customers to communicate via social media and as such we are taking a wait and see approach before making any major commitments in that regard," says Sunnen's Bob Davis, global communications manager. "However, we do have a YouTube channel so customers can view videos of our honing machines in operation and other informational videos we produce."

As for IMTS in particular—the greatest (manufacturing) show on earth?

Looking at it in a solely U.S.-based context, Gleason's Finegan states that "I assume this is intended to get at the question of IMTS *or* Gear Expo. To say that one is more important than the other is like comparing apples to oranges. IMTS is the largest manufacturing technology show in the western hemisphere, and even though the gear world is only a small part of manufacturing technology, our customers expect the market leader to be there with a significant presence.

"Gear Expo is of course very small but highly focused on gear manufacturing. In addition, it has the unusual dynamic of the manufacturing technology suppliers like Gleason exhibiting alongside some of our customers. Both shows are very important to the market and to Gleason."

"IMTS is the most significant show in North America for its size, quality of attendees and the opportunity to discover new customers and applications," says Miller.

"IMTS is where customers, technology and industry partners merge on a bi-annual basis," says Hern. "As an industry leader, Sandvik Coromant recognizes that IMTS is the best-acknowledged manufacturing event in North America and continues to bring innovation and cutting tool solutions to customers attending the show."

"By any standard, IMTS is the most important overall manufacturing show in North America, whether it is judged by size, number of exhibitors, number of attendees, media coverage or newsworthiness," Davis says. "Gear manufacturing is not done in a vacuum, so a broad-based show like IMTS is a very important event for gear manufacturers as well. However, there is still an important place for smaller events such as Gear Expo, which highlight the technology, equipment and issues of concern to gear manufacturers and their suppliers."

A show of such accepted significance is obviously no small matter in terms of cost, preparation and strategic goals. What does it take to make exhibiting at IMTS a success?

"Any show, regardless of size and location, involves strategic planning," Finegan says. "We carefully develop our global show plan on an annual basis, with strategy in mind. What are the right processes and products for the particular market? What are our competitors likely to exhibit? What message are we trying to impart to the audience at this show in this market at this time? And so on."

"A significant expense such as IMTS certainly requires extensive planning and promotion," Miller says. "The products we choose to display are selected to introduce the latest technology, and to best fit the anticipated growth markets at that time."

And at Sandvik Coromant, "It is important to us to be able to provide a great learning environment and experience to our customers and industry partners," Hern says. "Throughout the entire year we work on planning and developing the ultimate experience for attendees visiting our booth and the student summit area."

Sunnen's Davis points out that "Much of the strategic planning that goes into a large show such as IMTS is incremental from previous IMTS shows, so it is not an overwhelming task from year to year to develop our plan of attack. However, the implementation of the plan cuts across nearly all departments in the company to some degree, and for a handful of individuals it consumes nearly all of their time for several months leading up to the show."

So once everything is in place and the show curtain rises, who do exhibiting companies want stationed on the front lines? Which personnel are believed to be irreplaceable in the booth—sales or technical?

"Both sales and technical staff have an important role," says Finegan. "Sales has the contacts and the deep relationships with customers, but the nature of the technology requires solid technical support at any show. Customers have questions and they expect to receive answers on the show floor—answers to help their decision-making process."

Likewise Kapp's Miller—but for a different reason. "In fact, the most important personnel are management, who make it a priority to be in attendance to personally introduce themselves and to greet customers."

"Our IMTS staff is a true representation of how Sandvik Coromant works together in order to provide customers with the right answers," says Hern. "We provide our staff with the necessary knowledge, training and support to be able to provide answers to attendees when needed."

And for Sunnen, "It is very important to have the right mix of sales staff and technical staff working in the booth at an important show such as IMTS," Davis says. "The mix varies from company to company, but for the companies who are on the cutting edge of technology in their individual niche markets, such as Sunnen with the honing equipment business, the mix must include more technical personnel than for companies who are selling products with older or more generally accepted technology. We normally have one technical person for every 3 or 4 sales people working in the booth at any given time."

But at the end of the day—six days, to be precise—was it all worth it? And just how does a company determine that?

"We have a number of metrics for our shows that involve visitors, leads, sales and other things," says Finegan. "I expect most exhibitors have similar metrics. We also perform a detailed internal survey of all staff and others who participated in the planning and execution of the show. We have a pretty good idea of our success by the end of the show—but also a strong post-mortem process to back it up."

"Statistics can be compared shortly after a show," Miller says, "but in most cases success of a specific show can only be quantified beyond six months."

Sandvik's Hern says that "Success at IMTS is measured in several ways—the direct sales lead for a specific product interest, the overall attendance at the show, and the support seen with the machine tool builders."

"We generally know when we walk out of the show whether the show was good, bad or somewhere in between," Davis says. "By ranking the trade show leads on a percentage chance of turning into a sale we can come up with a rough idea of the actual short-term value of the show. However, it often takes months or even years for some show leads to turn into sales, so it is very difficult to get an exact dollar amount of the value of a show."

IMTS 2012

The following IMTS exhibitors are suppliers of products or services that may be of interest to gear manufacturers who visit the show. The Booth numbers include a letter indicating which building the booth is in (N=North, S=South, E=East, W=West).

Alphabetical Listings

COMPANY	BOOTH
American Broach & Machine Company	N-7027
American Gear Tools	N-7027
American Wera Inc.	N-6260
Andantex USA Inc.	N-6035
Atlanta Drive Systems Inc.	N-6420
Banyan Global Technologies	N-6670
Bates Technologies	N-7451
Bourn & Koch Inc.	N-6924
Broach Masters/Universal Gear	N-7112
Broaching Machine Specialties Co.	N-7229
Carl Zeiss Industrial Metrology, LLC	E-5504, N-6918
DMG/Mori Seiki USA	S-8900
Dontyne Systems	N-6791
Dr. Kaiser	N-7240
Drake Manufacturing Services Co.	N-6918
DSM Functional Materials	N-6072
DTR Corp.	N-6658
Dura-Bar	W-1272
Eldec Induction USA	N-6663
EMAG LLC	N-6846
EMAG Maschinenfabrik Gmbh	N-6918
Emuge Corp.	W-1536
Engis Corp.	N-7325
Erasteel Inc.	W-1381
Erwin Junker Machinery, Inc.	N-6840
Escofier SAS	N-6026
Euro-Tech Corp.	W-2453
Federal Broach and Machine Company	N-6924, N-7046
Felsomat USA, Inc.	N-7024
Frenco GmbH	W-2453
FROEMAG	N-7220
Fuji Machine America	S-9059
Gear Technology	N-7148
Gehring L P	N-6740
Gehring Technologies GmbH	N-6740
Gleason Corporation	N-7000
Gleason Cutting Tools Corporation	N-7000
Gleason Metrology Systems Corporation	N-7000
Gleason-Hurth Maschinen und Werkzeuge	N-7000
Gleason-Pfauter Maschinenfabrik GmbH	N-7000
The Gleason Works	N-7000
Gould & Eberhardt Gear Machinery	N-7030
Guyson Corp.	N-7245
Hainbuch America Corp.	W-2413
Halifax Rack & Screw -North America	N-6789
Hamai Co.	N-7451
Hangsterfer's Laboratories	N-7526
Hassay Savage / Magafor	W-1592
Hexagon Metrology	N-7163, E-5202
Hofler Maschinenbau GmbH	N-6837
Index Corp.	S-8450
Ingersoll Cutting Tools	W-1822
J. Schneeberger Corp.	N-6936
Kapp GmbH	N-7036
KAPP Technologies	N-7036
Kennametal Inc.	W-1522
Kitagawa Northtech Inc.	W-2412
Klingelnberg GmbH	N-6930
Koepfer America, LLC	N-6918

Alphabetical Listings

COMPANY	BOOTH
Leistritz Corporation	N-6746
Liebherr Gear Technology, Inc.	N-6930
LMT USA Inc.	W-2464
Logansport Machine Company	W-1314
Luren Precision Co. Ltd.	N-7072
MAG IAS LLC	S-8519
Mahr Federal Inc.	E-5242
Marposs Corp.	E-5519
Mazak Corp.	S-8300
Mecanica Comercial Meco, S.L.	N-7124
Mijno Precision Gearing	N-7227
Mitsubishi Heavy Industries America - Machine Tool Division	N-7046
Mitts & Merrill L.P.	N-7220
Mitutoyo America Corp.	E-5214
Monnier + Zahner AG	N-6918
Mutschler Edge Technologies	W-1843
Nachi America Inc.	W-2279
Nagel Precision	N-7040
Niles Werkzeugmaschinen GmbH	N-7036
Normac Inc.	N-7514
Northfield Precision Instrument	W-1251
Oak Ridge National Laboratory	N-7178
Oelheld US	N-6668
Oerlikon Balzers USA Inc.	W-2283
Paulo Products Co.	N-6068
Power Transmission Engineering	N-7148
Process Equipment Co.	N-6133
QC American LLC	N-7027
R.P. Machine Enterprises, Inc.	N-7030
Rattunde Corporation	N-6737
Reishauer Corporation	N-7018
Richardon GmbH	N-6918
Riten Industries	W-1336
Roeders of America	S-8017
Roto-Flo	N-7115
S&T Dynamics	N-7425
S.L. Munson and Co.	N-7240
Saacke North America LLC	N-7329
SAMP S.p.A.	N-6924
Sandvik Coromant	W-1500
Schiess Brighton GmbH	S-8275
Schunk Inc.	W-2000
Seco Tools Inc.	W-1564
Setco	N-6520
Sicmat S.p.A.	N-6924
Siemens Industry Inc.	E-5010
SKF USA	E-5842
SMW Autoblock	W-1400
Solar Atmospheres	N-6414
Solar Manufacturing	N-6414
Speedgrip Chuck-Cameron-Madison	W-1496
Star SU LLC	N-6924, W-1385
Suhner Industrial Products	W-1073
Sunnen Products Co.	N-7400
The Timken Co.	N-7190
Ty-Miles, Inc.	N-7127
Tyrolit GmbH & Co. KG	N -6918
U.S. Gear Tools, Inc.	N-7115
Wenzel America Ltd.	E-5261

IMTS 2012

IMTS 2012
International Manufacturing Technology Show
September 10 - 15, 2012 | McCormick Place | Chicago

Alphabetical Listings

COMPANY	BOOTH
WFL Millturn Technologies GmbH & Co. KG	S-8566
Winterthur & Wendt	N-7063
Wittenstein	E-5386
Zoller Inc.	W-2022

Listings by Booth Number

COMPANY	BOOTH
Siemens Industry Inc.	E-5010
Hexagon Metrology	E-5202, N-7163
Mitutoyo America Corp.	E-5214
Mahr Federal Inc.	E-5242
Wenzel America Ltd.	E-5261
Wittenstein	E-5386
Carl Zeiss Industrial Metrology, LLC	E-5504, N-6918
Marposs Corp.	E-5519
SKF	E-5842
Tyrolit GmbH & Co. KG	N -6918
Escofier SAS	N-6026
Andantex USA Inc.	N-6035
Paulo Products Co.	N-6068
DSM Functional Materials	N-6072
Process Equipment Co.	N-6133
American Wera Inc.	N-6260
Solar Atmospheres	N-6414
Solar Manufacturing	N-6414
Atlanta Drive Systems Inc.	N-6420
Setco	N-6520
DTR Corp.	N-6658
Eldec Induction USA	N-6663
Oelheld US	N-6668
Banyan Global Technologies	N-6670
Rattunde Corporation	N-6737
Gehring L P	N-6740
Gehring Technologies GmbH	N-6740
Leistritz Corporation	N-6746
Halifax Rack & Screw -North America	N-6789
Dontyne Systems	N-6791
Hofler Maschinenbau GmbH	N-6837
Erwin Junker Machinery, Inc.	N-6840
EMAG LLC	N-6846
Carl Zeiss Industrial Metrology, LLC	N-6918, E-5504
Drake Manufacturing Services Co.	N-6918
EMAG Maschinenfabrik Gmbh	N-6918
Koepfer America, LLC	N-6918
Monnier + Zahner AG	N-6918
Richardon GmbH	N-6918
Bourn & Koch Inc.	N-6924
SAMP S.p.A.	N-6924
Sicmat S.p.A.	N-6924
Federal Broach and Machine Company	N-6924, N-7046
Star SU LLC	N-6924, W-1385
Klingelnberg GmbH	N-6930
Liebherr Gear Technology, Inc.	N-6930
J. Schneeberger Corp.	N-6936
Gleason Corporation	N-7000
Gleason Cutting Tools Corporation	N-7000
Gleason Metrology Systems Corporation	N-7000
Gleason-Hurth Maschinen und Werkzeuge	N-7000
Gleason-Pfauter Maschinenfabrik GmbH	N-7000
The Gleason Works	N-7000
Reishauer Corporation	N-7018
Felsomat USA, Inc.	N-7024
American Broach & Machine Company	N-7027
American Gear Tools	N-7027
QC American LLC	N-7027
Gould & Eberhardt Gear Machinery	N-7030

Listings by Booth Number

COMPANY	BOOTH
R.P. Machine Enterprises, Inc.	N-7030
Kapp GmbH	N-7036
KAPP Technologies	N-7036
NILES Werkzeugmaschinen GmbH	N-7036
Nagel Precision	N-7040
Mitsubishi Heavy Industries America -Machine Tool Division	N-7046
Federal Broach and Machine Company	N-7046, N-6924
Winterthur & Wendt	N-7063
Luren Precision Co. Ltd.	N-7072
Broach Masters/Universal Gear	N-7112
Roto-Flo	N-7115
U.S. Gear Tools, Inc.	N-7115
Mecanica Comercial Meco, S.L.	N-7124
Ty-Miles, Inc.	N-7127
Gear Technology	N-7148
Power Transmission Engineering	N-7148
Hexagon Metrology	N-7163, E-5202
Oak Ridge National Laboratory	N-7178
The Timken Co.	N-7190
FROEMAG	N-7220
Mitts & Merrill L.P.	N-7220
Mijno Precision Gearing	N-7227
Broaching Machine Specialties Co.	N-7229
Dr. Kaiser	N-7240
S.L. Munson and Co.	N-7240
Guyson	N-7245
Engis Corp.	N-7325
Saacke North America LLC	N-7329
Sunnen Products Co.	N-7400
S&T Dynamics	N-7425
Bates Technologies	N-7451
Hamai Co.	N-7451
Normac Inc.	N-7514
Hangsterfer's Laboratories	N-7526
Roeders of America	S-8017
Schiess Brighton GmbH	S-8275
Mazak Corp.	S-8300
Index Corp.	S-8450
MAG IAS LLC	S-8519
WFL Millturn Technologies GmbH & Co. KG	S-8566
DMG/Mori Seiki USA	S-8900
Fuji Machine America Corp.	S-9059
Suhner Industrial Products	W-1073
Northfield Precision Instrument	W-1251
Dura-Bar	W-1272
Logansport Machine Company	W-1314
Riten Industries	W-1336
Erasteel Inc.	W-1381
Star SU LLC	W-1385, N-6924
SMW Autoblock	W-1400
Speedgrip Chuck-Cameron-Madison	W-1496
Sandvik Coromant	W-1500
Kennametal Inc.	W-1522
Emuge Corp.	W-1536
Seco Tools Inc.	W-1564
Hassay Savage / Magafor	W-1592
Ingersoll Cutting Tools	W-1822
Mutschler Edge Technologies	W-1843
Schunk Inc.	W-2000
Zoller Inc.	W-2022
Nachi America Inc.	W-2279
Oerlikon Balzers USA Inc.	W-2283
Kitagawa Northtech Inc.	W-2412
Hainbuch America Corp.	W-2413
Euro-Tech Corp.	W-2453
Frenco GmbH	W-2453
LMT USA Inc.	W-2464

IMTS 2012 Product Preview

STAR SU

Booth N-6924, W-1385

Star SU will exhibit a wide variety of products including coatings, carbide blanks, single-flute-gundrills, gear cutting solutions, carbide drills and reamers and the IMTS debut of the Star PTG-6L, a five-axis, CNC-controlled cutter/grinder for grinding, sharpening and re-conditioning a wide variety of cutting tools. Additionally, an extended version of the Bourn and Koch 100 H will be on display as well as the MAG H 400 hobber, configured for wet hobbing. Here's a breakdown of Star SU's technologies at IMTS:

***Advanced coatings*:** Balinite Alcrona Pro, the second generation of ALCr-based coatings, is now available on new and re-sharpened tools from Star SU. Developed by Oerlikon Balzers, Alcrona Pro can be used in a wider range of applications than other aluminum-based coatings because it provides better heat resistance for high temperatures and better wear resistance for tough cutting applications. Lower thermal conductivity allows Alcrona Pro-coated tools to work well in low temperature applications and allows faster hobbing speeds: 200 m/min is the new base speed. The cost savings include 30 percent lower tool costs, 50 percent longer tool life, 20 percent faster cutting parameters and 100 percent dry cutting.

***Pre-formed carbide blanks*:** Whether simply cut-to-length or machined into complex shapes, H.B. Carbide's high quality tungsten carbide, made-to-print preforms and extrusions have minimal grind stock, reducing the amount of time and energy needed to produce finished tools and wear parts. Choices include: rods, rectangles or squares, coolant holes, straight or angled cross holes, stepped diameters, centers (male or female), flats, chamfers, keyways, complex shapes and pre-formed sharpening angles.

***Single-flute gundrills*:** Single-flute gundrills machine straight, deep holes in virtually any material in one pass. High-pressure coolant delivered through the tool keeps the cutting edges lubricated, allowing for ad-

equate chip evacuation down the flute channel. Star SU gundrills are available in various lengths with diameters ranging from 0.078 to 0.75" (2–19 mm) for shipment within 24 hours. Larger diameter tools can be custom ordered.

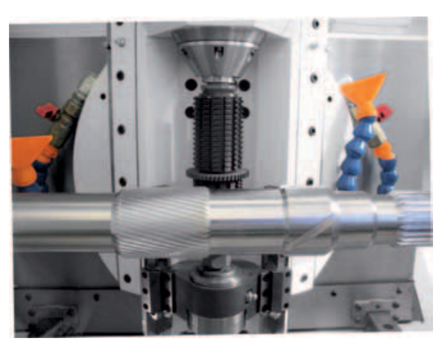
***Gear cutting tool solutions*:** Precision tool re-sharpening services from Star SU and advanced coatings, including Oerlikon Balzer's Alcrona Pro, can extend the life of your tools and lower your costs. Need more help managing your tool room? Let Star SU monitor the life cycle of your tools and resharpen, re-coat and replace them as needed. From new tools to design work to resharpening and re-coating, we have the equipment and resources to help keep your gear cutting operation running smoothly. If your plant does its own tool sharpening, Star SU carries a variety of tool and cutter grinders including the PTG-1 and the GS 400. Star's PTG-1 sharpens both straight and spiral gash hob designs up to 8" OD × 10" OAL. Additionally, it sharpens disk, shank and helical type shaper cutters and a wide range of round tools, making it a versatile tool room machine. Designed to grind shaving cutters and master gears, the GS 400 sets new standards for precision, reliability and ease of use. An integrated measuring unit automatically checks the quality of the first tooth ground without unclamping the workpiece.

***Multiple diameter carbide drills and reamers*:** Custom-designed carbide drills and reamers are now available from Star SU, including single-pass port cavity tools that allow complete cavity machining, reduce cycle times and hold industry tolerances for size and finish. The Super Round Tool (SRT) produces extremely round holes within microns, reams holes with interrupted cuts and provides excellent finishes for spool bore applications.

***Tool grinder with integrated linear motor*:** Debuting at IMTS, the new Star PTG-6L tool and cutter grinder is a five axis, CNC controlled cutter grinder for grinding, sharpening and reconditioning a wide variety of cutting tools. Manufactured in the United States and equipped with a six-station wheel pack changer, the PTG-6L is built for high produc-

tivity and precision. The PTG-6L features integrated linear motor and direct-drive rotary technology, a traveling tool platform for CNC steady resting and workholding adjustment, next generation NUM Flexium controller, the latest enhancements in tool grinding software from *Numroto*, proven high volume loader and grinding wheel auto-sticking capabilities for unmanned operations.

***Bourn and Koch 100 H*:** The Bourn and Koch 100 H horizontal hobbing machine can hob splines and geared shafts up to 100 mm in diameter. Mount tools in combinations and cut different gearings on one workpiece or mill keyways and slots in one tool setup without re-clamping the workpiece. Since the chip conveyor is located directly under the tool spindle, chips are evacuated immediately from the machine to avoid any thermal distortions. In addition, the 100 H can optionally be ordered with automation for machining larger lots. Star SU plans to exhibit an extended version of the 100 H with a NUM Flexium 68 CNC control at IMTS. This extended version can accommodate a workpiece up to 915 mm (36") long and 126 mm (5") in diameter.



***MAG H 400*:** Run small lots or mass produce straight and helical gears; crowned and tapered gears; worm gears; chain sprockets and toothed belt discs; cluster gears and special profiles with MAG's H 400 CNC hobbing machine. This machine can use standard hob or form milling technology, ranging from dry or wet machining with high capacity HSS or carbide tools to skive hobbing of heat-treated gears. The H 400 hobber includes: motorized hob head, direct drive table speed range of 400 rpm, maximum hob diameter of 175 mm, six CNC axes, Siemens control, aligning probe and MAG *Modul* dialogue software (metric or inches). Star SU will feature the H 400 hobber configured for wet hobbing.

For more information:
Star SU LLC.
5200 Prairie Stone Parkway,
Suite 100
Hoffman Estates, IL 60192
Phone: (847) 649-1450
www.star-su.com

GLEASON CORPORATION

Booth N-7000

Gleason will introduce a host of advanced new machines, tooling and global customer support services at IMTS 2012, covering a wide array of processes for the complete production and inspection of all types of bevel and cylindrical gears. Among the new technologies exhibited at the show will be:

***The Genesis 400H vertical hobbing machine*:** On display for the first time in the U.S., the 400H is a new addition to the highly popular Genesis Series of gear hobbing machines. Its compact footprint and slim profile, optimized workholding and tool change, and universal automation make it suitable for the widest range of user requirements, whether small batch or automated high volume production. Additionally, the 400H is available with two direct-drive work spindles, three different high-performance hob heads, multiple tool interfaces and integrated chamfering, making it a versatile solution for the production of spur and helical gears and shafts up to 400 mm in diameter. A smaller Genesis 260H model also is available for workpieces up to 260 mm in diameter. Both models are designed as well to help customers meet the need for greater sustainability, with a host of features that greatly reduce energy consumption.

***The Gleason-Heller CT8000 bevel gear machining center*:** First of a new generation of five-axis machining centers resulting from an alliance between Gleason and Gebr. Heller Maschinenfabrik GmbH, the Gleason-Heller CT8000 delivers gear cutting speeds four to eight times faster than competitive machining centers, for bevel gears as large as 1,800 mm in diameter. With the CT8000, manufacturers can quickly and easily accommodate new part series, design variations and corrections, while producing gears at production rates that make single setup machining in small and medium batches attractive economically. In addition, the new Gleason Heller alliance enables manufacturers to simultaneously benefit from Heller's renowned five-axis machining solutions and Gleason's design and process expertise and software.

***The 350GMS analytical gear inspection system*:** On display at the show will be one of a new family of GMS series inspection systems (with models available for gears up to 3,000 mm in diameter). The 350GMS Analytical Gear Inspection System features a Renishaw 3-D probe head to provide maximum accuracy and flexibility for the complete inspection of all kinds of gears and gear-cutting tools. All Gleason analytical gear testers are equipped with the new Windows VB.NET-based Gleason *GAMA 2.0* software with intuitive user interface allowing for simple

input screens for programming of workpiece and cutting tool data. The GMS series is also equipped with new ergonomically mounted operator work stations and optional remote pendant controls—both designed to greatly improve the operator's effectiveness at every stage of the inspection process.

***Power skiving process*:** For these and other cylindrical gear applications, the newly developed power skiving process is fast emerging as a practical and highly productive alternative to typical gear shaping, forming, pressing, and broaching. Visitors to the Gleason booth will learn more about how Gleason combines machine, tool and technology for power kiving of small- and medium-sized workpieces, with modules up to 2.0 mm.

***A complete line of gear-cutting tools and workholding solutions*:** For the production of large cylindrical gears, Gleason offers the Opti-Cut family, which provides users with all the performance benefits of the latest replaceable, indexable, carbide insert technology. Opti-Cut can reduce cost-per-part by as much as 50 percent as compared to conventional high speed steel cutters. The family is versatile too, including gear gashing, hobbing and shaping products in a variety of cutter body sizes, insert types and geometries to meet a wide range of roughing and finishing, and internal and external gear production requirements.

***Advanced workholding solutions*:** In addition, Gleason designs and produces a complete series of quick-change, tool-less workholding equipment for both bevel gear and cylindrical gear, and non-gear production machines. These systems range from the Gleason X-Pandisk systems which automatically align workpieces weighing up to 2,000 kg to reduce changeover time by up to 70 percent, to Quick-Flex and a large variety of quick-change workholding solutions that significantly reduce change-over times for the production of both bevel and cylindrical gears. For inspection systems, Gleason offers the high-precision Gleason LeCount expanding mandrels line, renowned for accurate, easy, extremely rapid location of all types of bore parts.

***Gleason Global Services*.** Gleason customers can rely on 250 factory trained service professionals located in over 50 countries throughout the Americas, Europe, and Asia, working around the clock to support a full range of support requirements, including:

***Services*:** Complete new offering of service programs ranging from our simple Fast Check machine inspection to our extended service programs which provide "No Worry" guarantees.

***Service parts*:** Globally stocked OEM repair parts to reduce downtime.

***Training*:** The largest range of gear process and gear machinery operation and maintenance courses in our industry with training supported globally.

***Application support*:** Programs to improve process quality, cycle times and reduce Total Cost of Ownership.

***Equipment upgrades*:** Recontrols, rebuilds, recondition and upgrades to ensure maximum machine production.

***Gleason Connect*:** A new "remote service" technology enabling Gleason service specialists from anywhere in the world to quickly and cost effectively identify, diagnose, repair and monitor products and minimize cost due to downtime.

For more information:

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sales@gleason.com
www.gleason.com

KAPP TECHNOLOGIES

Booth N-7036

Two grinding machines with flexible process capabilities will be on display at booth N-7036 along with Kapp CBN and Diamond-plated tools, and scale models of numerous other machine types for special applications. The KX 500 Flex demonstrates how process flexibility optimizes cost and delivery for prototype through medium- to high- volume production. The KX 500 Flex uniquely incorporates an indexing table with a direct-drive work spindle, tailstock support, and dressing spindles. This simple design greatly improves operator access, while also enabling simple integration of automation.

Also being shown is the ZX 1000, the big brother of the KX 500 Flex. The ZX 1000 shares common machine elements and software with the KX 500, and comes standard with the same process flexibility for profile or generating grinding. The large ductile iron bed and torque motor for high load capacity, allows high-speed grinding of "frac bull gears" with a dressable worm tool. Special gear types, such as beveloid and non-involute gears, can be ground with generating grinding.

Kapp CBN tools for direct grinding, and DIA dressers for grinding and honing, will also be on display. Kapp and Niles application and tool design engineers will be on-site to answer questions about specific applications. Working modules will aid in understanding the different processes.

For more information:

Kapp Technologies
2870 Wilderness Place
Boulder, Colorado 80301
Phone: (303) 447-1130 ext.133
Fax: (303) 447-1131
www.kapp-niles.com

MITSUBISHI HEAVY INDUSTRIES AMERICA

Booth N-7046

Mitsubishi will proudly be showcasing two machines at IMTS 2012. The first is the ZE40A generating/form gear grinder. With the flexibility to generate grind gears for batch as well as high production and form grind gears for small lot production, the ZE40A, in combination with its CNC dresser and onboard gear inspection system, offers users the best of both worlds. Having been designed with direct drives for both table and grinding spindles, the machine offers unsurpassed accuracy for gears within its diameter capacity of 400 mm. Demonstrations for gen-

erating and form grinding will be shown on alternating days during the show. The second machine is Mitsubishi's SE25A CNC gear shaping machine. Long known for its flexibility in job shop use, the SE25A will be put through its high-speed paces, dry shaping gears up to 1800 strokes per minute. The live demo will highlight the dynamic and static stability of the machine under extreme reciprocating loads. With 250 mm part diameter and 4.23DP capability the machine is diversified enough to satisfy those with even the most varied gear demands.

Mitsubishi will also be introducing the newest member of the Mitsubishi family at IMTS. With the recent acquisition of Federal Broach Company of Harrison, Michigan, it is only fitting that they will have a strong presence in the Mitsubishi booth. Featured from Federal Broach will be an item for which they have become uniquely famous—namely a helical broach. Federal Broach has mastered the difficulties of manufacturing these tools by implementing methods and controls which offer unsurpassed quality and performance. These tools in conjunction with the latest in broaching machine technology can be discussed at length with experts on site.

For more information:

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

HÖFLER MASCHINENBAU GMBH

Booth N-6837

The big news coming from Höfler is Klingelnberg's acquisition of the company in July. By joining forces with Höfler, Klingelnberg is becoming a one-stop-shop for gearing technology. "Besides extending our product range, we also significantly improve our gear-expertise, which is beneficial for bevel gear, spur gear and gear inspection applications," says Jan Klingelnberg, CEO of the Klingelnberg Group. This enhanced expertise, combined with the additional company locations, lays the groundwork for a strategically optimized service network all over the world. This will lead to shorter reaction times, improved availability of spare parts, and in the near future, more comprehensive training right near our customers manufacturing facilities.

"We take this alliance as a big opportunity to considerably improve the existing service and sales activities in North America and to pass on the resulting advantages and benefits to our customers", says Ralf-Georg Eitel, CEO of Höfler America Corp. The joint know-how base allows the company to focus even more on R&D, creating more innovations while at the same time continue to develop tailored solutions according to the users requirement. At IMTS 2012, Höfler will be featuring the Rapid 1250 W and the Helix 400 SK.

Höfler Rapid 1250 W

This Threaded Wheel Gear/Grinding machine is able to grind gears up to 1250 mm in diameter. Höfler, well known as a supplier of form grinders, shows its first grinder for the threaded gear grinding method at IMTS. The machine is useful as first in the world for modules up to Mn 16 mm and grinding wheels up to 400 mm in diameter. Both grinding methods: form grinding and threaded wheel grinding can be utilized on one machine.

Höfler Helix 400 SK

This form gear grinding machine is able to grind gears up to a diameter of 400 mm. The machine is equipped with a high speed grinding spindle for smallest grinding wheels. An additional shift axes allows the use of two different grinding wheels in one set up. This offers customers a nice solution for grinding workpieces at a high quality level with two different gears like shafts.

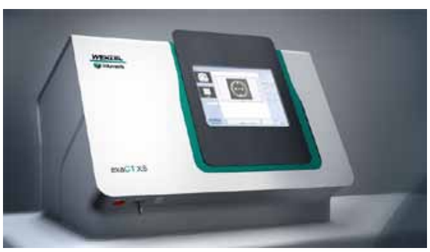
For more information:

Höfler Maschinenbau GmbH
Industriestr. 19
D-76275 Ettlingen/Germany
Phone: +(49) 7243 599 - 0
www.hofler.com

WENZEL AMERICA

Booth E-5261

The all new LH Generation will be the highlight of the Wenzel Booth at IMTS 2012 and the company will be presenting their new generation of CMMs. Wenzel has expanded the successful LH series with robust features and a new innovative design. With the new generation of air-bearing CMMs, Wenzel continues to improve precision, efficiency and longevity. The new LH Series models LH 65, LH 87 and LH 108 are extremely functional, effective, flexible, reliable and easy to operate.



Wenzel will also be showing their dedicated gear tester range, WGT, representing the ultimate in gear testing performance from Wenzel GearTec. All axes are made from natural South African Impala granite, guaranteeing excellent thermal behavior. Air bearings on all linear axes ensure smooth running and high accuracy performance with no mechanical wear over the life of the machine. WGT models feature fully counterbalanced tailstock, as standard, to support longer gears, tools and shafts with parts easily loaded due to its ergonomic design.

In the same booth, Wenzel will demonstrate the highly compact desktop CT exaCT XS. The exaCT XS is a suitable solution for the volume measurement of plastic parts and components with low density. Thanks to its optimized dimensions and low weight, it can be placed on desktops or portable trolleys easily. The device is controlled by a modern touch-screen monitor. The innovative and user-friendly operating concept allows the user to set up a measurement within a few minutes. All components of the exaCT XS are integrated in one unit. This ensures a very small footprint.

The final machine Wenzel will be showing is the XO5.7.5 equipped with a PH20 Renishaw probe. The Wenzel XO is a cost-effective derivative of the world renowned Wenzel LH series of intrinsically accurate CMMs. XO utilizes the industry standard Renishaw TP20 and TP200 probing systems. Wenzel XO is also available with the new high speed PH20 head, the probing system that will be on display in the Wenzel Booth.

For more information:

Wenzel America
46962 Liberty Drive
Wixom, MI 48393
Phone: (248) 295-4300
www.xspectsolutions.com

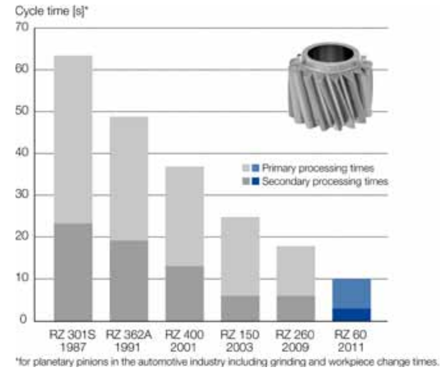
REISHAUER

Booth N-7018

The RZ 60 on display at IMTS has been optimized for machining planetary pinions for the automotive industry. When grinding planetary gears, the cycle times are very short due to the small size of the workpieces and large batch volumes. The large batches are primarily a result of using three to five identical planetary pinions for every automatic transmission produced. In contrast, each component occurs only once in manual or double-clutch transmission. For the machine tool, this means that high priority has been given to the reduction of the cycle times, while compromises if required can be made for change-over times.

Design of a gear grinding machine with two work spindles.

Due to numerous, innovative measures, the primary machining times for grinding planetary pinions on the RZ 60 has been drastically reduced in comparison with previous applications. The robust machine structure, adopted from the much larger RZ 260, allows for the use of aggressive grinding parameters without negative effects on workpiece quality. At maximum speed the grinding and workpiece spindle positions are controlled with the new "Precision-Drive" electronic gearbox developed by Reishauer. This also enables the use of multiple-start grinding wheels for planetary pinions, which typically have a relatively small number of teeth, resulting in high workpiece speeds and tooth meshing frequencies. In addition, it is possible to increase the cutting speed from the previous limit of 80 m/sec. to 100 m/sec due to the development and manufacture of new grinding wheels by Reishauer. Overall, these new advancements permit grinding times that can be as short as seven seconds for some gears.



Development of the cycle times for Reishauer generating grinding of planetary pinions.

With such short grinding times, the reduction of the unproductive or secondary times has become increasingly important. The RZ 60 incorporates the familiar two-spindle concept that was successfully introduced on the RZ 150 in 2003. This enables grinding of a workpiece on one spindle while the workpiece on the second spindle is changed and synchronized with the threads of the grinding wheel.

The basic difference of the RZ 60 as compared with the RZ 160/RZ 260 is that each work spindle has its own meshing probe. In contrast to the other machines, the probes are not fixed in a stationary position on the machine bed but on the work spindle turret, allowing the synchronization of grinding wheel and workpiece during the turret rotation. High workpiece spindle speeds of up to 3,000 rpm make it possible to spin the grinding oil off the part during the turret rotation when the grinding operation is completed. All axis movements have been optimized to significantly reduce unproductive segments of the cycle.

All these efforts to minimize the primary processing and secondary times result in cycle times which could be reduced to approximately ten seconds (*see table above*) excluding the proportionate dressing times. The technology for these extremely short cycle times is no longer in development; the previously described processes are already successfully being applied in industry today. Previous productivity puts the high investment costs for generating grinding into perspective when considering the other necessary precision machining processes. This means that excellent quality for generating grinding does not have to be paid for with high machining costs in combination with reasonable perishable costs and high process reliability. Reishauer makes it possible to fulfil increasing requirements for load capacity and noise reduction of automatic transmissions in the automotive industry.

RZ 60 with Felsomat automation—completely automated production of planetary pinions in the automotive industry.

Felsomat, another member of the Reishauer Group, has developed an automation system that is optimally matched to the specific requirements of the RZ 60.In combination with the Felsomat Flex Stacking Cell FSC 600, the machine can exploit high productivity and operate autonomously without operator intervention over a period of several hours. The complete system can be integrated in the Reishauer & Felsomat FlexLine.

For more information:

Reishauer
1525 Holmes Road
Elgin, IL 60123
Phone: (847) 888-3828
www.reishauer.com

EMAG

Booth N-6846

The VL 2 P is an innovative vertical turning production center, equipped with two spindles and pendulum technology to increase precision and efficiency, for workpieces that have a diameter of up to 100 mm. The focus during the design of the VL 2 P was to make the machine extremely efficient by eliminating idle times. With this technology, non-productive times due to loading and unloading have been completely eliminated. The machine is suitable for workpieces with short machining times since the ratio of machining time to idle time is vital for the economy of the process.

The VL 2 P represents a comprehensive solution to vertical turning. This vertical turning machine offers complete machining in two setups (using a variety of technologies, such as vertical turning, milling, drilling).The machine is equipped with two work spindles working in pendulum mode, i.e. whilst the first spindle holds the workpiece during the machining process, the second spindle utilizes the pick-up method to automatically load itself with raw parts. This ensures that the follow-on raw part is always ready for

vertical turning (machining). After completion of the vertical turning operation on the first component the turret swings (like a pendulum) to the second workspindle. On the VL 2 P, the work spindles are mounted to the left and right of the machine base and carry out the movement in the Z axis. The turret is located at the front and moves in the X axis. The focus of the VL 2 P design has been on reducing the idle times in vertical turning. Unproductive times for loading and unloading work are almost totally eliminated. The vertical turning machine is particularly suitable for the machining of workpieces with short cycle times, where the decisive factor in judging the efficiency level of the process is the ratio between machining and idle times. Additionally, the company will feature PECM technology, production laser welding and heat shrink assembly technology at IMTS.

For more information:

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38800 Grand River Avenue
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Phone: (248) 477-7440
www.emag.com

SUNNEN PRODUCTS COMPANY

Booth N-7400

Sunnen's IMTS demonstration of the VSS Series 2 Single Stroke Honing system will highlight the accuracy, reliability and flexibility that have made the machine a mainstay of Chinese manufacturing in the air conditioning, automotive and hydraulics sectors. According to Sunnen, more than 100 U.S.-made VSS machines have been sold in China since its introduction.

"Value-added fixturing and strong application support from Shanghai Sunnen Mechanical Co. Ltd. make the VSS Series 2 highly competitive in the China market," said Mike Burton, Sunnen managing director, Asia. "The machine's reliability and consistent accuracy in 24/7 production led a single Chinese company to purchase nearly 70 of the machines over the past three years for manufacturing air conditioner parts. We have also had success with customers making turbochargers, power steering valves, hydraulic valves and connecting rods. At IMTS, we will demonstrate single-pass honing of cast iron hydraulic valve bodies."

VSS-2 machines incorporate up to six spindles to progressively size and finish part bores with tools of preset diameter and grit size. The machines are suitable for precision sizing of bores 3.9-50 mm (0.149-2.0") diameter in stamped parts, hydraulic valve bodies, gears and sprockets, parking pawls, rocker arms, turbocharger housings and similar parts. Materials include cast iron, powdered metals, ceramic, glass, graphite and other free-cutting materials.

"The VSS Series 2 sets a new standard for single-pass bore sizing efficiency," Burton added. "If a part is suitable for single-pass honing, the VSS-2 provides a level of precision not available in other designs. And, with the new touch screen control, the machine is very operator-friendly. No custom electronics or special training is needed and the control is designed to interface with part handling automation systems."

The VSS-2 utilizes a belt-drive spindle cartridge with a 724 mm (28.5") stroke and 2-105 mm/sec (2–250 ipm) stroking speed for increased flexibility with a wide variety of parts and tooling combinations. The servo-powered stroke system provides process flexibility and is hand-wheel-controlled for quick setup.

The menu-driven touchscreen control allows the column feed and spindle speed to be easily varied throughout the cycle. Operational flexibility is enhanced by the use of six available profiles, including pecking, short stroke and dwell, which are easily added to a setup. More than 100 setups can be stored. Additional I/O and memory are standard for ease of automation.

The VSS Series 2 is available in three models—the 84 (eight-station, four-spindle), the 86 (eight-station, 6-spindle) and the 64 (six-station, four-spindle)—to meet various mid- to high- production needs. Spacing between spindles is 190 mm (7.48"). The 7.5 kW (10 hp) spindle drive provides a speed range of 100–2,500 rpm. Removable, maintenance-free stainless steel guarding and electrical panel mounted to the rear of the machine allow easy access to the work envelope from either side of the machine to facilitate tool change or integration of custom part handling systems.

When properly applied, Single Stroke Honing is a quick, cost-effective method to get a precise bore size, geometry and surface finish. Parts made of cast iron, powdered metals, ceramic, glass, graphite and other free cutting materials–with L/D ratios up to 1:1–are suitable for the process. Single-pass bore sizing is also appropriate for splined bores or longer L/D ratios if cross holes or other interruptions are present to allow chip flushing. Sunnen offers a range of single-pass plated-diamond tooling for the VSS-2 for precise, accurate and consistent bore sizing.

Other standard features of the VSS-2 include an electric rotary index table and solid tool holder. Available options include floating or rigid/adjustable tool holders, 12- and 16-port programmable rotary air unions for index output, base coolant evacuation pump, automatic lubrication system, work area light kit, stack light and tool alignment indicator.

For more information:

Sunnen Products Company
7910 Manchester Ave.
St. Louis, MO 63143
Phone: (314) 781-2100
www.sunnen.com

INDEX CORPORATION

Booth S-8450

Index Corporation will introduce a new concept machine tool featuring two independent 5-axis subsystems, each with one motorized milling spindle and one assigned work spindle, able to completely machine complex parts, short bars up to 102 mm and chucking up to 315 mm diameter, simultaneously. The new Index R300 turning/milling center is the most recent addition to the RatioLine series and introduces a highly productive version for machining short bars up to 102 mm and chuck parts up to 315 mm in diameter. The R200 covers the range for bar diameters up to 65 mm. The new Index R300 is geared toward applications where larger chuck parts require a large amount of milling and drilling work, such as machine and farm machinery con-

struction, in tool and mold making or in the aerospace industry.

From very simple to highly complex components, the main benefit is that the complex machining operations are possible simultaneously on the front and rear side - and, at the same time, are highly productive with two motorized milling spindles. The use of HSK tools instead of live tool holders on turrets reduces tool costs. Suitable for difficult milling operations, the R300 is also capable of hobbing or deep-hole drilling with single-lip tools and high-pressure coolant to 80 bar to the tool edge through the motorized milling spindle. Grinding operations with a grinding point or an external grinding wheel up to 150 mm are additional machining options.

For more information:

Index Corporation
14700 North Pointe Blvd.
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sales@index-usa.com
www.indextraub.com

IMTS (International Manufacturing Technology Show): Connecting Global Technology September 10–15, 2012; Chicago, IL

Show Sponsor: **AMT (Association for Manufacturing Technology)**
Show Dates: **September 10–15, 2012**
Show Location: **McCormick Place, Chicago, IL USA**

Attendees. Manufacturing industry professionals from all over the world attend IMTS to see more than 15,000 new machine tools, controls, computers, software, components, systems and processes that can improve their efficiency.

Exhibitors. Over 1,100 exhibitors from the metalworking industry will display their products and productivity solutions covering 1.2 million net square foot of show floor.

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- ***Tooling/workholding systems***: features jigs, fixtures, cutting tools of all types and related accessories.
- ***Metal forming/fabricating/laser processes***: home to waterjet, plasma-arc and laser systems, welding equipment, heat treating and more.
- ***Other pavilions at IMTS***: Abrasive Machining/Sawing/Finishing; Controls & CAD-CAM; EDM; Gear Generation; Industrial Automation North America; Machine Components/Cleaning/Environmental and Quality Assurance.

IMTS conference. The IMTS 2012 Conference brings the industry together, under one roof and at one time, to discuss new opportunities.

IMTS 2012 individual registration

- * $30 per person through August 10, 2012
- * $50 per person August 11–September 15, 2012

Group registration. To qualify as a group, you must have five or more people from the same company, and everyone must register at the same time.

- * $15 per person through August 10, 2012
- * $30 per person August 11, 2012–September 15, 2012
- * Includes access to the exhibit hall floor for all 6 days of the show
  * IMTS 2012 registration is non-refundable.

International visitors. An International Visitor is a person working in the manufacturing industry outside the U.S. Exhibits only registration is free for international visitors.

Students. Individuals at all levels of learning are invited to attend IMTS 2012 at no charge. Students, educators, administrators and guidance counselors, check out the NIMS Student Skills Center program and register for free!

Conference registration. Conference registration is open. You may register for more than one conference at the same time. Includes access to the exhibit hall for all six days of the show.

- **IMTS 2012 Conference**
  (Full Pass: $495; Day Pass: $295; Special Combo Pass: $695)
- **Motion, Drives & Automation Conference**
  (Early Bird: $165; Standard: $195; Discount Package: $295; Special Combo Pass: $695)
- **ISA Inside**
  (ISA Member Rate: $445 per course; Community Member/List Rate: $630 per course)
- **EHS Today's America's Safest Companies**
  (Rate: $395)
- **IANA Global Automation & Manufacturing Summit**
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- **TRAM3 Aerospace Conference**—Trends in Advanced Machining, Manufacturing and Materials


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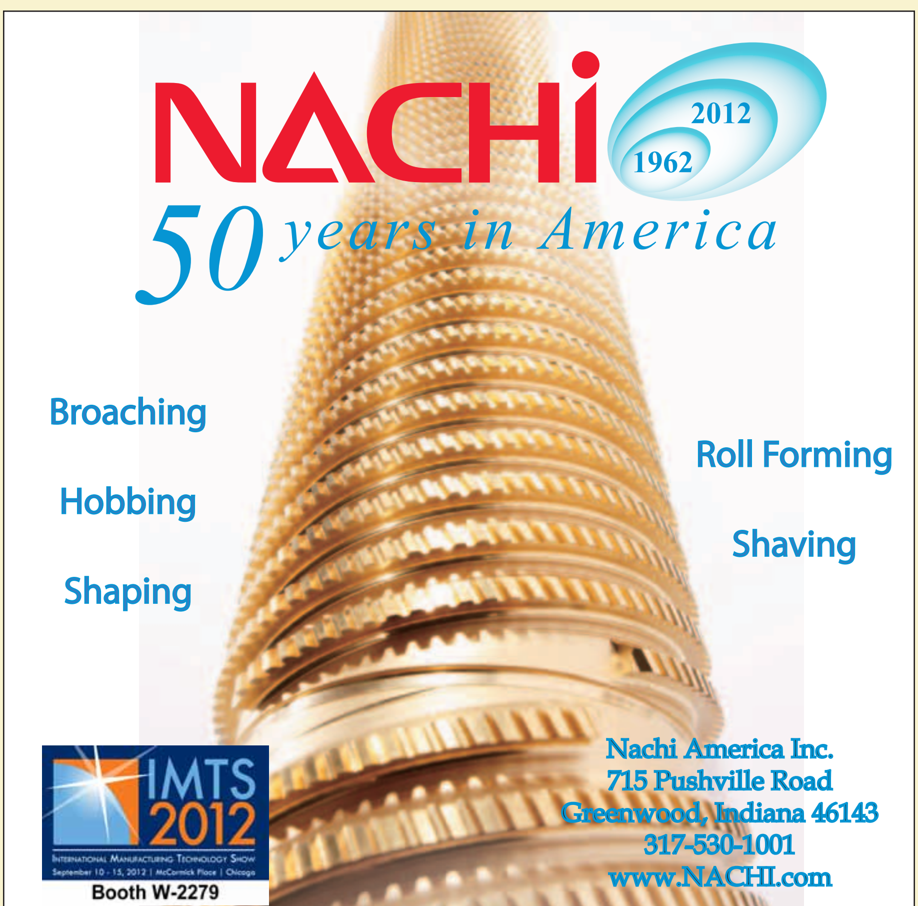
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BOOTH # N-7148


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Got a Gear Question?

Ask the Expert!

Welcome back to *Gear Technology*'s Ask the Expert—a regular feature intended to help designers, specifiers, quality assurance and inspection personnel in addressing some of the more complex, troublesome gearing challenges that never cease to materialize—whether on the drafting table or the shop floor. Simply e-mail your question—along with your name, job title and company name (if you wish to remain anonymous, no problem)—to: *jmcguinn@geartechnology.com;* or, you can submit your question by visiting *geartechnology.com*.

QUESTION #1

Profile Shift

Regarding profile shift: What kind of data must be considered when we grind a gear with shift profile?

A few days ago we received a series of gears that need to be corrected (profile shift). Our engineering department had a question about this topic; they tell me that they do not know how to calculate the gears with profile shift and that they have big doubts over whether—with each profile shift factor—the pressure angle also changes.

A friend in Texas told me that you cannot make a profile shift gear with a cutter in a traditional way. For each correction factor, you require a cutter according to the modification. Is this is correct?

Ing. David Ruiz, production manager
Grupo Meusnier S.A. de C.V.

Dear David,

AGMA 913–A98—Method for Specifying the Geometry of Spur and Helical Gears—gives all the equations you need for calculating profile shift.

The reference pressure angle measured on the generating pitch diameter (the same as the standard pitch diameter or reference pitch diameter) is determined by the cutter pressure angle and is usually 20° for most gears. It is independent of profile shift. The operating pressure angle is determined by the operating center distance of the mating gears and is again independent of the profile shift.

You can think of profile shift as simply shifting the teeth outward or inward so that the active profile of the teeth uses a different sector of the same involute curve.

Profile shift does not require special cutters if straight-sided hobs are used (the usual case). The hob is simply shifted outward or inward to shift the profiles, and the outer diameters of the gears are changed to accommodate the profile shifts. Therefore, the advantages of profile shifting are achieved with no cost consequences. Only form cutting such as milling requires a different cutter for profile shifted gears. That's because form-cutting or form-grinding require a cutter or grinding wheel with a profile that matches the shape of the tooth space. Since profile shifting changes the shape of the tooth space, the shape of the form cutter must change.

One of the most important parameters in any gear design is the number of teeth in the pinion, and profile shift has its greatest relevance when the pinion has a small number of teeth. In fact, the first use of profile shift was to avoid undercut in pinions with less than 17 teeth. It was later realized that profile shift improves most aspects of gear operation, and today it is used for many reasons including:

- Avoiding undercut
- Avoiding narrow top-lands to avoid case/core separation in carburized gears
- Balancing specific sliding to maximize wear resistance and Hertzian fatigue resistance
- Balancing flash temperature to maximize scuffing resistance
- Balancing bending fatigue life to maximize bending fatigue resistance

Gears with few teeth are more sensitive to profile shift, and their tooth shape changes more dramatically, whereas profile shift changes tooth shape only slightly for gears with a lot of teeth. In fact, the teeth of a rack (with theoretically infinite number of teeth) do not change shape as the teeth are profile shifted. These effects can be seen in Figure 4 of AGMA 918–A98. It's best to design gear sets with pinions with at least 20 teeth—and preferably 25—in which case the

profile shifts for balanced specific sliding, balanced flash temperature and balanced bending fatigue life are all nearly the same.

See AGMA 901–A92—A Rational Procedure for the Preliminary Design of Minimum-Volume Gears—for a method to design gears with maximum-load capacity by balancing the macropitting resistance and the bending fatigue resistance.

Figures 1 and 2 demonstrate how profile shift dramatically improves specific sliding. Figure 1 shows the specific sliding for a gear set with no profile shift. Figure 2 shows the same gear set after the pinion and gear have profile shifts designed to balance and minimize the specific sliding. Profile shifting has greatly reduced the specific sliding from -4.03 to -1.28. This improves the meshing characteristics of the gear set by reducing the frictional loss, lowering the contact temperature and increasing the resistance to wear, macropitting, micropitting and scuffing.

Robert L. Errichello, *a longtime* Gear Technology *technical editor, is owner-operator of Geartech—a gear industry consultancy. Bob also is a current member of the AGMA Nomenclature, Helical Gear Rating, Epicyclic Enclosed Drives and Wind Turbine committees.*

Dear David,

Profile shift—sometimes known as 'addendum modification' or 'correction'—is the displacement of the basic rack (or cutting tool) datum line from the reference diameter of the gear. The size of the profile shift (mm or inches) is usually made to be non-dimensional by dividing it by the normal module (or multiplying by the DP), and it is then defined by the profile shift coefficient 'x'. A positive profile shift increases the tooth thickness while a negative profile shift reduces tooth thickness (this applies to internal and external gears alike). This is illustrated in Figure 1, which is copied from ISO 21771:2007, i.e., Gears: Cylindrical Involute Gears and Gear Pairs—Concepts and Geometry.

The only difference in machine setup required for cutting profile shifted gears is to change the radial position of the cutting tool by an amount defined by the profile shift. The cutting tool module or DP, cutting tool pressure angle and number of teeth on change gears on manual machines, remain unchanged. This in turn means the base diameter (and base helix angle on helical gears) remain the same. A key benefit from using involute gears is that we don't need to change the cutting tool to make gears with a different diameter and tooth thickness.

Profile shift is used by designers for many reasons including the elimination of undercut when hobbing or shaping gears with few teeth, minimizing sliding at the gear pair start of active profile, increasing bending strength, increasing or decreasing the center distance and changing tooth thickness

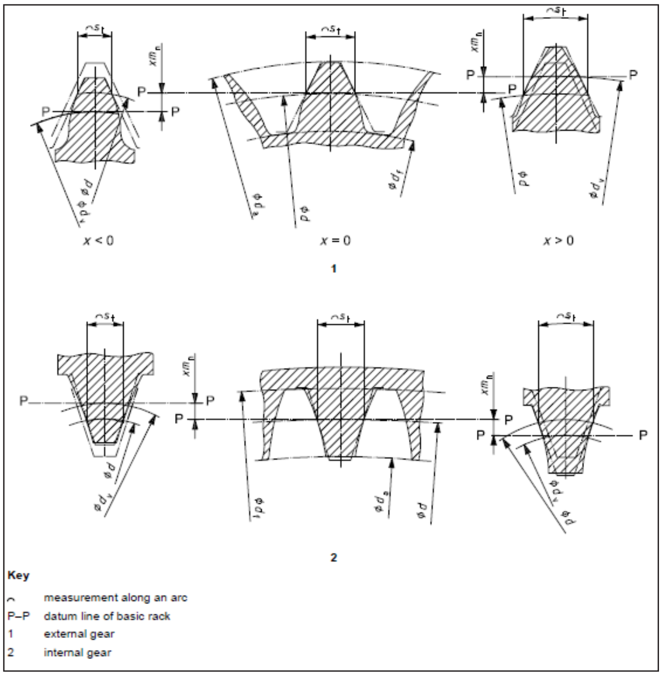

Figure 1—Profile shift for external and internal gears, as defined by ISO 21771:2007. Gears: Cylindrical Involute Gears and Gear Pairs—Concepts and Geometry.

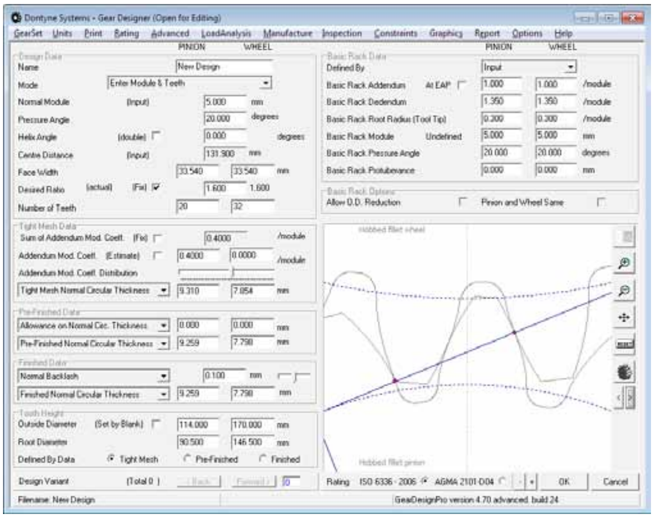

Figure 2—Example geometry software package with graphical display illustrating the effect of profile shift (addendum modification) on tooth shape and operating pressure angle.

or backlash. In fact all gears have some profile shift when you consider that we normally move the cutting tool radially to change the tooth thickness.

A common perception is that profile shift changes the 'pressure angle' of a gear.

This is wrong.

The pressure angle we specify on the drawing is the pressure angle of the cutting tool. The actual gear flank pressure angle changes from root to tip and the working pressure angle (the angle of the line of contact) of a gear pair depends on gear center distance and gear base diameters only. If the sum of the pinion and wheel profile shift is zero, the gears operate at the reference center distance. If this sum is negative the gears have smaller center distance and thus they have a smaller operating pressure angle, while a positive sum requires a larger center distance increased operating pressure angle.

For further information on this subject I recommend a document published by British Standard PD 6457—Addendum Modification to Involute Spur and Helical Gears, and also ISO 21771:2007, published by ISO. These references contain the calculations and recommendations for minimum profile shift to avoid undercutting and maximum profile shift that can be applied before the tooth crest thickness become too thin. Most commercial software packages provide options for specifying profile shift; the effects can be demonstrated graphically and improvements in gear performance can be quantified, as seen in Figure 2.

Dr. Robert Frazer, *a* Gear Technology *technical paper contributor, heads the U.K. National Gear Metrology Laboratory and as such is responsible for gear design and analysis within The Design Unit at the University of Newcastle-Upon-Tyne. Rob is also actively involved with delivering the British Gear Association (BGA) training seminar program and is an active member of the AGMA Gear Accuracy and Calibration committees.*

Dear David,

Profile shift, also known as *x* factor, is just a method for specifying tooth thickness. If the gear drawing has a "measurement over pins" or "span over a given number of teeth" or other tooth thickness specification that you are familiar with, you can just grind the gear to meet the specified tooth thickness and safely ignore the profile shift.

Many of those familiar with profile shift find it very easy to use during the design of a gear pair. However, the resulting gear is not fundamentally different from one designed by other methods. Cutters do not need to be modified to create gears with different amounts of profile shift.

The concept of profile shift is quite simple: as a gear cutter is shifted radially towards the center of an external gear, the tooth profile will of course also be shifted towards the gear center. At a given diameter, such a shift of the tooth profile results in the teeth appearing thinner. Since the actual pressure angle varies with diameter, a shift in the profile changes the pressure angle at a given diameter. But this change in pressure angle does not mean there was a change in tooling; it is the natural result of sinking a given tool deeper into the part.

The symbol for profile shift is *x*, and it is a coefficient; i.e., it is normalized so it is non-dimensional. The sign convention for profile shift is that a positive profile shift results in thicker teeth. So shifting a cutter towards the center of an external gear is a negative profile shift, since it makes the teeth thinner.

The profile shift usually used by gear designers is for a zero backlash gearset. To provide some backlash, some designers increase center distance while others reduce the profile shift. When you subtract an additional small shift as a backlash allowance from the non-dimensional zero backlash profile shift, and multiply by module to get millimeters, the result is called the “rack shift.”

In Europe, some gear designers specify only the zero backlash profile shift and the manufacturer will thin the teeth according to tables in the DIN standards. If you receive such a drawing that does not specify an actual measurement of the finished gear teeth, then you should discuss with your customer what is actually expected.

For more information, see AGMA 913–A98. This information sheet was written to introduce profile shift to engineers in the United States. There are also many computer programs, such as AGMA’s *Gear Rating Suite*, that will allow you to easily convert from profile shift to other forms of tooth thickness specification.

John M. Rinaldo, *senior development engineer at New York-located Atlas Copco Comptec LLC, is also a current member of the AGMA Computer Programming (vice-chair), Nomenclature, Gear Accuracy (vice-chair) and Helical Enclosed Drives High-Speed Units committees.*

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Powder Metal Magic

Design Innovations in PM Applications

Matthew Jaster, Associate Editor

Capstan Atlantic, located in Wrentham, Massachusetts, produces powder metal gears, sprockets and complex structural components. The company has provided unique powder metal products in a variety of industries including automotive, business machines, appliances, lawn and garden equipment and recreational vehicles. The recent resurgence of the automotive industry has played a large role in increasing opportunities in powder metal, particularly in areas like suspension, powertrain, steering column and electronic power steering (EPS). Richard Slattery, vice president of engineering at Capstan Atlantic, recently discussed some of the latest powder metal gear designs that are more cost effective compared to their cut steel alternatives.

Automotive Application

A helical/spur combination gear—where all gear data is relative to the journal diameters, rather than an inside diameter—was utilized for a power liftgate application. The elemental gear data is very precise to enable quiet gear performance as NVH (noise, vibration and harshness) thresholds are very sensitive to the end user. In order to function properly, the gear must run quietly. The part is compacted using two lower and upper punches, coupled with a proprietary helical bearing system to allow punches to spin freely under 45 tsi of pressure. (*Ed's note: See sidebar page 57 for more information*). A custom designed robotic material handling system is used to remove parts from the press and place them in sinter carriers. The pinion and gear have very precise elemental gear tolerances.

The significant process control challenge is that all the gear data is measured relative to the central axis of the part as established by the two opposing journal diameters. This presents challenging tool setup requirements as well as special fixturing for part measurement. The material is an FC 0208-50 (copper steel) with a nominal density of 6.85 g/cm^3 and a typical hardness of HRB 75, a yield strength of 55,000 psi and a tensile strength of 65,000 psi.

"This near-net-shape process is highly cost competitive versus other metalworking/gear manufacturing processes associated with this level of precision," Slattery says. "The part offers precise elemental gear tolerances for system noise reduction, without an inside diameter as a datum."

Lawn and Garden Application

A high precision, copper infiltrated, helical gear was needed for a two-cylinder engine application in the lawn and garden market. "This copper infiltrated helical crankshaft gear is compacted with a custom geometry to allow for subsequent gear tooth modification for high strength and minimum noise," Slattery says.

The gear offers a 25.5 degree helix angle, a custom involute profile that includes tip relief and a "mirror like" surface finish on the tooth flanks. The teeth have a maximum helix error

A net-shaped PM clutch hub combines multi-level technology, an innovative material system and a unique PM processing method (courtesy of Capstan Atlantic).

This helical/spur combination gear is utilized in a power liftgate actuator application (courtesy of Capstan Atlantic).

(lead) of 15 microns and a profile error of less than 30 microns. Additionally, this gear has an accurately machined inside diameter (24 microns total tolerance) and locating face, enabling precise assembly.

The gear requires a high level of tool geometry control along with minimum weight and sectional density variation at a compact and very consistent sinter temperature profile. The inside diameter is then precision machined and the teeth are rolled for densification and final qualification of the gear geometry. The material is an FX 1008-50 (copper infiltrated steel) at a 7.3 g/cm^3 minimum density and apparent hardness of RB 90. The elongation exceeds three percent and the impact strength exceeds 15J (10 ft-lbs). This elongation enables very high press fit interference on the mating crankshaft to eliminate the potential of gear slippage in service. The tensile strength of this material is > 600 MPa (90,000 psi).

This gear's as-sintered, near-net shape and its physical strength, along with precise dimensional control, replace a far more expensive wrought steel alternative, offering a 35 percent cost reduction. "This gear has successfully passed all levels of endurance testing in this two-cylinder industrial engine application," Slattery says. "It's economically attractive, highly precise and costs almost fifty percent less than the cut steel alternative."

Industrial Application

A net-shaped PM clutch hub replaces a machined alternative that is more expensive. It combines multi-level technology, an innovative material system and a unique PM processing method. The part is compacted using four lower and a stepped single upper punch, coupled with an enhanced powder feed system to facilitate equalized local densities. Additional proprietary tool material and treatment systems are used to enable long, thin punches to withstand extreme tonnage. This is a complex, multi-level, higher dense component, capable of withstanding very high torque loads in service. The part is provided net shape, in the as-sintered/shot peened condition, replacing a previously machined version.

"The functionality of this hub requires very close relationships between the five diameters," Slattery says. "The tooth run-out to the internal spline is less than 100 microns (0.1 mm)."

The process control of the part is the consistent dimensional change for all levels through the sintering operation. This control is maintained by achieving sectional density variation within 0.05 g/cm^3 at the compaction step in the process. The material is a hybrid Fe/Mo/Cu/C alloy with very good yield strength and as-sintered tensile properties. The flange of this component is subjected to repetitive bending fatigue in service. Therefore, the ability to achieve the required strength, as well as the bending fatigue resistance, is the key to the field success of this component. "Simply put, this PM part offers precision, economic value and strength," Slattery adds.

Appliance Application

A complex, off-center-loaded PM rack has multiple lower levels, one of which is formed on the core rod platen and a dual upper punch system. Special robotic automation is required to remove the part from the lower tooling, flip it 180 degrees and place it on a special conveying system. "This is a seven level part requiring six punches. The rack system incorporates a progressive variable tooth space to compensate for system tooth engagement variation in service. The U slot density is controlled through off standard power distribution by the dual upper punches," Slattery says.

He continues, "This rack's as-sintered, near-net shape and its physical strength along with precise dimensional control, replace a far more expensive die cast alternative (a 38 percent cost reduction)."

The engineering properties include a highly controlled rack tooth profile and spacing characteristics. Perpendicularity of U slot to opposing locating surface is critical along with the flatness of the locating surface. This part requires a high level of tooth geometry control along with minimum weight and sectional density variation at compact and a very consistent sinter temperature profile. Sinter distortion cannot be tolerated due to required component flatness. Specially engineered sinter fixturing assists in achieving this flatness, typically within 0.075 mm.

The material is an FC0205 with density in the rack, flange and U slot region at 6.8 g/cm^3. The sectional density is kept equal within 0.08 g/cm^3. This part has a minimum yield strength of 43,000 psi and typical tensile strength of 55,000 tsi, with a hardness of HRB 65.

"The rack has successfully passed bench and in-service life testing in this industrial washing machine application," Slattery says. "This rack along with the mating gear is what agitates the drum in these machines. The die cast alternative to this PM system is far more expensive due to the extensive machining required."

All of these examples illustrate the highly dense, high performance and improved dimensional precision found in PM gears. This has certainly helped powder metals gain significant growth within the gear industry and will continue to do so in the future.

For more information:

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10 Cushing Drive
Wrentham, MA 02093
Phone: (508) 384-3100
www.capstanatlantic.com

This part requires a high level of tooth geometry control along with minimum weight and sectional density variation at compact and a very consistent sinter temperature profile (courtesy of Capstan Atlantic).

New PM Designs Highlight PowderMet2012

The 2012 Powder Metallurgy Design Excellence Awards (presented during the 2012 International Conference on Powder Metallurgy & Particulate Materials in Nashville) exemplify PM's special engineering benefits including net shape, precision, innovative fabrication methods, production efficiency, energy and materials savings, and manufacturing cost reduction. These advantages continue to stir designers to choose PM for critical applications in auto engines and transmissions, electronics, medical devices, agricultural equipment, consumer products, military equipment and emergency applications.

GKN Sinter Metals (located in Auburn Hills, Michigan) won the grand prize in the automotive engine category for a VVT rotor adapter assembly consisting of a PM steel rotor and adapter. The parts are joined by an adhesive, which joins them during machining cross holes and other features on the inside diameter, and seals the joint between them. GKN also won the grand prize in the automotive transmission category for a unitized one-way clutch (OWC) module made for the Chrysler Group. The module has four PM steel parts (powder-forged race and cam, and two pressed and sintered retainer plates) as well as 22 additional parts (clips, springs and roller elements).

Capstan Atlantic (located in Wrentham, Massachusetts) was awarded the grand prize in the automotive chassis category for a complex PM steel two-stage helical gear and spur pinion used in a power lift gate actuator. The precise elemental gear data tolerances enable quiet gear performance and decreasing noise, vibration and harshness.

FMS Corporation (located in Minneapolis, Minnesota) won the grand prize in the lawn and garden/off-highway category for a PM steel race gear used in the OnTrac2 GPS-assisted steering system made for Novariant Corporation in California. The system positions agricultural planting and harvesting equipment to more accurately perform tillage, spraying and spreading as well as reducing skips and overlaps, thus reducing fuel consumption.

In the hardware/appliances category, ASCO Sintering (located in Commerce, California) won the grand prize for a copper-infiltrated PM steel inside deadbolt chassis for a commercial electronic lock system. Maintaining the density between the hub and flange is especially critical in this application. The part has two PM posts manufactured and installed while maintaining true position and squareness.

FloMet LLC (located in Deland, Florida) won the grand prize in the aerospace/military category for a very complex 17-4 PH stainless steel rotor made by metal injection molding (MIM) and used in a hand-emplaced munitions device. The intricate design

Foreground: Medical introducer parts and eyeglass bridges. Second row: Helical gear and pinion, rotor, and VVT adapter. Third row: Deadbolt chassis, coil housing, and clutch hub. Back row: Gear-race and one-way clutch module (photo courtesy of MPIF).

is demonstrated by its four holes on two perpendicular planes, two-angled slots with square corners, and numerous internal and external radii, flats, slots and cutouts.

The medical/dental grand prize was awarded to Parmatech Corporation (located in Petaluma, California) for a mechanical introducer device used in minimally invasive OB/GYN surgery. The device contains five 17-4 PH stainless steel MIM parts, right and left cover, curved needle, curved needle linkage and center linkage. The covers have a complex 3-D geometry incorporating assembly pins and slots for moving the internal parts that require smooth action for suturing.

The electrical/electronic components category was won by Capstan California (located in Carson, California) for a soft magnetic PM alloy coil housing used in a magnetic door closer for emergency/fire protection applications. The PM design replaced a three-piece assembly and features the locations of drafts, radii and chamfers, as well as redefining tolerances for a near-net shape part.

Capstan Atlantic won the grand prize in the industrial motors/controls and hydraulics category for a PM steel alloy power take-off clutch. The part is designed to withstand very high torque levels in service, and the flange is strong enough to resist repetitive bending fatigue.

Smith Metal Products (located in Lindstrom, Minnesota) won the grand prize in the consumer market category for a 17-4 PH stainless steel MIM top and bottom of an eyeglass-frame bridge made for Superfocus LLC. Featuring very thin walls, the parts form the bridge section over the nose, which also houses an actuator for changing the magnification levels of the glasses.

Companies that accepted awards of distinction include SolidMicron Technologies (located in Singapore), Burgess Norton Mfg. Co. (located in Geneva, Illinois), PMG Group (located in Spain), ACL Bearing Company (located in Australia), Porite Taiwan Co. (located in Taiwan), Capstan Atlantic, Megamet Solid Metals, (Earth City, Missouri), Capstan California, Advanced Materials Technologies (located in Singapore) and Smith Metal Products.

PM Today and Tomorrow

In all materials, process and market sectors, the North American PM industry has built on the growth momentum begun last year, according to Matthew Bulger, president, MPIF.

Traditional press-and-sinter PM, metal injection molding (MIM), hot isostatic pressing (HIP), and other specialty PM technologies are thriving. PM is an interconnected technology that innovates and grows by leveraging its different sectors. Looking back at the past two years clearly suggests that the industry's recovery is sustainable. Iron powder shipments soared in 2010 after a terrible previous year. Total iron powder shipments grew modestly in 2011 to 363,831 short tons, a three percent increase. This increase was also achieved despite the shutdown of a major powder supplier's main plant for two months. Shipments of North American metal injection molding (MIM)-grade powders, including imports, jumped nearly 40 percent in 2011. The MIM process continued to garner greater acceptance in the materials marketplace. Some interesting R&D programs include developing MIM ultrasonic dentalscaler tips and endodontic tips, and titanium and cobalt–chromium alloys for medical-implant applications. The HIP business has also experienced robust growth in 2011 due to a general surge in manufacturing, and gains in the oil-and-gas, tool-steel, and aerospace markets. The HIPing of MIM parts continues to be a growing market.

Bulger noted that 2012 began on a very positive note, with rising confidence levels. First-quarter shipments of metal powders were up, as were volumes of PM parts and MIM parts. U.S. light-vehicle sales are expected to top 14 million units, up substantially from the 12.8 million units sold in 2011. Iron powder shipments through April this year rose by 11.25 percent to 134,925 short tons. Copper and copper-base and tin powder shipments have remained stable.

One of the key issues facing the entire industry is the serious need for experienced production workers and PM engineering professionals. Industry-wide employee reductions during 2008–09 have not been easy to reverse as the industry has rebounded. Another issue is capacity constraints: will the industry be ready to meet rising demands, particularly driven by the automotive industry, in the next several years? As was the case with staffs, rationalization moves during the same 2008–09 period included several plant closings and the scrapping of older equipment. Because it can take upwards of 10 to 12 months to build a high-end press and put it into production, Bulger cautioned, the equipment investment bandwagon must begin rolling sooner rather than later. Within the automotive sector, PM is approaching a saturation point in auto-engine content with existing technology. The average auto engine now contains up to 50 PM parts weighing more than 18 pounds, including connecting rods, bearing caps, valve-seat inserts, and VVT parts. With the average North America–built engine containing up to 170 individual parts, PM parts currently represent about 30 percent of the content. Potential growth appears more likely in transfer-case and transmission applications. For more information, visit *www.mpif.org*.

High-Performance Sintered-Steel Gears for Transmissions and Machinery: A Critical Review

Dr.-Ing. Senad Dizdar

Management Summary

Except for higher-end gear applications—found in automotive and aerospace transmissions, for example—high-performance, sintered-steel gears match wrought-steel gears in strength and geometrical quality. The enhanced P/M performance is due largely to advances in powder metallurgy over last two decades, such as selective surface densification, new materials and lubricants for high density and warm-die pressing. This paper is a review of the results of a decade of research and development of high-performance, sintered-steel gear prototypes at Höganäs AB.

(First presented at International Conference on Gears 2010, Munich, Germany)

Introduction

The mechanical power transmissions and machinery of today are designed and manufactured to meet the difficult demands of sustainable production, low cost, compact size, low weight, high efficiency, quiet operation, long service life and—when it ends—full recycling. And when comparing powder metallurgy (P/M)—sintered gears—with wrought steel gears, there is no doubt the latter have attained the best-possible levels in gear strength, geometry and material quality. In contrast, while sintered-steel gears have also reached very high levels in gear strength, geometry and material quality, they also offer highly sustainable production, low total cost and full recycling for a range of applications in the automotive, agricultural, construction, power tools and home appliances industries.

Another method for making machined-sintered gears is the so-called blank concept. Here the gear blanks are manufactured by pressing and sintering, selective surface densification and hardening, and are then sent for hard finishing to attain final geometrical quality. With this concept, production sustainability is enhanced by pressing geometrical features in the press direction and eliminating material waste, while also providing high gear strength and material and geometrical quality.

Both sintered and sintered-machined gears are in step with global trends toward improvements in production sustainability. Table 1 lists results of a recently published study by the Metal Powder Industry Federation (MPIF); the analysis was done on a truck transmission notch segment, but the numbers for gears will not much vary. In comparison to machining, P/M gear manufacturing will certainly reduce raw material needs—due to very limited material loss—and at half the energy used.

High-Performance Sintered Gears

P/M entered gear applications through sintered pump gears in the early 1940s (Ref. 2). Since that time P/M has advanced in developing pressing technologies for high density such as selective surface densification (Ref. 3); warm compaction (Ref. 4); high-density lubricants and warm-die compaction (Ref. 5); fully pre-alloyed chromium steel powder grades such as Astaloy CrM, Astaloy CrL (Ref. 6) and, most recently, Astaloy CrA and high-density powder solutions, such as Hipaloy (Ref. 7).

Today it is readily possible to produce spur and helical P/M gears with a

Table 1—Side-by-side comparison of truck transmission notch-segment manufacturing steps by Metal Powder Industries Federation (MPIF) (Ref. 1)

Manufacturing technology	Finished part weight (g)	Raw material utilization (%)	Material loss (g)	Manufacturing steps	Energy used (kWh/piece)
P/M	300	95	16	6	1.243
Machining	312	40..50	260	17	2.847

sintered density exceeding 7.2 g/cm³ by virtue of:

- Single-pressing/single-sintering process with warm- and warm-die compaction.

It is possible to exceed 7.4 g/cm³ by virtue of:

- Double-press/double-sinter (DPDS) process.

It is possible to exceed 7.5 g/cm³ by virtue of:

- High-density powder solutions and fully densified, 7.8 g/cm³ gear tooth flank and/or root surface by, for example, gear rolling (Refs. 3; 8–9), shotpeening or Densiform process (Ref. 10).

However, gears for several transmission and machinery applications have been found to fit application demands based on what may be called trial and error. Often, there is neither load capacity calculation nor experimental verification of the main gear design parameters available; therefore any change of the design and/or manufacturing process is connected with many questions and uncertainties. A particular uncertainty develops when a conversion to sintered gears is discussed, due to reasons such as the low market share of sintered gears—approximately 3%, according to AGMA in 2009 (Ref. 11)—the presence of pores in the material; a rather low presence of powder metallurgy in material courses for mechanical designers and premature failures of earlier sintered components due to their low strength.

High-Performance Sintered-Steel Gear Development

For some time now, high-performance sintered steel gears have been extensively investigated by Höganäs AB in order to screen the feasibility of using new technologies in powder metallurgy for sintered gears. That included, among others techniques, surface densification via gear rolling; burnishing; shotpeening; high-density pressing; warm compaction and warm-die pressing techniques, together with new low-chromium-alloyed, fully pre-alloyed steel powder grades and a new generation of powder mixes with powdered lubricant and lubricant coated on steel powder. Sintered materials of interest were for the low Cr- and Mo-alloyed, fully pre-alloyed steel powders with good hardenability. Sintered materials of note are (Ref. 12):

- ***Astaloy CrL (Fe alloyed with 1.5% Cr, 0.2% Mo).*** Fully pre-alloyed Cr powder grade; relatively impervious to price fluctuations of Mo as alloying element; very high hardenability and strength already at sintered densities such as 7.0 g/cm³. Gears made of this material can be gas-carburized as common if core-sintered density exceeds the level of 7.4–7.5 g/cm³; otherwise, vacuum- or low-pressure-gas-carburizing is required (Ref. 13).
- ***Astaloy 85Mo(Fe alloyed with 0.85% Mo) and Astaloy Mo (Fe***

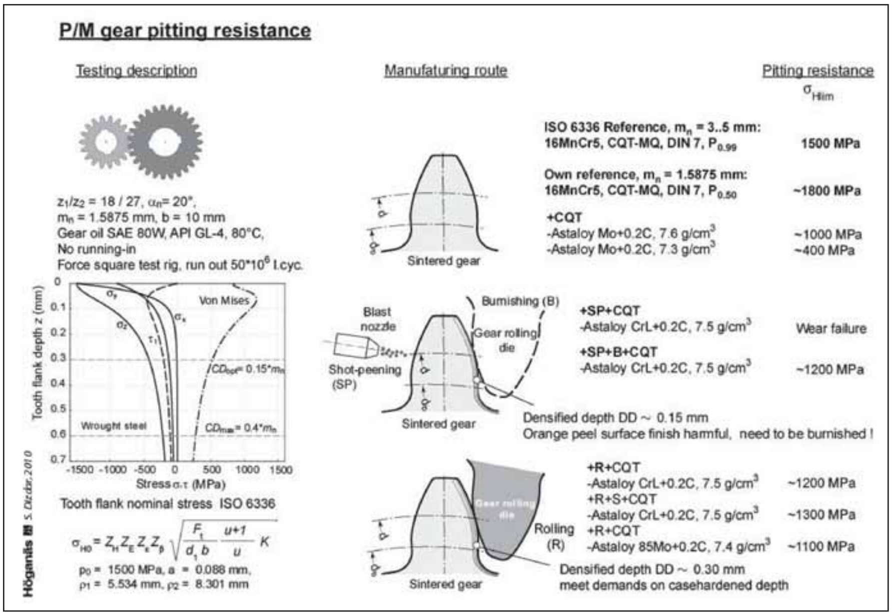

Figure 1—P/M gear pitting resistance.

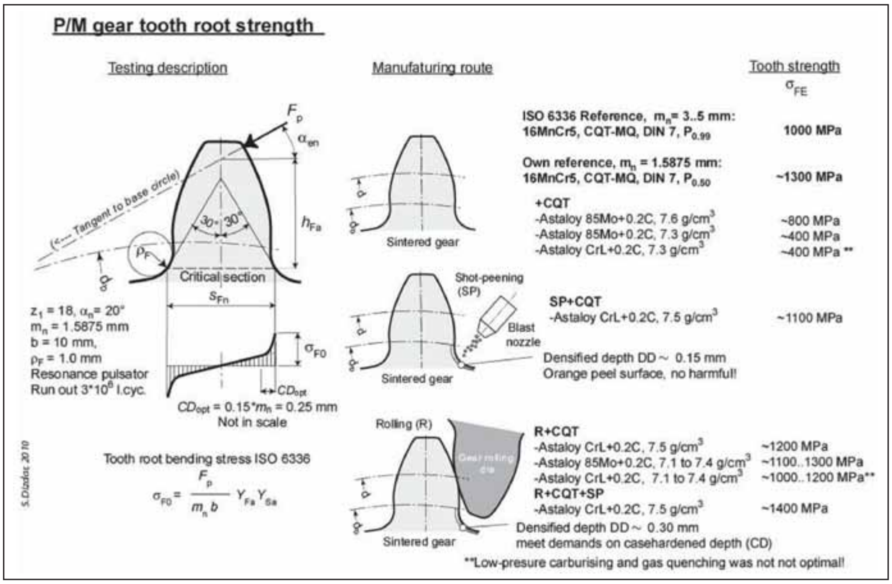

Figure 2—P/M gear tooth root strength.

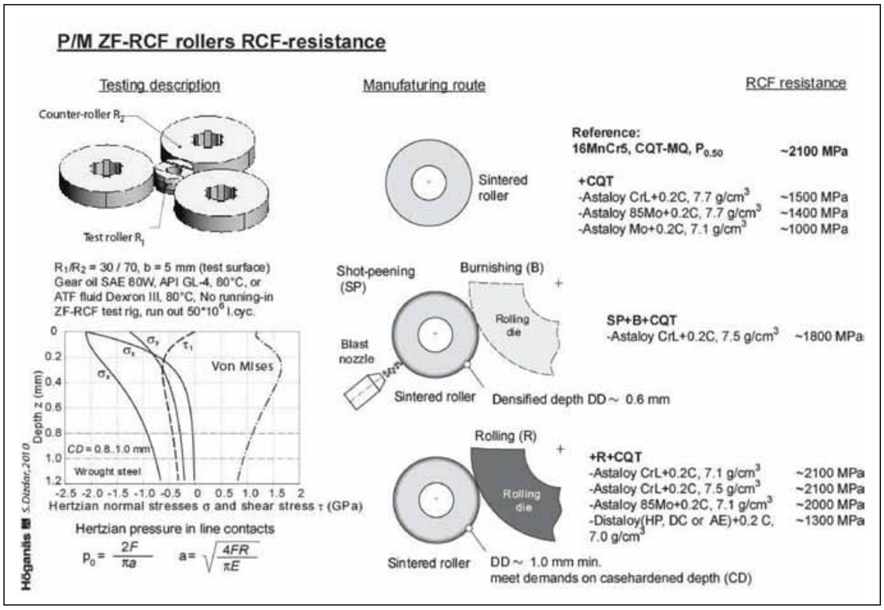

Figure 3—Rolling contact fatigue (RCF) resistance of P/M rollers.

alloyed with 1.5% Mo). Fully pre-alloyed Mo powder grade; relatively sensitive to price fluctuations of Mo as alloying element; high hardenability.

- ***Distaloy HP (Fe alloyed with 1.4% Mo, 4.0% Ni, 2.0% Cu).*** Fully pre-alloyed Mo powder grade diffusion alloyed with nickel and copper.
- ***Distaloy DC (Fe alloyed with 1.5% Mo, 2.0% Ni).*** Fully pre-alloyed Mo powder grade diffusion alloyed with nickel.
- ***Distaloy AB (Fe alloyed with 1.75% Ni, 0.5% Mo and 1.5% Cu).*** Plain iron grade powder diffusion alloyed with nickel, molybdenum and copper. Distaloy grades are very robust powder grades with high hardenability developed for components requiring density of up to 7.3 g/cm^3; use of warm- or warm-die compaction recommended.
- ***Basic sintered materials (Fe alloyed with 1.5% Cu, 0.4% C).*** Basic sintered materials for low-to-moderate-performance sintered components.

It is important to explain how sintered density affects hardening. To illustrate, a common cold-pressing density level for machinery gears in powder metallurgy is 6.9–7.1 g/cm^3; for warm- and warm-die pressing: 7.2–7.3 g/cm^3; and for high-density pressing and double-pressing: double-sintering (DPDS) is up to 7.7 g/cm^3. Sintered materials with densities lower than approximately 7.0–7.1 g/cm^3 have a fully connective pore system that allows deep penetration of gases in a carburizing atmosphere; and, soaking times are shorter compared to wrought components. A problem that may arise is carburization of unwanted surfaces—it must be prevented, which may include additional costs for a carbon-inhibiting mask and its removal after hardening. Depending upon sintered density, this problem may be less-pronounced, but when reaching sintered densities of over 7.4–7.5 g/cm^3, the sintered components start behaving like wrought components during carburization (Ref. 13).

But our focus here is documented results (see references). In addition, Figures 1–3 detail the current gear pitting resistance, gear tooth root strength and respective rolling contact fatigue (RCF) roller resistance existent in sintered gears. These figures provide an overview of prototype specimens—e.g., their testing method, wrought references and manufacturing techniques with achieved results. The prototype gears are described with manufacturing process, material composition and sintered density level.

P/M gear pitting resistance (Fig. 1) was experimentally evaluated in a force-square—or back-to-back—test rig with closed power loop (Ref. 14). Sintered gears (Fe alloyed with 1.5% Cu and 0.4% C) were reported in a classic gear book (Ref. 15) to have a gear pitting resistance of 400 MPa (no details about sintered density available). ISO 6336 declares a gear tooth root strength of 1,000 MPa for case-hardened, low-alloyed wrought steels manufactured in material quality—or MQ, a common, good gear quality. Tests with case-hardened Astaloy Mo+0.2C, 7.3 g/cm^3-sintered gears indicated an equal, 400 MPa pitting resistance level. When gear-sintered density reached a 7.6 g/cm^3 level, pitting resistance approached a level of 1,000 MPa. Surface densification by means of shotpeening applied to the Astaloy CrL+0.2C, 7.5 g/cm-sintered gears resulted in a densified layer of 0.15 mm (DD = 0.15 mm means that full density dropped to 98 % relative density at 0.15 mm depth), but caused an orange peel-like surface finish that led in turn to adhesive wear failure. However, additional burnishing, i.e.—gear rolling in order to smooth the surface and partly correct the tooth profile (Refs. 9; 3)—boosted gear pitting resistance to a 1,200 MPa level. Radial gear rolling (Ref. 3) achieved deeper densification—DD = 0.3 mm—at equal level of pitting resistance. A post-rolling sintering—or "re-sintering"—provided an additional 100 MPa in pitting resistance, likely due to the additional homogenization of the material structure.

By looking at the plot of contact stresses vs. tooth flank depth—and for reference, a Hertzian stress of 1,500 MPa and wrought-steel (full-dense) material in Figure 1, it can be seen that the Von Mises stress knee has a maximum at 0.06 mm depth and that the magnitude of all contact stress components drops below 500 MPa at less than the 0.3 mm case depth recommended in ISO 6336. Results showed that a surface densification of 0.15 mm applied on high-core-density sintered gears resulted in pitting resistance levels of 1,200 MPa—*a 20% increase*. Deeper densification—to 0.30 mm—combined with re-sintering after rolling—resulted in a 30% increase in pitting resistance. To be clear, however, these findings require further investigation.

P/M gear tooth root strength (Fig. 2) was experimentally evaluated by using a high-frequency, resonance-type linear pulsator and applying testing requirements from ISO 6336 (Ref. 16) and DIN 3990 (Ref. 17). Again, sintered Fe–1.5Cu–0.4C gears were reported in the classic gear book (Ref. 15) to have a gear tooth root strength of 500 MPa (no details about sintered density given). ISO 6336 declares a gear tooth root strength of 1,000 MPa for case-hardened, low-alloyed wrought steels manufactured in material quality (MQ—a common, good quality) and having a core hardness of at least 30 HRC. However, ISO gear tooth root strength data were generated by testing gears with a module of 3–5 mm and comparing them with relatively small modules of 1–3 mm—a more frequent occurrence in gear manufacturing today. A 23% increase in the gear tooth root strength of case-hardened gears when decreasing the module from 3–1.5 mm was observed by Jeong (Ref. 18), and aligns well with our own test results. The results in Figure 2 should therefore be compared to 1,300—not 1,000 MPa; results also included case-hardened sintered gears with a density of 7.3 and 7.6 g/cm^3, and a tooth root strength of 400 MPa and 800 MPa, respectively. Shotpeening raised the tooth root strength to a 1,100 MPa level. It should be noted here that selective root shotpeening produces 0.15 mm densification depth as well an orange peel surface finish, but benefits of the densified depth are greater than losses associated with a rough surface finish. Application of gear rolling to 7.1–7.4 g/cm^3-dense Astaloy CrL+0.2C and Astaloy 85Mo+0.2C gears—with densification depth of 0.3 mm—resulted in a tooth strength of 1,000–1,200 and 1,100–1,300 MPa, respectively. Astaloy CrL gears normally exceed the strength of Astaloy 85Mo gears, but in this case low-pressure carburization was not optimal (Ref. 13). Gas-carburized, gear-rolled, 7.5 g/cm^3 core-dense Astaloy CrL+0.2C gears, with a densification depth of 0.3 mm, reached 1,200 MPa; if also shotpeened after common carburize-quench-temper operations, gear tooth root strength increased to 1,400 MPa.

The RCF resistance of P/M rollers (Fig. 3) was experimentally evaluated by using ZF–RCF test rigs through external testing on contract. As known, this type of testing reveals a general picture of RCF for a severity of rolling-sliding contact applications, including gears and bearings. However, while the achieved testing results are useful for ranking of materials/processes, they cannot be directly transferred to gears. RCF resistance of 2,100 MPa for 16MnCr5 rollers case-hardened to 1.0 mm in case depth was used as the reference. Case-hardened sintered rollers with a density of around 7.0 g/cm^3 reached close to 1,000 MPa. Increasing the roller's sintered density to 7.6–7.7 g/cm^3 by high-density pressing elevated RCF resistance to 1,500 MPa. It appears that to increase RCF resistance, a surface-densification technique must be used. 7.5 g/cm^3-sintered rollers—densified to 0.6 mm depth by shotpeening and burnishing the RCF resistance—reached a 1,800 MPa level. Both 7.1 and 7.5 g/cm^3 -sintered rollers—densified to deeper than 1.0 mm by radial rolling—met the reference RCF resistance of 2,100 MPa. The likely reason for this is that high magnitudes of all contact stress components stand inside a fully densified surface layer.

P/M gears with sintered density of 7.1 g/cm^3 manufactured by using pressing-sintering hardening routes usually achieve gear quality no higher than DIN 10 (Ref. 20). But by gear rolling, the quality of sintered gears can be improved to quality 6 to 7 for all deviations suggested in DIN 3961 having general or particular importance for uniformity of rotation, load capacity and noise reduction of gears. Quality DIN 8 can be more appropriate to envelop all teeth deviations, but of course the real question is whether all the teeth deviations need to achieve a certain quality. A subsequent case-hardening can make the teeth "top-small," and so lower the tooth profile quality to quality DIN 10 (Ref. 19). However, the pressing die and the rolling die geometry can compensate for it. A high core density is of benefit when trying to achieve high gear quality, since high (core) density techniques produce less density gradients in the gear teeth.

Surface roughness of sintered gears is a particular question. Sintered components in general achieve so-called stratified surfaces, including deep surface pores; and surface roughness, as defined for machined surfaces, cannot be fully applied here. However, using the machined surface roughness approach—until consensus is reached on acceptable surface roughness for sintered surfaces—the average surface roughness Ra is normally smoother than 0.8 µm for sintered gear flanks over 7.1 g/cm^3 in density, and smoother than 0.2 µm for gear rolled flanks (Refs. 3; 19). And that is even smother than for ground teeth.

A very brief summary of the all testing results is listed in Table 2.

Conclusions

High-performance-sintered, low-alloyed Cr and Mo steel gears are equal to wrought-machined gears for a number of difficult applications in transmissions and machinery—excepting the high-end ones in automotive and aerospace. In production sustainability, the sintered gears clearly exceed wrought-machined gears. Taking into account the gear size transferability issue, the following conclusions were reached:

- Pitting resistance of sintered-steel gears reached over 70% of the wrought-steel reference (standard)
- Gear tooth root strength of sintered-steel gear prototypes met the wrought-steel reference (standard)
- RCF roller resistance of sintered-steel gear prototypes met the wrought-steel reference (standard)
- Sintered low-alloyed Cr steels, such as Astaloy CrL for gear applications, reached 70% gear pitting and 100% RCF resistance of reference wrought-steel gears. These are important and very encouraging results showing that sintered-gear pitting performance is already of sufficient severity resistance for demanding gear applications.
- Gear quality achieved by gear rolling of sintered gears reached DIN 6–7 quality, which can be maintained after case hardening if compensated by use of a press-rolling die for top-small teeth during case hardening. The surface roughness of gear- sin-

Table 2—Brief comparison of guide values for gear strength and quality

	DIN 16MnCr5, m_n= 3..5 mm -machined, CQT, ground -manufact. quality MQ (ISO 6336)	P/M Astaloy CrL, m_n=1.5875 mm -pressing, sintering, shot-peening / gear rolling, CQT
Pitting	1500 ($P_{0\ 99}$)	1800 (P0.50)
Tooth root bending	1000 ($P_{0\ 99}$) 1300 (P0.50) — m_n=1.5875 mm	1100..1300 (P050)
Gear quality	DIN 7	DIN 7-8
Surface finish	R_a< 0.25 pm	R_a< 0.20 pm

tered rolled gears is even smoother than that of the ground gears.

- The key for achieving high-performance, sintered-steel gears is in making the surface densification depth equal to a required case-hardened depth, in combination with a properly high core density for a particular gear application. An increase in core density positively affects case-hardening and, if exceeding 7.4–7.5 g/cm^3, makes case-hardening of sintered steels as simple as case-hardening of wrought steels.

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Case Study Involving Surface Durability and Improved Surface Finish

G. Blake and J. Reynolds

Management Summary

Gear tooth wear and micropitting are very difficult phenomena to predict analytically. The failure mode of micropitting is closely correlated to the lambda ratio (Refs. 1–2). Micropitting can be the limiting design parameter for long-term durability. Also, the failure mode of micropitting can progress to wear or macropitting, and then go on to manifest more severe failure modes, such as bending. The results of a gearbox test and manufacturing process development program will be presented to evaluate super-finishing and its impact on micropitting.

Testing was designed using an existing aerospace two-stage gearbox with a low lambda ratio. All gears were carburized, ground and shotpeened. Two populations were then created and tested; one population was finish-honed; the second was shotpeened and isotropic super-finished.

A standard qualification test was conducted for 150 hours at maximum continuous load. The honed gears experienced micropitting and macropitting during the test. The isotropic super-finished (ISF) gears were also tested for 150 hours under the same loading. The ISF gears were absent of any surface distress, and so were then further subjected to a 2,000-hour endurance test. The ISF gears had less surface distress after 2,000 hours than the baseline honed gears after 150 hours.

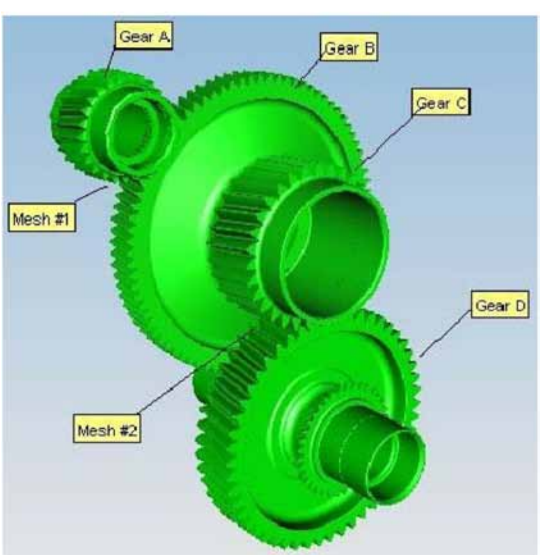

Figure 1—Rolls-Royce demonstrator gear train.

Introduction

Isotropic super finishing (ISF) is a technology that public literature suggests having potential for increased power density (Ref. 3). Three tests were conducted to test the surface durability difference between honing and ISF. Demonstration of bending fatigue strength was out of scope. Previous testing has shown ISF not to increase bending fatigue strength (Ref. 4).

The testing utilized a Rolls-Royce technology demonstrator gearbox assembled with a gas turbine engine. Testing was performed at Rolls-Royce Corporation in Indianapolis. The gear train on test was a compound idler arrangement (Fig. 1). Two sets of gears from the same manufacturing lot were used for testing. A comparison of the baseline gears and ISF gears is shown in Table 1.

The configuration of Gear C was silver-plated. As such, the ISF test gear was also silver-plated. A chemical process was used to prepare the surface prior to plating to minimize alteration of the surface. Measurement presented later in this paper will show that.

Test methods and parameters. Three tests, using two different sets of gears, were conducted as part of this project. A Rolls-Royce technology demonstrator gearbox was used for all three tests. The first two tests were conducted for 150 hours each; the third was conducted for 2,000 hours.

An aerospace gas turbine load cycle was selected for the first two150-hour

Table 1—Finishing processes of baseline and ISF test gears

Mesh	Gear	Baseline	ISF
#2	D	Ground, shot peened, honed	Ground, shot peened, ISF
	C	Ground, shot peened, honed, silver plated	Ground, shot peened, ISF, silver plated
#1	B	Ground, shot peened, honed, silver plated	Ground, shot peened, ISF, silver plated
	A	Ground, shot peened, honed	Ground, shot peened, ISF

tests. The graph shown (Fig. 2) is the test cycle. The load cycle was repeated 25 times for the baseline and ISF gears. All testing was done with MIL–L–23699 oil.

The ISF gears were reassembled and tested for an additional 2,000+ plus hours. The test was conducted using 14 different duty cycle profiles. A summary of the actual time spent at-power is shown (Fig. 3).

Baseline 150-hour test results. The gear tooth surface condition and any failure modes were classified using ANSI/AGMA 1010–E95 (Ref. 6). Table 2 contains a summary of the baseline gears subsequent to the 150 hour test. Figures 4–7 are low-magnification, white-light photos of the active profile surfaces, post test.

A dimensional and metallurgical evaluation was performed on all baseline gears; all gears were found to be conforming. Figure 8 is a sample post-test photomicrograph showing micropitting of Gear C. Figures 9–11 are post-test analytical inspection traces showing the change in form.

Roughness measurements were made of the baseline gears prior to test (Table 3).

As stated previously, the literature states that surface durability improves with increased specific oil film thickness. The composite roughness is one variable in specific oil film thickness. As such, the gear finishing process has an impact on the specific oil film thickness.

The specific oil film thickness (λ) was calculated for three roughness values (Table 4). The values were calculated at max HP and max oil temperature per AGMA 925–A03. The roughness values were selected based on expected values for typical honing, threshold of honing, and ISF. The calculated specific oil film thickness values were used to guide selection of a finishing process to improve surface durability. Measurement data from

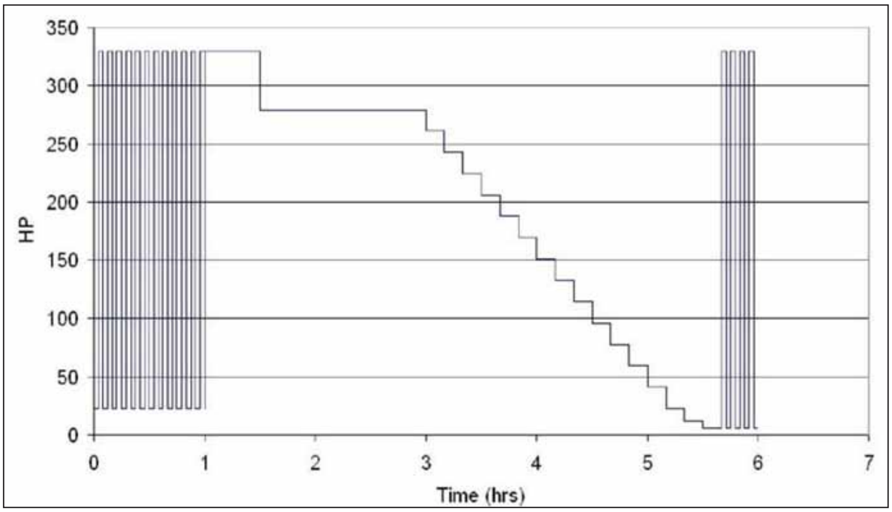

Figure 2—Endurance test (six-hour cycle) repeated 25 times for baseline and ISF gears.

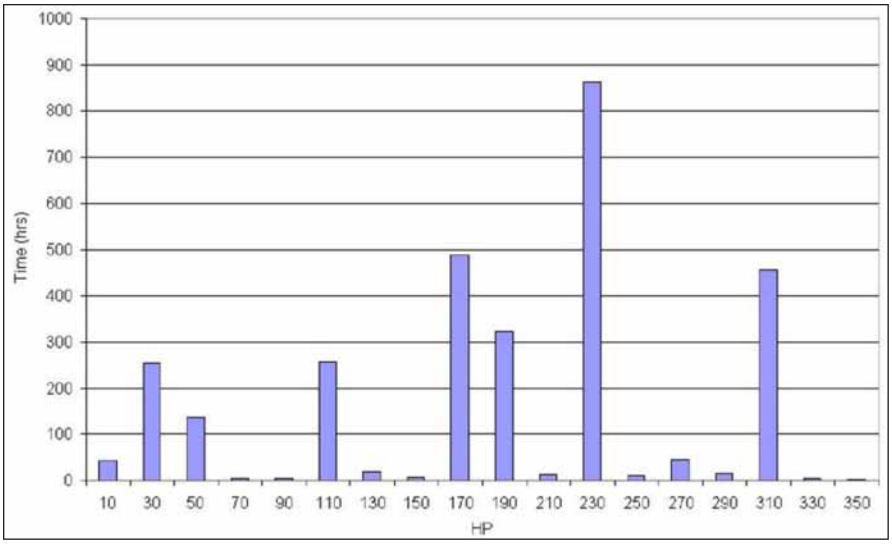

Figure 3—2,000-hour endurance test time at HP.

Table 2—Post-150-hour engine test evaluation of baseline gears

Gear	Failure mode(s) per ANSI/AGMA 1010-E95		
	Failure mode class	General failure mode	Specific mode / degree
D	Wear	Polishing	Moderate
	Contact fatigue	Macropitting	Initial
	Contact fatigue	Micropitting	Progressive
	Scuffing	Scuffing	Mild
C	Contact fatigue	Micropitting	Progressive
	Contact fatigue	Macropitting	Initial
B	Contact fatigue	Micropitting	Progressive
A	Contact fatigue	Micropitting	Progressive

Figure 4—Baseline Gear A, Mesh 1, drive side: post-150-hour test.

Figure 5—Baseline Gear B, Mesh 1: post-150-hour test.

Figure 6—Baseline Gear C, Mesh 2: post-150-hour test.

Figure 7—Baseline gear D, Mesh 2: post 150-hour test.

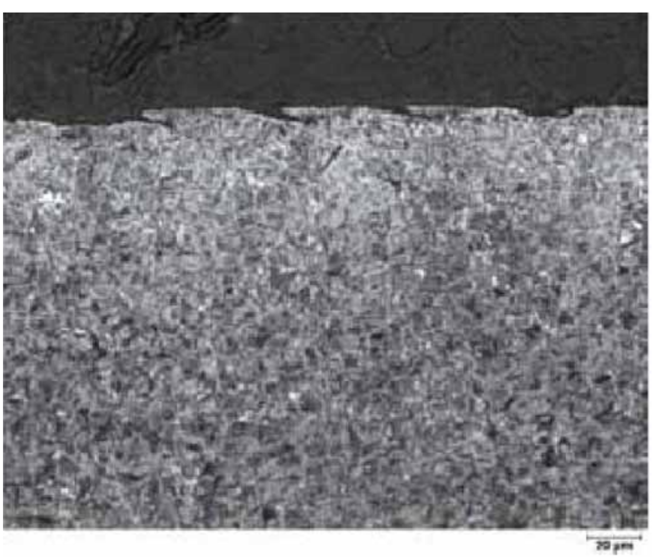

Figure 8—Sample metallurgical evaluation of Gear C, Mesh 2 displaying micropitting.

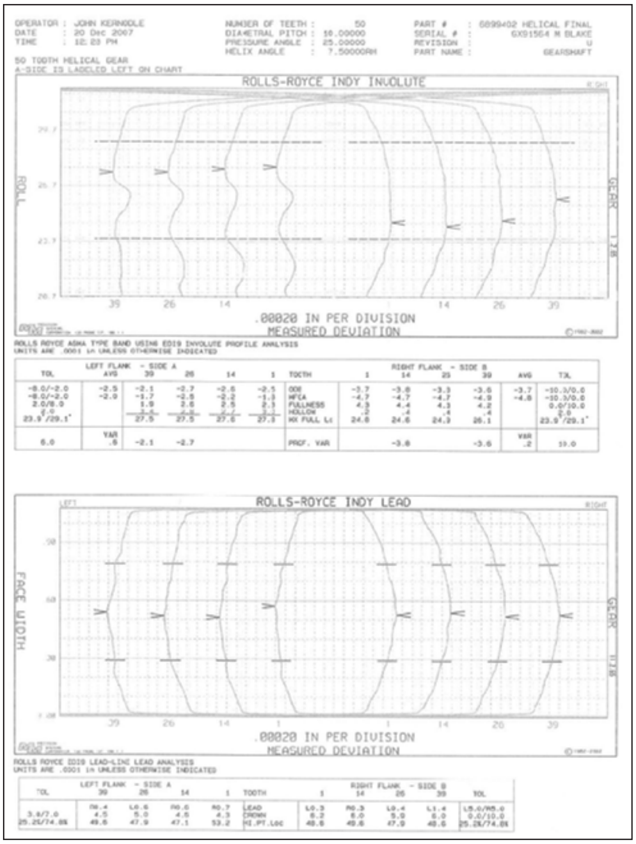

Figure 9—Baseline Gear D, Mesh 2 and analytical inspection: post-150-hour test.

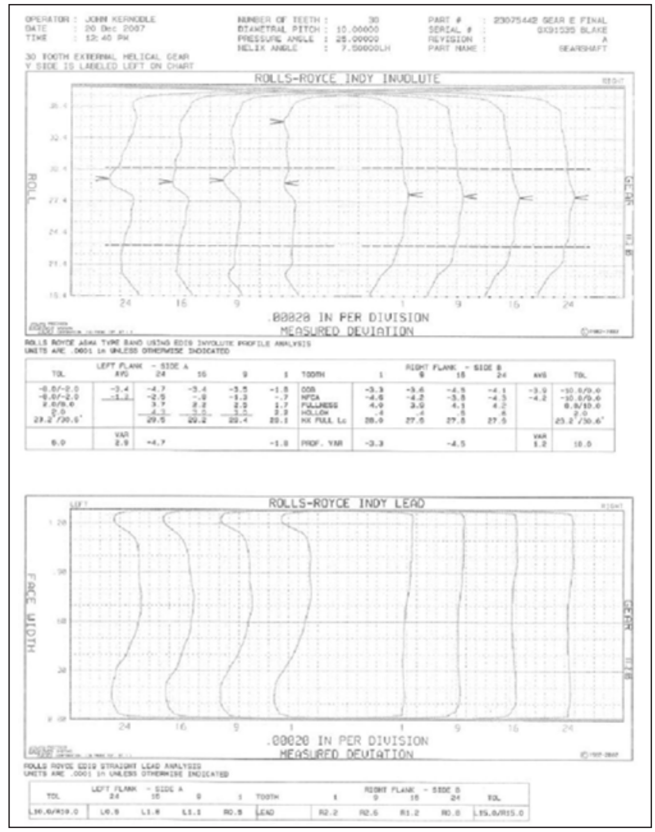

Figure 10—Baseline Gear C, Mesh 2, analytical inspection: post-150-hour test.

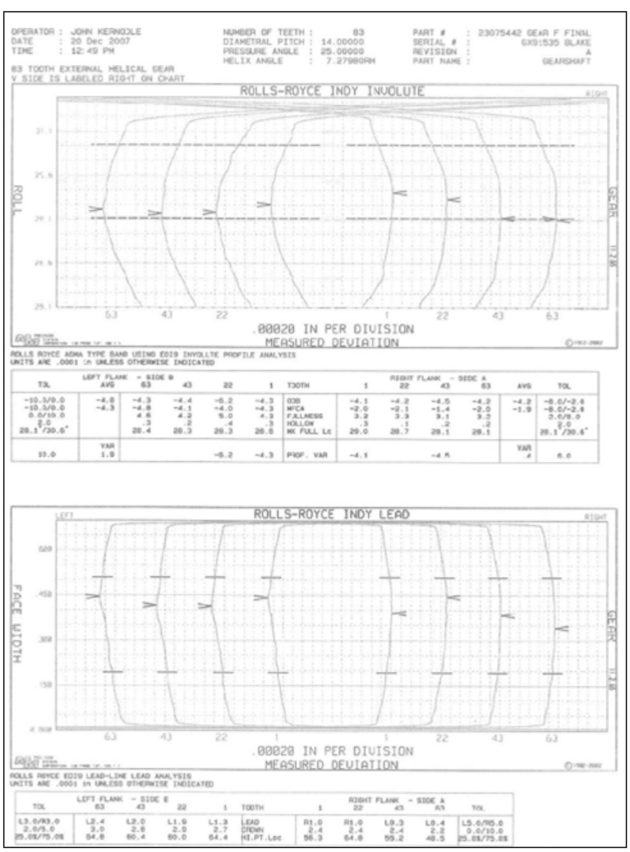

Figure 11—Baseline Gear B, Mesh 1, analytical inspection: post-150-hour test.

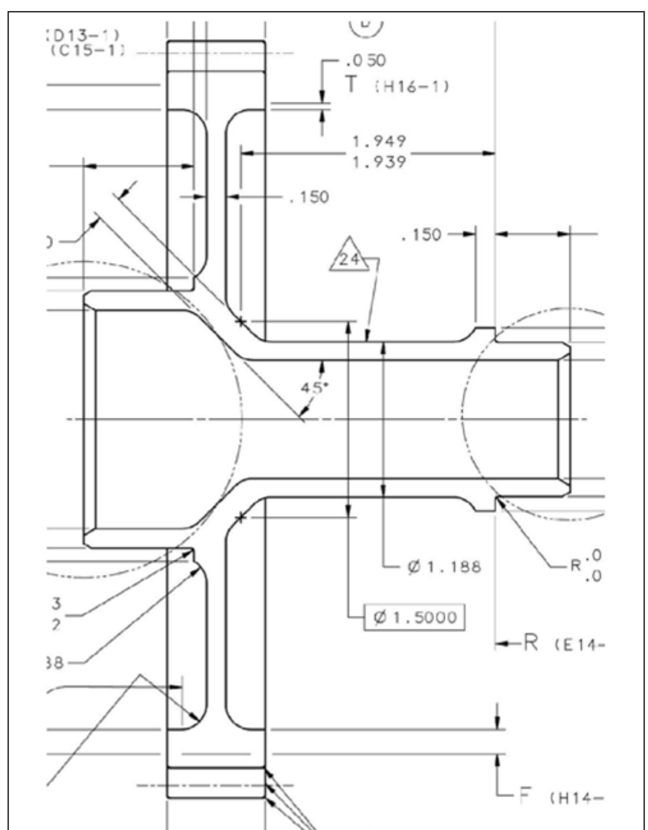

Figure 12—Honing test gear: 56-tooth, 6-DP, 25° nominal pressure angle spur gear.

Table 3—Roughness parameters of baseline gears as measured along involute; units = μin

Part name	Ra	Rp	Rt
Gear D, mesh #2	12.005	19.034	89.541
Gear C, mesh #2	+9.599	+25.026[1)]	73.388[1)]
Gear B, mesh #1	+6.611	+16.464[1)]	48.721[1)]
Gear A, mesh #1	11.222	33.209	57.504

NOTE: 1 = measurement performed post-silver-plate stripping.

Table 4—Calculated, specific oil film thickness vs. roughness for different finishing processes

Finishing process	Ra gin	X	
		Mesh #1	Mesh #2
Production honing	12	0.8434	0.4881
Threshold of honing	8	1.2882	0.7519
ISF	2	5.2601	3.1025

Table 5—Contact fatigue Margin of Safety at maximum HP

Mesh	S_c MOS
#1	1.190
#2	1.340

Table 6—Honing trial process: X = normal processing time

Step	Description
1	Select production part (post grind, pre peen)
3	Shot peen per **RR** specification
4	Inspection involute, lead, roughness, and waviness
5	Hone (1.0X) using production setup and legacy machine
6	Inspection
7	Hone (1.9X)
8	Inspection
9	Hone (4.4X)
10	Inspection

Table 7—Roughness vs. hone processing time: units = μin

Process time factor	Ra	Rv	Rt
0.0	33.4	92.5	205.4
1.0	11.6	69.8	159.3
1.9	6.8	22.5	98.2
4.4	8.5	40.2	81.6

gears processed each of these four ways is presented later in this paper.

The contact fatigue margin of safety for both gear meshes was calculated and presented in Table 5.

The specific oil film thickness of Mesh 1 is greater than Mesh 2, while the contact fatigue margin of safety is less for Mesh 1 than Mesh 2.

Honing test. Honing is a hard finishing technology for improving gear tooth surface roughness (Ref. 7). A test was conducted to determine the threshold surface roughness and the geometric interactions. An aerospace spur gear (Fig. 12) was used for the honing test. The gear material and pre-hone processing were common between the test gear and those in the endurance testing. The process time was incrementally increased. Roughness and form were measured at each interval. The test process is listed (Table 6). It should be noted that other hone variables—hone material, hone geometry, stock removal, traverse speed and rotational speed—can also influence surface roughness and form. The variable cycle time was chosen based on experience.

The post-shotpeening, pre-honing condition of the honing test gear is shown (Fig. 13). Figure 14 shows the honed surface after 4.4X—the normal production process time.

The involute form and surface roughness were measured at each

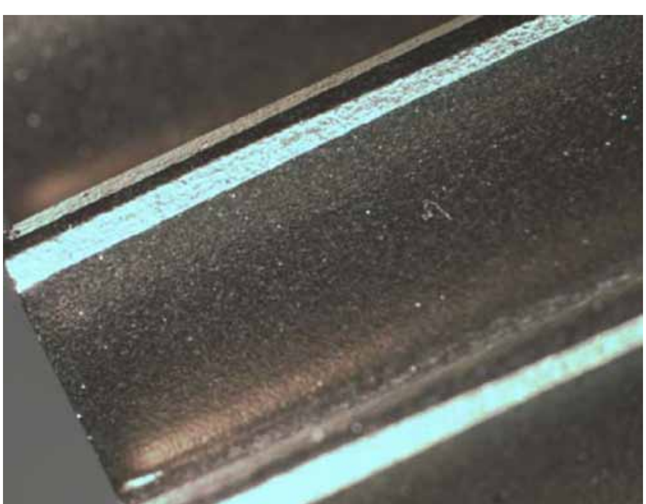

Figure 13—Starting condition: post-shotpeen, pre-hone test gear.

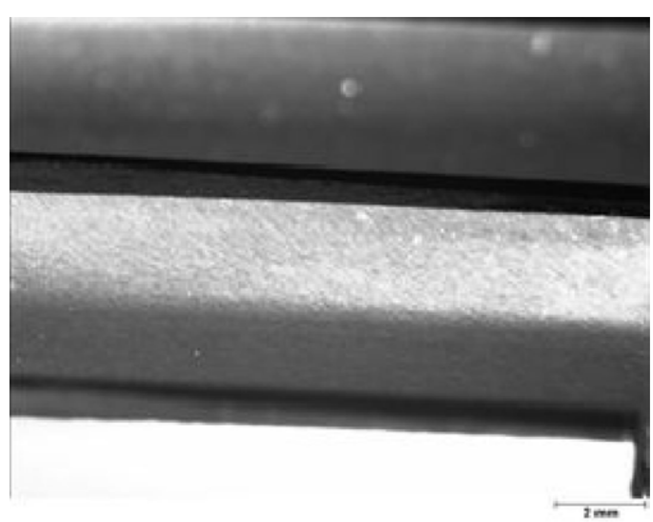

Figure 14—Post-final hone step: 4.4X normal hone process time.

interval. Figure 15 shows the change in roughness and form involute slope error as process time increased. The roughness values are listed (Table 7). The involute traces from each interval were superimposed and shown (Fig. 16). The form error can be seen as localized—near the end of active profile—vs. true slope error.

150-hour ISF test results. A second set of gears was processed using ISF. The ISF gears were incorporated into the same gearbox and tested to the same parameters as the baseline set. Table 8 shows the surface roughness of the ISF gears. Figures 17–20 are low-magnification, white-light photos of the ISF gears post test. The post-test surface distress was minimal and the gear deemed acceptable for further testing.

2,000 hour ISF test results. The same gears used in the 150-hour test were reassembled. Testing was continued at the same parameters for 2,000 hours. Figs. 21–24 are low-magnification, white-light photos of the ISF gears post-2,000 hours. The gears showed little surface distress.

ISF process development. The design requirements for the four gears were as shown in Table 9. The area that is required to be ISF-finished is the full facewidth, including the gear faces on Gears A–D.

Media selection. Media selection was originally based upon a test gear for the process approval. The gear had a much larger pitch, and the media was able to fully engage throughout the profile and root of the test gear. Minimal profile change was present with the process approval test gear. Correct media selection is critical to a successful isotropic finishing process.

Figure 25 shows Gear B and a piece of the initial media used to process the gear. As can be seen, the media is too large to contact the full depth of the tooth.

The media used is a mixture of several different sizes and shapes (Fig. 26).

Figure 27 shows the before-ISF and post-ISF involute form using the initial media.

Media selection for 2nd lot. Selection of the media for the sec-

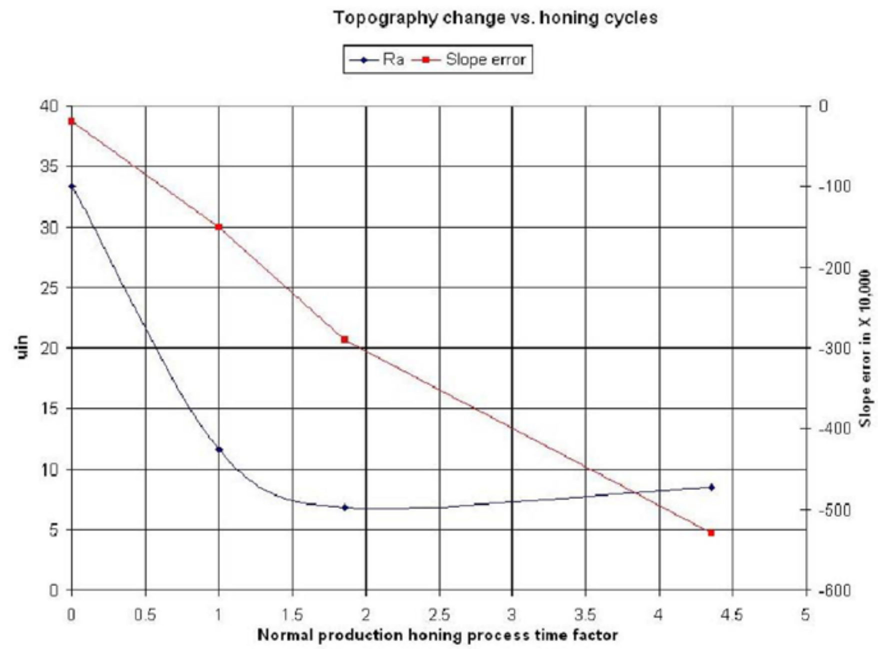

Figure 15—Honing process time vs. gear profile slope error.

Table 8—ISF test gears: roughness parameters as measured along involute, units=µin

Part name	Ra	Rp	Rt
Gear D, mesh #2	1.2	5.8	13.0
Gear C, mesh #2	1.7	6.1	16.0
Gear B, mesh #1	1.8	8.5	15.9
Gear A, mesh #1	2.2	8.3	19.2

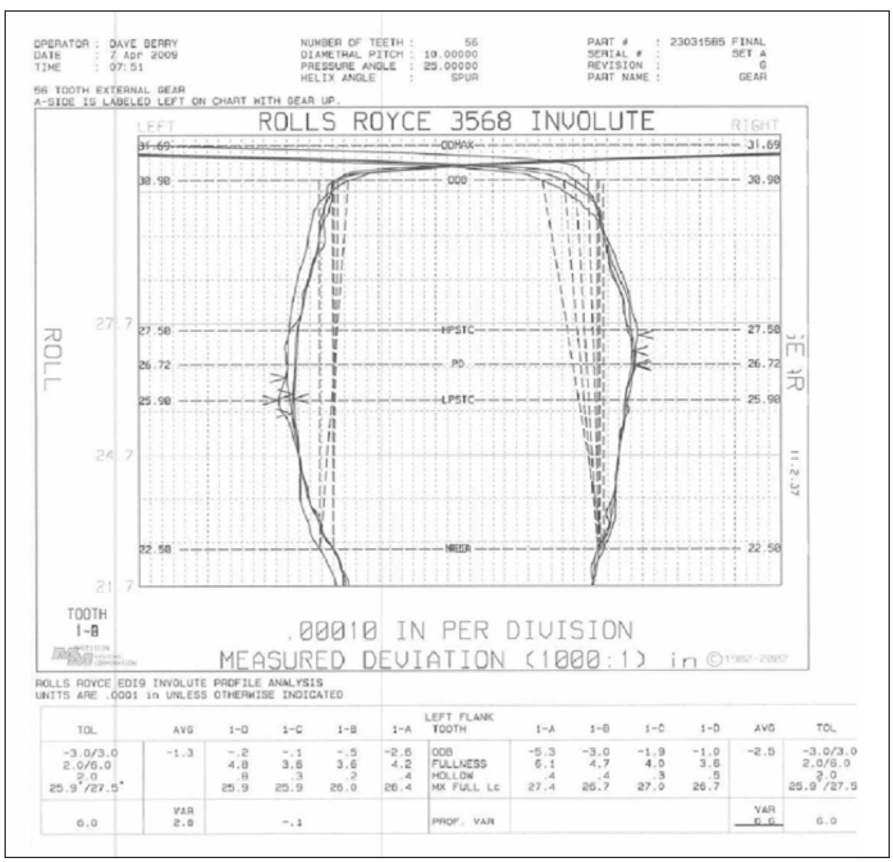

Figure 16—Hone specimen involute comparison after each hone cycle: A=4.4X; B=1.9X; C=1.0; D=0.

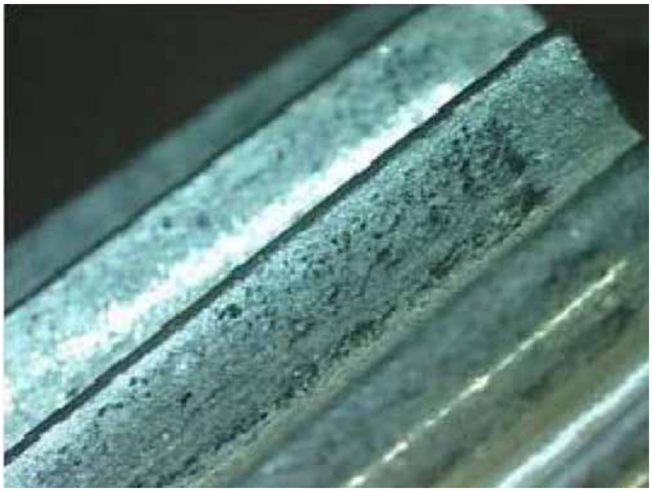

Figure 17—ISF Gear A, Mesh 1: post-150-hour test.

Figure 18—ISF Gear B, Mesh 1: post-150-hour test.

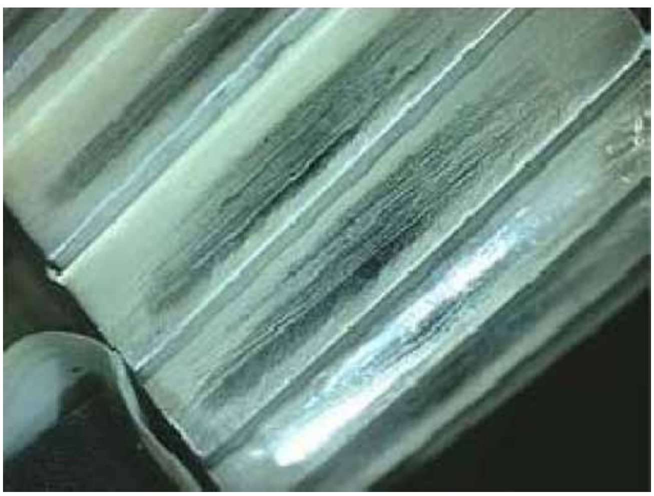

Figure 19—ISF Gear C, Mesh 2: post-150-hour test.

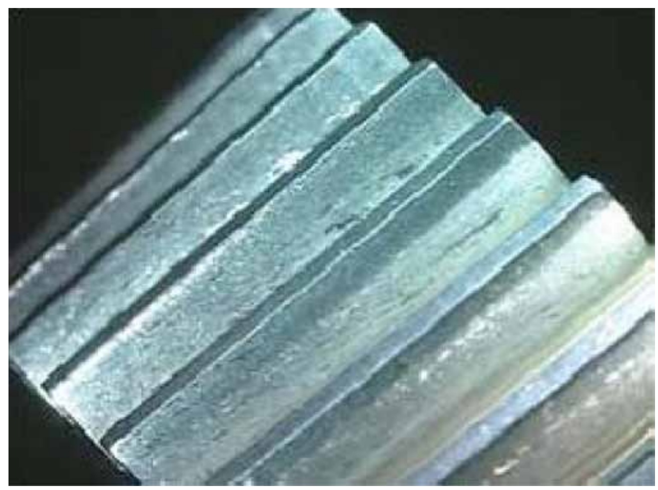

Figure 20—ISF Gear D, Mesh 2: post-150-hour test.

Figure 21—ISF Gear A, Mesh 1: post-2,000-hour test.

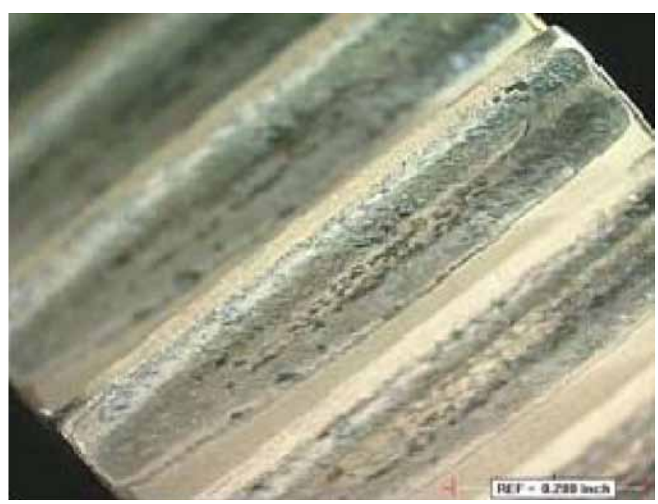

Figure 22—ISF Gear B, Mesh 1: post-2,000-hour test.

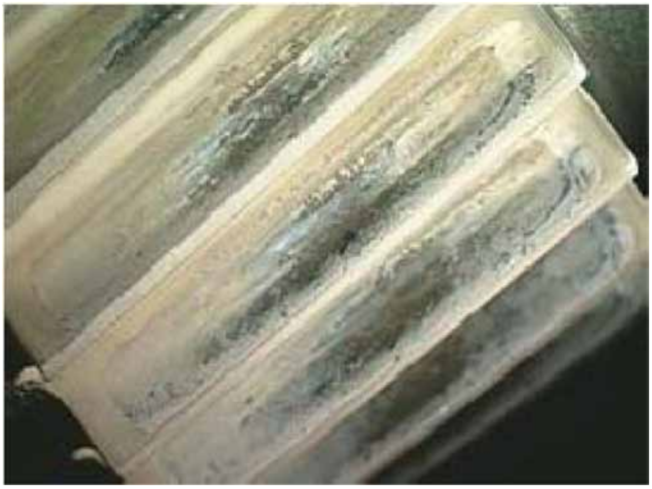

Figure 23—ISF Gear C, Mesh 2: post-2,000-hour test.

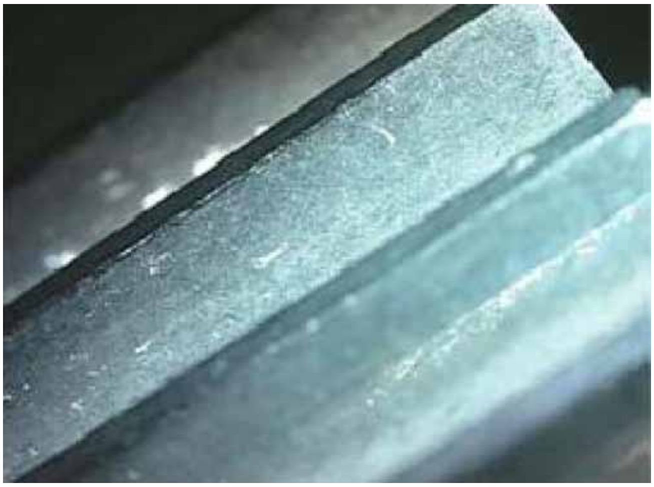

Figure 24—ISF Gear D, Mesh 2: post-2,000-hour test.

Figure 25—ISF process development shown: Gear B.

Figure 26—ISF process development: media mix.

ond lot of parts involved a new media that fit the gear tooth pitch. Figure 28 shows Gear B and the smaller media fitting into the tooth space to the root. The final media mixture used is shown (Fig. 29).

Dimensional change through ISF. The dimensional change through ISF was established during process development.

The pre- and post-measurement data of roughness and basic dimensions is shown (Tables 10–11). Figure 30 shows the pre- and post-involute form. The degradation observed in the initial trials (Fig. 27) was eliminated with the smaller media.

Table 9—Design requirements for ISF development, units = μin

Part name	Surface Ra
Gear A	4
Gear B	4
Gear C	4
Gear D	4

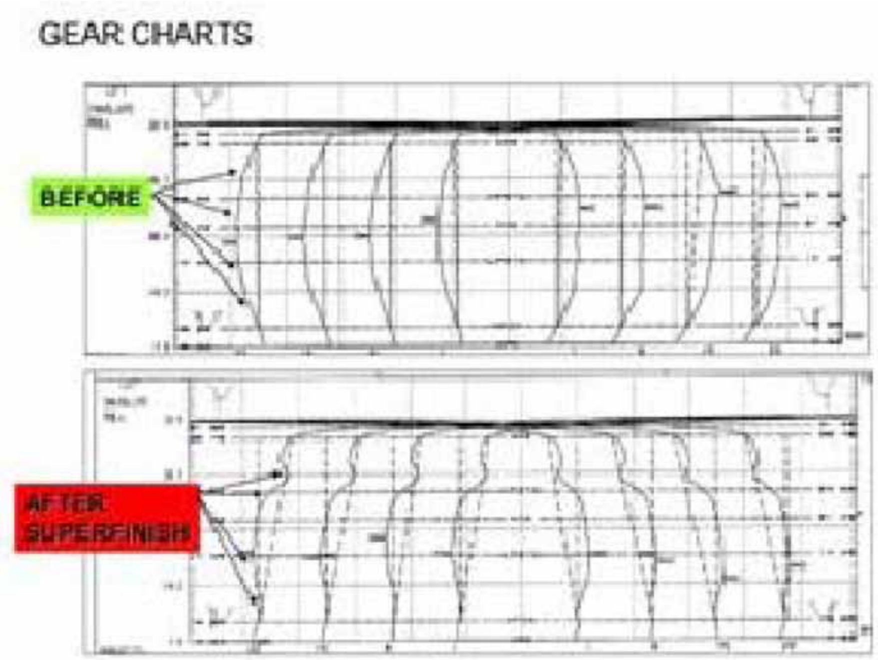

Figure 27—ISF process development: gear chart showing excessive tip stock removal.

Conclusions

- This case study demonstrated that surface durability is related to specific oil film thickness, which is related to surface roughness.
- Decreased surface roughness is one method of increasing specific oil film thickness.
- Honing and ISF are gear finishing processes that improve surface finish.
- The ISF process produced a surface with a lower roughness than honing.
- Gears processed with ISF had improved resistance to micropitting and thus longer surface durability life.

Figure 28—Gear B with smaller ISF media.

Figure 29—ISF process development: final ISF media mixture used for test gears.

Acknowledgments. The authors would like to thank the following organizations for their contributions: Rolls-Royce Helicopter Engine Program for technical oversight, funding and support of this project.

- Metal Improvement Co. and REM Chemical for super-finishing selected test gears.

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Table 10—Pre-ISF measurements

	Ra after shot peen	Root diameter	Outside diameter	Face width	DOP
Gear A	19.2	1.683	2.009	.892	2.081
Gear B	23.4	5.847	6.1753	.678	6.2635
Gear C	19.7	2.787	3.2672	1.267	3.2945
Gear D	20.2	4.751	5.199	1.057	5.2357

Table 11—Post-ISF measurements

	Ra after ISF	Root diameter	Outside diameter	Face width	DOP
Gear A	2.728	1.683	2.009	.892	2.081
Gear B	2.547	5.847	6.1753	.677	6.2633
Gear C	2.263	2.787	3.2672	1.267	3.2943
Gear D	2.826	4.751	5.199	1.057	5.2355

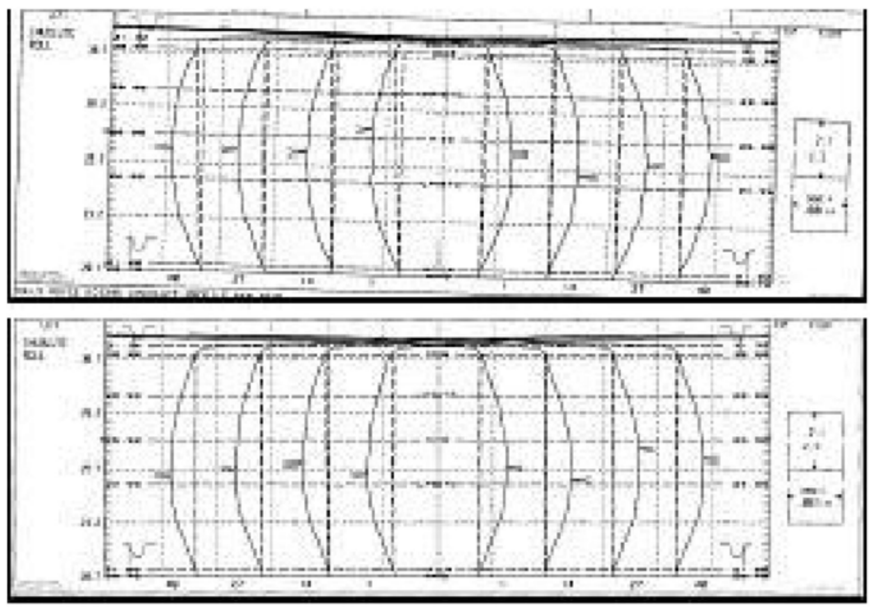

Figure 30—Pre- and post-ISF involute form traces.

Gregory Blake *is a senior specialist and mechanical engineer at Rolls Royce Corporation, where he is product definition manager of gearboxes. His primary professional experience is in the areas of gear manufacturing, design, product development and technology.*

In Memoriam

JAMES J. CERVINKA

James J. Cervinka, 92, died July 12, 2012. Cervinka was CEO of Arrow Gear Co., located in Downers Grove, Illinois. He founded the company in 1947 with Frank E. Pielsticker. He was a Navy veteran, serving in World War II. Arrow Gear began in a modest industrial building in Worth, Illinois which was without heat or plumbing. Within a few years, they built a new facility in Lyons, Illinois, and as the company continued to grow, moved to the company's final Downers Grove location in 1961. Today, Arrow Gear is among the most technologically advanced gear companies in the world, supplying precision gears to aerospace and commercial customers, employing 250.

Through the years, Cervinka was directly responsible for many innovations and new technologies introduced at Arrow Gear. In 2010, he spearheaded the move to expand Arrow's size capability for the manufacture of spur gears. The significant investment for this upgrade resulted in Arrow's ability to pursue a wider range of work–particularly in the helicopter field.

"Mr. Cervinka believed that the success of Arrow Gear was his greatest achievement. And the fact that he was able to provide good paying jobs for those in the community was always a source of pride for him. It should be noted that in the six decades since the company was started, nearly 2,000 people have been employed by Arrow Gear," stated Joe Arvin, Arrow's president.

Surviving family members include his wife Janet (Miller); sons, Michael Cervinka and John Cervinka; daughters, Mary Jo O'Brien and Lisa Mackey; stepson, Mark Karavakis; stepdaughter, Marcie Karavakis; and two grandchildren. He was preceded in death by his first wife, Patricia (Sears) Cervinka; and daughter, Jane Chester. Memorial contributions may be made to M.D. Anderson Cancer Center, P.O. Box 4486, Houston, TX 77030 or Glenwood School for Boys, 500 W. 187th St., Glenwood IL 60425. Services: Services were on July 17 at Adolf Funeral Home and Cremation Services in Willowbrook Illinois. Burial was at Bronswood Cemetery in Oak Brook, Illinois.

Klingelnberg

ACQUIRES HÖFLER

Klingelnberg GmbH, the German subsidiary of the Switzerland based Klingelnberg AG, acquired the activities of Höfler Maschinenbau GmbH from NDW Draht und Stahl GmbH, a member of the NDW Group. The relevant contracts were signed on July 11, 2012. Höfler Maschinenbau GmbH is a well established manufacturer of gear grinding machines and gear hobbing machines. The machines are employed in the production of high-precision gears for use in the industry sectors of transport, shipping, mining, machine tools and renewable energies, e.g. wind turbines. The company generated revenues of EUR 83 million in 2011 with approximately 300 employees. The Klingelnberg Group is a world leader in the development, manufacture and sale of machines for the production of spiral bevel gears, measuring centers for axially symmetrical objects of all types, and the production of high-precision gear components made to customer orders. The Group recorded revenues of approximately EUR 200 m in 2011 with approximately 1,000 employees, and is renowned for product and service quality, absolute reliability and strict adherence to deadlines. The company demonstrates its capacity for innovation with some 230 R&D engineers around the globe, and made 90 successful patent applications over the last five years. "Höfler Maschinenbau's technology is an excellent completion of the Klingelnberg Group's existing product range of cutting and grinding machines, both in terms of application areas and the industries served" says Jan Klingelnberg, CEO of the Klingelnberg Group. "The installed base of over 1.550 machines worldwide is clear evidence of a well established clientele. The addition of Höfler Maschinenbau allows the Klingelnberg Group to advance significantly in reaching its strategic goal of being able to provide all gear technologies."The shareholders of the NDW-Group added: "We are pleased to pass Höfler Maschinenbau to a very competent strategic owner, who will secure the long term development of operations at its current location in Ettlingen. The disposal allows us to focus more closely on our core business."The transaction was executed by way of an asset deal and includes the subsidiaries in the USA and in China.

Codina

NAMED SANDVIK MARKETING AND COMMUNICATIONS MANAGER

Sandvik Coromant is pleased to announce the appointment of Ester Codina as the company's new marketing and communications manager, market area Americas. Prior to her appointment, Codina spent nine years within Sandvik Group, most recently as marketing and communications manager.

In her new role, Codina is tasked with developing a comprehensive strategic communications plan that will drive activities to help the market area achieve its goals for sales and growth. She will be responsible for developing a strong communications network that will leverage the talent and resources in each of the Americas markets.

"As a company, we have to make sure we continue to develop our business in a successful way and to have aggressive growth targets that we can support with an active marketing and communications plan," says Codina. "I'm looking forward to starting my journey with Sandvik Coromant, supporting the brand and moving it forward."

Codina earned a bachelor's degree in business administration from the University of Barcelona in Spain and a master's in marketing from the University of Pompeu Fabra in Spain. She began her career with Sandvik in 2003 and worked as product manager for Solvay Group.

Palumbo

NAMED MECHANICAL ENGINEERING MANAGER

Drake Manufacturing Services Co., a Warren, Ohio, precision machine tool builder, has recently promoted Jill Palumbo to mechanical engineering manager. Palumbo earned a BS in Chemical Engineering at Youngstown State University, and joined Drake in 1997 as a systems engineer. In this position she assisted in electrical systems design, CNC programming, machine runoffs, and customer training. In 2000, she was promoted to project engineer, managing machine assemblies from start to finish, and was involved with machine design, sourcing of materials, and customer machine runoffs. In her present position, Palumbo supervises the design of mechanical and electro-mechanical systems on Drake machines, and manages design and project engineering teams in the mechanical engineering department. Drake President Jim Vosmik affirms, "Jill's thread grinding process expertise, knowledge of our customers' production requirements, and her intellectual curiosity are real assets in this key position."

Dixon

JOINS KAPP TECHNOLOGIES

Kapp Technologies of Boulder, Colorado recently welcomed Eric Dixon to its applications engineering department. Dixon graduated from the University of Illinois at Urbana-Champaign in 2007 with a bachelor of science degree in mechanical engineering. After graduation he worked at Bison Gear and Engineering in St. Charles, Illinois as both product engineer and project engineer. While his primary work there was specifying and supporting fractional horsepower gear motor applications, he guided the procurement of a high precision bevel gear grinding machine as well. He also managed several projects geared towards the development of a new line of motor enclosures and gearboxes that would utilize bevel gear technology. Dixon is a certified Six Sigma Green Belt and earned the PMI Project Management Professional certification this year. He was born and raised in Woodridge, Illinois outside of Chicago. He currently lives in Denver with his fiancée, Stacy. In his spare time he enjoys snowboarding, hiking and playing golf.

McClain

JOINS SCHAFER GEAR WORKS

Matthew McClain has joined Schafer Gear Works, Inc., as corporate controller in the company's South Bend office. McClain will be taking over for Greg Parnin, who retired in June. Prior to joining Schafer Gear, McClain held various financial and business positions including controller at Affinia Group, Krizman International in Mishawaka, Indiana, and manager of IT controlling at Robert Bosch, LLC. McClain most recently was sourcing manager/global indirect procurement IT manager for Whirlpool Corporation in Benton Harbor, Michigan. McClain has a B.S. in accounting from the Indiana Institute of Technology.

Polygon Solutions

JOINS SRMA

Polygon Solutions Inc. is joining the Southwest Regional Manufacturers Association (SRMA). One purpose of the SRMA is to bring manufacturers together to encourage the economic development of Southwest Florida through manufacturing. Polygon's growth in rotary broaching technology prompted the move. Polygon Solutions Inc. is a small Fort Myers, Florida manufacturer of industrial cutting tools. Polygon's core business is focused on rotary broaching tools, which are used to make hexagon, square and other shaped holes in precision metal parts. Typical parts made using rotary broaching include bone screws, custom fasteners and small shafts with serrated or spline ends.

This year, Polygon was the recipient of the prestigious Manufacturing Leadership 100 Award for Innovative Enterprise. The Manufacturing Leadership 100 Awards, now in their eighth year, honor manufacturing companies and individual manufacturing leaders that are shaping the future of global manufacturing. Polygon hopes to join other manufacturing leaders such as Arthrex and Structure Medical who are shaping the future of Southwest Florida.

"SRMA is pleased to accept Polygon Solutions, Inc. to our membership. They join an esteemed and inspired group of large and small manufacturers all interested in a better educated manufacturing-ready workforce, lobbying for more manufacturing support at the local, state and national levels and overall advocacy for manufacturers," says Betsy Allen, executive director, SRMA.

"SRMA is committed to helping manufacturers of all sizes realize value through the association with tangible returns of time saved, money saved and networking with like-minded individuals." Matt Chambers, president, SRMA.

NEWS

Sunnen

RECEIVES GLOBAL PIONEER AWARD

Pictured (L-R) Tom Dustman, director, international sales; Mike Haughey, chief operating officer; and Matthew Sunnen Kreider, president

Sunnen Products Company has received the 2012 Global Pioneer Award from the St. Louis Regional International Partnership (SLRIP). The award is given annually to a St. Louis-based company that demonstrates an exemplary understanding of, and commitment to, innovation for global expansion. Matthew Sunnen Kreider, president of Sunnen Products, accepted the award at the 4th annual International Trade Night, held May 16 at Washington University's Knight Executive Education and Conference Center.

Sunnen has exported its honing machines, tooling, abrasives and fluids since the 1930s, and is the world's largest fully integrated honing company. The company exported 42 percent of its sales in 2011. Sunnen locations abroad include facilities in Belgium, China, the Czech Republic, France, Italy, Poland, Russia, Switzerland and the United Kingdom. The company also has a network of more than 50 factory-authorized distributors to support customers worldwide. Sunnen was recognized for its success as an international leader of advanced honing technology, as well as its expert technicians, training, services and support.

Byers

NAMED PRESIDENT OF STLE

Jerry Byers, manager of research and development for Cimcool Fluid Technology, is the new president of the Society of Tribologists and Lubrication Engineers (STLE). His term will span 2012–2013. Byers joined STLE in1977 and has been active with the society at both the national and local levels. He served as a member of the Metalworking Fluids Education and Training Subcommittee, was an associate editor for STLE's peer-reviewed journal *Tribology Transactions*, and held several offices with the Cincinnati Section, including treasurer and chairman. He is currently chair of the society's Sections Affairs Committee. Byers was appointed to the STLE board of directors in 2003, and joined the society's Executive Committee three years ago, serving as treasurer, secretary, vice president and now president. This summer, Byers will celebrate 40 years with Cimcool Fluid Technology.

Metal Powder Society

NAMES FELLOWS

APMI International, professional society for the powder metallurgy (PM) industry, has named Ian Donaldson and Al Dornish to the 2012 Class of Fellows. They received the award during PowderMet2012.

Donaldson has distinguished himself as an expert in materials with a strong engineering background. With more than 30 years of PM experience, he has established an international reputation in the field of powder metallurgy. As director, research and development North America and materials engineering, GKN Sinter Metals LLC, he has utilized his BS, metallurgical engineering, from the University of Michigan, and MS, material science and engineering, from Worcester Polytechnic Institute, in a collaboration with academia, customers,

Ian Donaldson

and colleagues that has had significant impact on the PM industry. He has been involved in research, process and product development, design, manufacturing and production, education/teaching, and many other technical advancements programs. A member of APMI International for 25 years and a current member of the APMI board of directors, Donaldson is a judge for the annual APMI metallography competition. He has participated on many technical program committees for MPIF conferences, and is a co-chairman for PowderMet2012. He was a co-author recipient of the 2010 Howard I. Sanderow Outstanding Technical Paper Award. He received the MPIF Distinguished Service to Powder Metallurgy Award in 2011.


Al Dornish

Dornish has often been referred to as a renaissance man. Having spent nearly 55 years in the PM industry, he has touched upon nearly every facet of PM: manufacturing, engineering, tool design, plant start-ups, sales and marketing, and, most important, education, to which he is consummately dedicated. A member of APMI International for more than 30 years, he has parlayed his manufacturing and engineering knowledge into his teaching accomplishments. His quest for mechanical engineering knowledge began at Penn State University, after which he indulged his interest in journalism during studies at Gannon University. Following stints with Powder Metal Products and Honeywell, in 1968 he developed a formal PM education program at Hennepin Technical College, Minnesota, and served as an instructor and the program's director until 1985. Dornish remains active in the PM arena as a consultant with Northern Precision Materials. He conducts formal PM training classes through the Community Education facility in St. Marys, Pennsylvania, and has participated in many workshops and seminars. His credits include a patent for bronze-lined bearings and the MPIF Distinguished Service to Powder Metallurgy Award, which he received in 2001. For more information, visit *www.mpif.org.*

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September 10–15—IMTS 2012. McCormick Place, Chicago. The 29th edition of the manufacturing technology show boasts more than 1,100 exhibiting companies that will occupy 1.1 million net square feet of exhibit space. The show attracts 82,000 buyers and sellers from more than 116 countries. Leading manufacturers will display their equipment in pavilions including Metal Cutting, Tooling and Workholding Systems, Metal Forming and Fabricating/Laser Processes, Gear Generation, Industrial Automation and many more. The IMTS 2012 Conference brings the industry together, under one roof and at one time, to discuss technologies, business development and optimization, plus workforce efficiency and productivity. Special emphasis will be placed on maintaining focus on short- and long-term goals during a tough economic environment. For more information, visit *www.imts.com*.

September 11–13—International Conference on Manufacturing Research 2012. Aston University. For over two decades it has been the main manufacturing research conference organized in the U.K., successfully bringing researchers, academics and industrialists together to share their knowledge and experiences. Initiated as a National Conference by the Consortium of U.K. University Manufacturing Engineering (COMEH) it became an International Conference in 2003. COMEH is an independent body established in 1978. Its main aim is to promote manufacturing engineering education, training and research. Keynote speakers for the event include Hamid Mughal, executive vice president, manufacturing, Rolls-Royce Plc.; professor Sir Mike Gregory, Institute for Manufacturing, Cambridge University; John Ladbrook, European simulation specialist, Ford Motor Company and Professor Jay Lee, director of the Center for Intelligent Maintenance Systems, University of Cincinnati. For more information, visit *www1.aston.ac.uk/icmr2012*.

September 18–19—Human Error Prevention Seminar. Fogelman Executive Conference Center, Memphis, Tennessee. The principles and practices of human error prevention are universally applicable regardless of the type of industrial, commercial or governmental enterprise, and regardless of the type of function performed within the enterprise. This seminar is truly unique and up to date with the latest developments in human error prevention. Ben Marguglio's new taxonomy of human error causal factors and his human error-related models demonstrate his leadership in this subject. Examples and case studies amply reinforce the human error prevention principles and practices. This seminar covers: classifications of human error; quality and safety culture and the quality- and safety-conscious work environment; leadership responsibilities; the total quality and safety function and much more. For more information, contact Ben Marguglio at (845) 265-0123 or e-mail *ben@hightechnologyseminars.com*.

September 20–21—Root Cause Analysis Seminar. Fogelman Executive Conference Center, Memphis, Tennessee. This seminar covers all of the elements of a problem/condition reporting, root cause analysis and corrective action system with emphasis on the following root cause analysis techniques: failure mode and effects analysis for hardware problems and hazard-barrier-effects analysis for management and technical process problems. This seminar will also cover a modified hazard-barrier-effects analysis technique that allows the root cause analysis resource expenditure to be proportional to the significance of the problem, while still enabling the analyst to identify human performance root causes. Persons who are responsible for identifying and reporting off-normal conditions, evaluating the conditions and their effects, identifying causal factors, recommending various types of corrective actions, tracking the implementation of corrective actions, and managing the overall system should consider attending this seminar. For more information, contact Ben Marguglio at (845) 265-0123 or e-mail *ben@hightechnologyseminars.com*.

October 15–19—AME Chicago 2012. Sheraton Chicago Hotel and Towers. The Association for Manufacturing Excellence (AME) has a long track record for finding and convincing some of the best manufacturing practitioners from around the world to share their lean practice experiences. More than 60 leading presenters will be on hand to discuss customer focus, process sustainment, continuous improvement, material flow and other lean practices and strategies. Manufacturing tours highlighting some of the best lean and six sigma operations in and around the Chicago area include Caterpillar, Bimba Manufacturing, Whiting Corporation, S&C Electric Company and Winzeler Gear. Workshop topics include maintenance management, lean behaviors, training within industry, lean business simulation and lean tools for the office. Six keynote speakers will be featured at the conference including Mike Abrashoff and Jason Jennings. For registration information, visit *www.ameconference.org*.

October 28–30—AGMA Fall Technical Meeting. Hyatt Regency Dearborn, Dearborn, Michigan. The FTM highlights the latest research in the industry from experts all over the world on topics including micropitting, gearbox design, materials and manufacturing. The conference is designed for attendees to listen to all the presentations and take home practical information that may ultimately affect your company's bottom line. In addition, the meeting is designed to provide invaluable networking time between sessions and in the evenings to interact with colleagues and meet new experts in the industry. Programs include lubrication and components, gear drive applications, manufacturing and inspection, gear design issues and materials and heat treatment. For more information, visit *www.agma.org*.

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6) What is your primary job function responsibility? (Check one)

- ❑ Corporate Executives (B)
- ❑ Manufacturing Production Management (C)
- ❑ Manufacturing Production Department (D)
- ❑ Manufacturing Engineering Management (E)
- ❑ Manufacturing Engineering Department (F)
- ❑ Product Design, R&D Management (H)
- ❑ Product Design/ R&D Personnel (I)
- ❑ Purchasing (L)
- ❑ Marketing & Sales, Communications (M)
- ❑ Quality Control Management (P)
- ❑ Quality Control Department (Q)
- ❑ Other (N) ____________________

7) How is THIS LOCATION involved in the gear industry?
(Check all that apply)

- ☐ WE MAKE GEARS (or Splines, Sprockets, Worms, etc.) (20)
- ☐ WE BUY GEARS (or Splines, Sprockets, Worms, etc.) (22)
- ☐ WE SELL NEW MACHINES, TOOLING OR SUPPLIES TO GEAR MANUFACTURERS (24)
- ☐ WE provide SERVICES to gear manufacturers (25)
(please describe) ____________________
- ☐ WE distribute gears or gear products (including agents and sales reps. (26)
- ☐ WE are a USED MACHINE TOOL dealer (30)
- ☐ Other (please describe) ____________________ (32)

8) Which of the following products and services do you personally specify, recommend or purchase? (Check all that apply)

Machine Tools

- ☐ Gear Hobbing Machines (50)
- ☐ Gear Shaping Machines (51)
- ☐ Gear Shaving Machines (52)
- ☐ Gear Honing Machines (53)
- ☐ Gear Grinding Machines (54)
- ☐ Gear Inspection Equipment (55)
- ☐ Bevel Gear Machines (56)
- ☐ Gear/Spline Roll-Forming Equipment (57)
- ☐ Broaching Machines (58)
- ☐ Heat Treat Equipment (59)
- ☐ Deburring Equipment (60)
- ☐ Non-Gear Machine Tools Turning, Milling, etc.) (61)

Tooling & Supplies

- ☐ Functional Gages (62)
- ☐ Workholding (63)
- ☐ Toolholding (64)
- ☐ Cutting Tools (65)
- ☐ Grinding Wheels (66)
- ☐ Gear Blanks (67)
- ☐ Lubricants/Cutting Fluids (77)

Service & Software

- ☐ Heat Treat Services (69)
- ☐ Gear Consulting (70)
- ☐ Tool Coating (71)
- ☐ Tool Sharpening (72)
- ☐ Gear Design Software (73)
- ☐ Gear Manufacturing Software (74)

Power Transmission Components

- ☐ Gears (75)
- ☐ Gear Drives (76)
- ☐ Bearings (78)
- ☐ Motors (79)

9) What is the principal product manufactured or service performed at **THIS LOCATION?**

____

10) How many employees are at THIS LOCATION (Check one)
☐ 1-19 ☐ 20-49 ☐ 50-99 ☐ 100-499 ☐ 500+

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Technology Mash-Up

The Mind Melds with Gears for Cycle Project

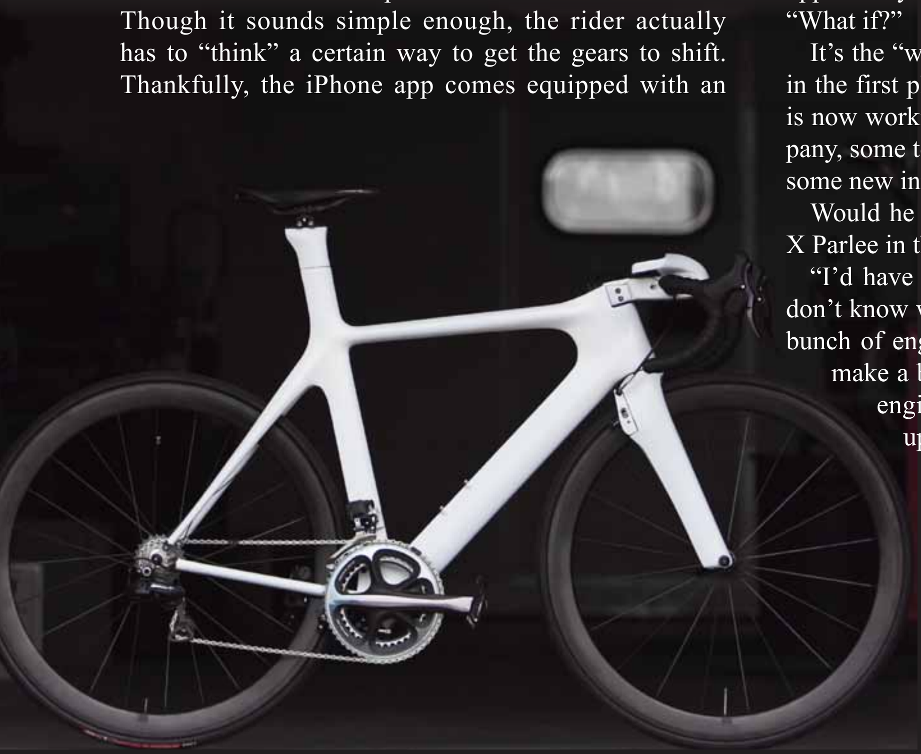
Engineers love engineering. They love mashing together a variety of tools, instruments and technologies to take a project in an entirely new direction. This was certainly the case when Patrick Miller, senior creative engineer at DeepLocal (Pittsburg, Pennsylvania) worked with Parlee Cycles (Boston, Massachusetts) Saatchi & Saatchi (New York, New York) and Toyota on what can only be described as a prototype bike for the science fiction/techno geek crowd.

The project began with a fairly straightforward question.

"What if we had a Prius-inspired bicycle that offered some of the crazy hybrid technology of the car?" Miller said. "From there we started discussing different ideas such as shifting experimentation; what if we did a brain-shifting bike?"

The Prius X Parlee offers a series of technological advances including a mounted iPhone that monitors the rider's heart rate, speed and cadence. But it's most incredible feature is a neuroheadset that essentially allows the cyclist to shift gears up and down by transmitting brainwaves to the bike.

According to Miller, the headset detects certain signals and sends these signals to a computer that translates them into "shift up and shift down" commands. Though it sounds simple enough, the rider actually has to "think" a certain way to get the gears to shift. Thankfully, the iPhone app comes equipped with an override mechanism that allows you to change gears manually if your mind doesn't cooperate.



"We took several technologies that were already out on the market and combined them with some of the bike innovations created at Parlee Cycles." Miller adds.

The Prius X Parlee was demonstrated earlier this year at the 2012 SouthbySouthwest show in Austin, Texas. It was up to Miller himself, a University of Pittsburgh grad, to demonstrate its various features in front of a large group of attendees and reporters.

"I was pretty nervous about the initial presentation," Miller says. "I wasn't sure if I was going to be able to focus on the gear shifting, so I turned the bike around and faced the other direction so no one was looking at me. Fortunately, it worked and it's been getting a lot of attention ever since."

Today, the Prius X Parlee is touring the globe with some other Toyota products. These demonstrations give people the opportunity to ask the simplest engineering question there is, "What if?"

It's the "what ifs" that got Miller excited about the project in the first place—a project that started back in 2011. Miller is now working on a packaging project for a soft drink company, some technological wizardry for a laptop computer and some new innovations for a shoe company.

Would he be opposed to taking another crack at the Prius X Parlee in the future?

"I'd have to dig out the original helmet," Miller says. "I don't know where it is anymore. This was really just about a bunch of engineers sitting around discussing how we could make a bike more interesting. I think the best part about engineering is taking a technology and improving upon it."

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