May 2008

# GEAR TECHNOLOGY

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The Journal of Gear Manufacturing

# The Global Gear Industry

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- Communication Breakdown

## Technical Articles

- Pitting Load Capacity of Helical Gears
- Net-Shaped, Cold-Formed Gears
- Calibration of Two-Flank Roll Testers
- Update on the National Metrology Lab

THE GEAR INDUSTRY'S INFORMATION SOURCE

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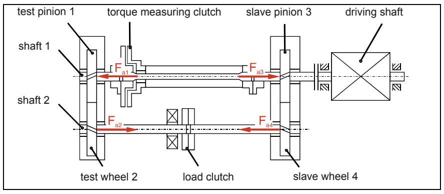


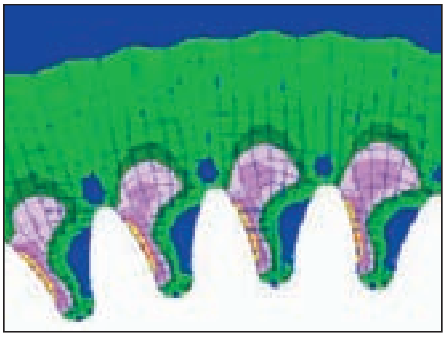



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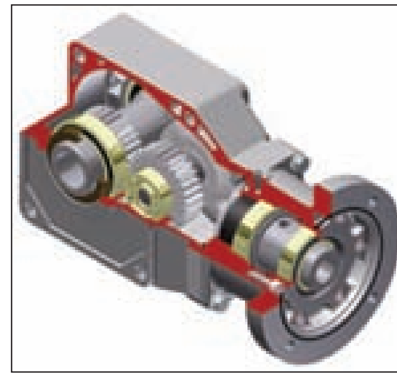

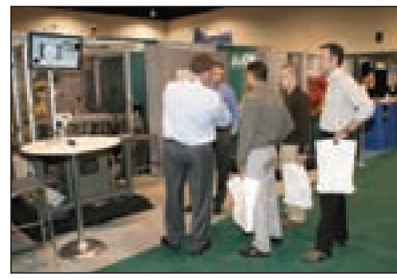

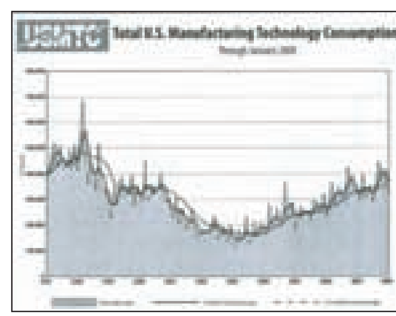


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BPA WORLDWIDE

# JUST A BAD DREAM?

There's a monster under the bed of the nation's economy. It has the same power over many adults as a child's nightmare. But lately, in discussions about the economy, some people have begun talking about the monster. They've been mentioning the 'R' word.

Whether the U.S. economy is in a recession—or whether it's heading there—is a matter for debate. But a wide variety of factors—from the uncertainty of a presidential election year to the subprime mortgage crisis, from soaring oil prices to the housing bubble, are causing high levels of unease about the economic future.

According to the University of Michigan's Consumer Sentiment Index, consumer confidence is at its lowest point since 1982—a time when the country was in the heart of a deep and long recession. Similarly, the Conference Board's Consumer Expectations Index is at its lowest point since 1973, when the United States was dealing with the oil embargo and Watergate. It's not yet clear how today's situation will compare with the economic troubles of the 70s or 80s.

**What is very clear is that people are worried.**

Some would say that the manufacturing sector is already in a recession. One popular measure, the Purchasing Managers Index (PMI), has now shown two consecutive months of contraction with the index falling below 50 February and March. A PMI below 50 indicates contraction in the manufacturing economy. Two consecutive months of contraction is the standard definition of a recession. According to the PMI, at least, we're already there.

But there's no need to hide under the covers. I'm not here to spread gloom and doom. In fact, my outlook—at least for the gear industry—is still fairly optimistic.

One reason is that many of the industries that use gears are not affected by the credit and consumer-driven woes that have everyone else on edge. Strong growth is still expected in the mining, aerospace and oilfield industries. There will be major investments in big-project infrastructure all over the world in the coming years, including power plants, maybe even nuclear, that will require a lot of gears. China is opening a new power plant every week. And of course, with wind farms popping up all around the world, the demand for wind turbine gears should remain strong for many years.

This is all happening at a time when there seems to be, at least outside the automotive industry, a shortage of gear manufacturing capacity—not just in the United States, but in many other parts of the world, too. It's also a time when there are two huge factories being built on the planet Earth. Their names are India and China, and these markets need increasing numbers of gears just to satisfy their own requirements.

Another reason I'm optimistic is that the weak U.S. dollar makes American gears much more attractive to foreign buyers. Many U.S. gear manufacturers are expanding their overseas sales. Others are selling more gears to manufacturers of construction equipment, whose products are needed by the continued industrialization of other parts of the world, especially China.

Recently, I attended the AGMA annual meeting in Las Vegas, where I had the chance to hear economist Dr. Mike Bradley speak about the gear manufacturing economy. His presentation also gave me reason for optimism. Dr. Bradley's projections indicate that orders for gears and gear products may already have bottomed out. Although there is still modest growth in gear and gear products shipments, these naturally lag orders. At the time of Dr. Bradley's presentation, it was unclear whether gear shipments would dip into negative growth, but in any case, he suggested that if there is a gear manufacturing recession, it should be shallow and short-lived.

There are, of course, some areas for concern, especially if you manufacture gears for sectors of the economy that are being affected.

One gear manufacturer who visited our office in April told us that about 80 percent of his business comes from the automotive industry. He classified these as "trying times" because of that dependence. However, because his company focuses on selling technology and solutions, he also rattled off half a dozen new business opportunities he had either recently sold or was currently working on. Even in trying times, there appear to be plenty of opportunities, at least for those who have continually invested in the latest technology.

If you're one of those gear manufacturers who is well positioned to weather the current economic storm, now might be a good time to invest in more technology of your own. The recently signed Economic Stimulus Act of 2008 provides tax relief in the form of 50 percent bonus depreciation for new capital expenditures (like machine tools) placed into service in 2008 as well as increases in the amounts small businesses can write off as expenses for new and used equipment purchases in 2008.

Overall, I expect the mitigating factors—most particularly the strength of certain gear-consuming industries and the weakness of the dollar—to keep the gear manufacturing industry out of trouble. Those who have continually invested in modern equipment and technology should be poised for years of continued growth. There's strength in the gear manufacturing industry that should keep the monster at bay.

Michael Goldstein,
Publisher & Editor-in-Chief

# The Global Gear Industry – What Does the Future Hold?

Younsu Park, Global Business Director, Romax Technology

Understanding the differences of how the gear industry works in individual territories around the world is vital to any company that wishes to succeed on a global basis. Whether it's simply recognizing cultural differences in the workplace or understanding the challenges each country is faced with—it is all essential to working on a global scale.

***Different worlds, same challenge***. At Romax, we spend time looking at the weaknesses and strengths of the gear industry within a region and understanding the challenges we face in each. Knowing the marketplace enables us to see the best opportunities for our software and consulting services, but it also gives us an indication of the state of the industry and where it's heading.

In the United States, the gear industry often looks for software tools and consulting services to support, and sometimes even replace, the experience of engineers. Developing sufficient knowledge with an understanding of design and manufacturing can typically take an engineer some 10 to 15 years. By this stage, engineers have often moved into management positions or they have retired, taking this knowledge with them.

Europe is similar with the exception of Germany, which is the market leader, where engineers tend to be specialized and take on more responsibility. While Europe and the United States are open to buying into expertise and technology, Germany has an industry supported by government and academia, and often solutions are found through government-funded universities to work on specific issues.

Europe and the United States have traditionally focused on the established automotive industry and, as such, have a strong network of expertise to draw upon while the gear industries in China and Korea are developing their own techniques.

Korean manufacturers reach the production stages very quickly by acquiring the knowledge they need, whether they buy it or benchmark it. They go into production in a third of the usual time, which is one of their biggest strengths. Korea began with manufacturing electronic products and is now moving into the mechanical engineering sectors, in particular automotive and wind turbines. While China's gear industry is similar to Korea's, its working process is much slower, and it's still developing its engineering skills. Manufacturing is easy for China, thanks to its domestic situation, but the country needs to develop its technological capabilities to take its engineering to the next level.

The biggest issue the industry as a whole must address is the global shortage of engineers and the growing lack of expertise. This is a problem common across all territories. Some, such as the United States, are suffering more than others. Germany is only beginning to feel the effects.

A frequent challenge we face is getting the industry to recognize the importance of the design process and how it impacts manufacturing, and as engineers retire or move up the management ladder so too does that knowledge and experience. Knowledge transfer and process integration are two key elements that address this issue and are core to Romax's software and service offerings.

***Environmental issues will shape the future of the gear industry***. The pressure of lowering carbon emissions, combating climate change and ever increasing populations as well as traffic congestion and the higher costs of conventional fuels will help shape the future of the gear industry. We feel that there will be three key industries that are going to lead the way and are positioning Romax to be at the forefront of these.

Car manufacturers will continue to look for innovative ways to reduce the carbon footprint of their vehicles with the growth and development of hybrid powertrains and electric vehicles. This in turn will increase the need for quieter gearboxes, so NVH (Noise,

continued

Vibration, Harshness) will be a key area of development for the industry. Romax has already undertaken considerable work with major OEMs to develop quieter designs and resolve issues such as gear whine and rattle.

Meanwhile, the single largest growth area for the global gear industry is the energy sector. Over the last five to 10 years, the wind energy industry has developed from a government-backed initiative to a market-driven industry with explosive growth. Already wind energy has moved from being a niche market to a driver with more than 35 percent market share in spheroidal graphite cast iron. Since gears are the single most common cause of wind turbine failure, there will be plenty of opportunities for the gear industry to grow and develop within the wind turbine industry. Romax has launched the first industry-specific element of our RomaxDesigner software, *RomaxWind*, to meet the growing demand of our customers in Europe, the United States, China and Korea.

Finally, we think that the future growth industry will be integrated transport systems (light rails/trams, heavy rail/trains and high-speed rail, which countries with the largest populations and highest congestion, such as China, are already considering, and lobby groups elsewhere, such as the United States, are already pushing for.

With new markets opening up, the geographical shift in the manufacturing landscape, the development of quieter transmissions, the growth of the renewable energy and the resurgence of industries such as rail, Romax is busier than ever, and we see exciting times ahead for the global gear industry.



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***to send us your opinion.***

# Sumitomo's New Grades

## FINISH A RANGE OF MATERIALS

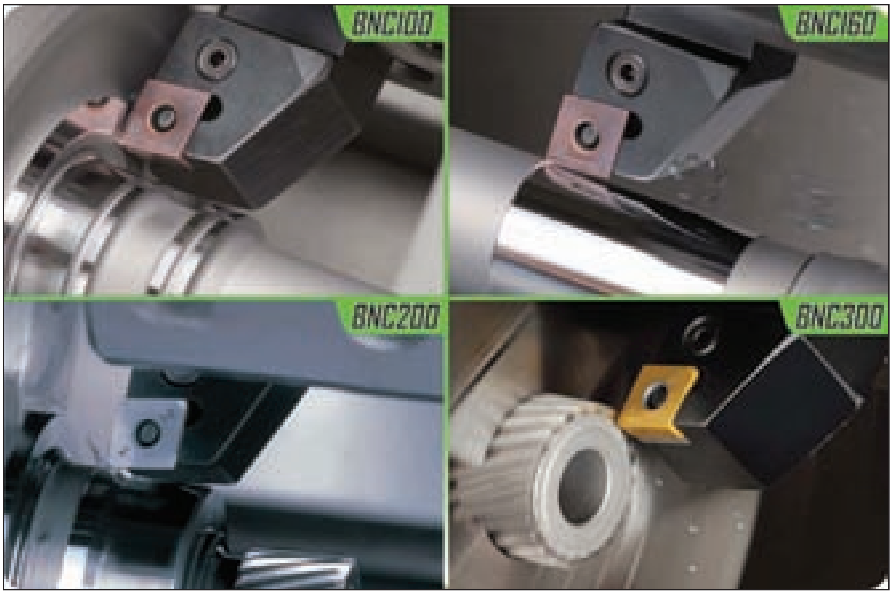
Sumitomo Electric Carbide Inc. released several new insert grades for use in turning of exotic materials, high speed cast iron turning and hardened steel turning applications.

The AC510U and AC520U grades are recommended for roughing, finishing and medium-cut machining of super alloy materials. They have a Super ZX multiple-layer coating consisting of TiAlN and AlCrN layers stacked up to 1,000 layers, resulting in high speed and improved wear resistance. They are both available in molded and ground insert types.

The AC410K grade presents new coating technology consisting of two coating layers, which offer peeling resistance and insert stability, according to the company's press release. The inner layer, called the Super FF Alumina, supplies thermal resistance; the outer Super FF TiCN layer imparts resistance to chipping. The combination of these coatings with a harder carbide substrate provides high wear resistance for continuous to light interrupted machining of gray and ductile cast iron. These features serve to double the tool life of cast iron grades. The AC410K can cover medium- to high-speed machining applications and is available in positive and negative insert types.

A new series of grades, BNC, features four PcBN grades with three styles of edge preparations, all geared at hardened steel machining. Each member of the BNC series has ceramic based coatings, brazings on all cutting edges and cutting edges etched with numbers for identification of used corners.

The BNC100 withstands flank and crater wear because of a CBN substrate, and a hybrid TiCN coating provides surface roughness stability.




The BNC160 uses the CBN substrate along with a new binder material for crater wear resistance and edge strength in general and high precision finishing.

For medium-speed machining and carburized surface deduction, the BNC200 offers reliable tool life and integrity due to the grade's edge strength and TiAlN based ceramic coating.

The BNC300 resists chipping and insert wear better than other grades, so finishing applications that engage in both continuous and interrupted surfaces are well-suited for it.

### For more information:

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*info@sumicarbide.com*
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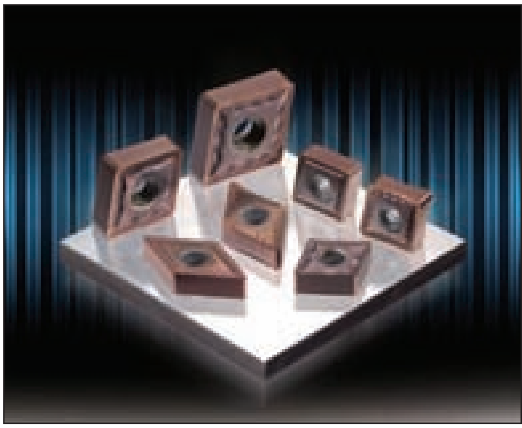
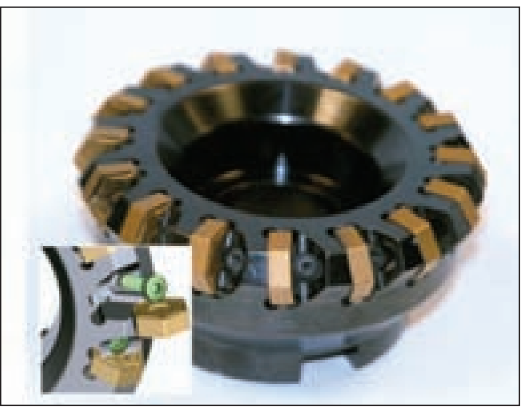


# Milling Cutter's Clamping

## HEIGHTENS PRODUCTIVITY



Valenite's ValMILL VFORCE milling cutter system highlights a patent-pending, direct insert clamping device, 'Side Lock,' which has a compact insert mounting providing more cutting teeth per revolution, so the system has feed and material removal rates as much as three times the speed of other traditional milling cutters. The ValMILL VFORCE is capable of cutting a variety of workpiece materials, including cast iron and high temperature alloys, according to Valenite's press release.

The side lock concept releases an insert quickly to reduce changeout times, and the screw size is larger in order to take a bigger force, demonstrating high anti-fling resistance to centrifugal forces during high-speed applications. As the screw tightens, forces in two directions are applied to the insert; it is pushed against the pocket side walls and pulled down to the pocket bottom. The insert becomes locked in, and as a result, the lock screw is tightly positioned to reduce potentially hazardous situations.

"Wedging conditions put the insert into a compressive stress state. Carbide materials are ideally suited to compressive stress and do not perform well under tension (stretching). Carbides are susceptible to fast fracture under tensile loads and sharp fragments are dangerous to operators," explains Brian Hoefler, manager of product development for Valenite. "Our system, basically, is engineered to optimize the carbides' fundamental characteristic of compressive properties, far greater than compared to systems on the market today."

continued

The high-density capability of the side lock design translates to more inserts for any given cutter diameter, distributing chip loads more evenly and minimizing work forces at the disperse engagement points. This process helps reduce indexing and tool-change downtime. The mill's cutting action is smoother because the side lock design is compact, providing a longer cutting edge throughout. The ValMILL VFORCE milling cutters come in sizes between 3" and 10" diameters.

**For more information:**

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P.O. Box 9636
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*Customer.service@valenite.com*
*www.valenite.com*

# Dura-Bar Products

## GET BIGGER

Dura-Bar's continuous cast bars are now made in extra-large sizes, up to 25" in diameter. The Dura-Bar XL product line is intended for use by industrial equipment manufacturers that produce large parts like gears, pulleys, ways, flywheels, bearings, housings, manifolds and pistons. The extra-large bars are useful for producing molds and pattern and mounting plates. The company hopes the new product will be considered an alternative to steel in large metal component manufacturing, according to Dura-Bar's press release.

Similar to the traditional continuous casting from Dura-Bar, the extra-large line also has the same permanent mold process that eliminates recurring pattern costs and defects like gas holes, inclusions and hard spots, typically found in material from conventional sand casting techniques. The Dura-Bar XL comes in 65-45-12 ductile and G2 gray iron, and the company also offers large-sized rectangles. All Dura-Bar products are available immediately.

### For More Information:

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2100 West Lake Shore Drive
Woodstock, IL 60098
Phone: (800) 227-6455
*sales@dura-bar.com*
*www.dura-bar.com*

# Mini Thread Grinder

## CAPABLE OF HIGHER VOLUME

Drake introduces the GS:TEM "MINI" thread grinder that is equipped to grind parts from 1 mm to 10 mm diameter and up to 100 mm long. The new grinder is aimed towards manufacturers in the cutting tool, automotive, aerospace, thread gage and medical equipment industries. A linear motor, ball screw axes and robot loader are available, and a pallet changer for the robot loader allows the machine to run unattended for three shifts, according to the company's press release.

The Drake MINI is capable of grinding taps, thread rolls, worms, ballscrews, e-steering components, aerospace fasteners and surgical bone screws. The new thread grinder is also capable of dressing topping and non-topping wheel forms like full radius and gothic arch, acme with crest and root

continued

radii or chamfers due to a diamond roll contour dresser. The Drake *PartSmart* software is included with the grinder, and the client's parts can be pre-programmed in the system.

**For more information:**
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4372 North Leavitt Road
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Phone: (330) 847-7291
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*info@drakemfg.com*
*www.drakemfg.com*

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# Tornos Lathes

## SUITED FOR VARIOUS USES

Several new lathe models were released at the Simodec 2008 international screw-cutting machine tool show in March, including two single-spindle lathes.

The Deco 13e is similar to its predecessor, the Deco 13a, but a fourth independent tool system is replaced with a fixed tool holder that is mounted on one of the two intersecting carriages used for bar-turning, on the Deco 13e. Scope for bar-turning work and counter-operations is provided by the eight linear axes across three tool systems. The Deco 13e allows for an equal level of simultaneous machining operation at both the front and back of the work pieces. The maximum speed of the spindle and back spindle is 10,000 rpm. Tornos has made program transfer from the 'a' version to the 'e' version possible, as well as adaptation for all equipment, tools and accessories, for users looking to switch to the new lathe.

The Sigma 32 is an automatic single-spindle lathe intended to manufacture medium-complexity components using a sliding headstock capable of machining diameters up to 32 mm, according to Tornos' press release. Each member of the Sigma line of machines has six linear axes, and the Sigma 32 involves simpler programming. The maximum speed of the spindle and back spindle is 8,000 rpm, and the power of those components is 3.7 kW and 5.5 kW, respectively, for both new machines.

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continued

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# Proportioning Pump Series

## HANDLES CAUSTIC CONCENTRATES

Zebra Skimmers introduces a proportioning pump series designed to deal with caustic concentrates and featuring a wide mixing range, compatibility with caustic concentrate and the ability to dilute with water at high temperatures, according to the company's press release.

"Our metalworking customers have to not only manufacture parts but also provide them debris free. Being able to provide our customers with an adequate unit to easily mix and pump their part washer cleaner is very important to us," says Meg Grant, inside sales and service.

**For more information:**

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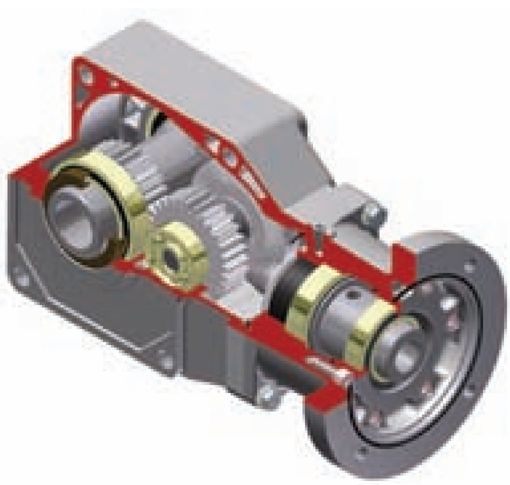
*meg@zebraskimmers.com*
*www.zebraskimmers.com*

# Hyponic Right Angle Reducer

## DESIGNED FOR FOOD-GRADE, WASHDOWN

Sumitomo Drive Technologies introduces its newest Hyponic product variant designed for the food industry and high-pressure washdown (HPW) applications. Developed in response to customer requests, the food-grade, HPW Hyponic features a C-face quill design; a unique FKM antimicrobial, multi-lipped, rotary output seal that acts as flinger to expel contaminants; corrosion resistance; stainless output shaft and hardware; synthetic NSF H1 food-grade lubricant; and antimicrobial DuPont Alesta AM powder coating. The combination of the antimicrobial seal, synthetic lubricant, stainless parts and severe duty antimicrobial powder coating results in a Hyponic right angle reducer equipped for long, reliable service in aggressive, HPW food industry applications, according to the company's press release.



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# Heidenhain Contouring Control

## EQUIPPED TO HANDLE COMPLICATED TASKS

The TNC 620 contouring control functions with digital drive control, and it is suitable for use on milling machines and machining centers with five axes plus spindles and complicated tasks that use swivel and rotary axes. The TNC 620 can handle strict requirements for the surface of finished workpieces using look-ahead, algorithms for jerk limitation and intelligent motion control, according to the company's press release.

The Heidenhain serial controller interface (HSCI) is a new feature of the main computer, controller unit and other components of the control system. The basis of the HSCI is the 100BaseT Ethernet network connection standard, which contributes to short cycle times for data transfer, lowered cable expenses and easier installation. The TNC 620 has a uniform digital design from the main computer to the encoder. Wiring in the electrical box is simpler due to the location of the main computer inside the operating panel behind the TFT flat-panel display. Heidenhain provides various options for users to customize the TNC 620 to their specific needs, whether they are the simplest machine applications or the most complex.

**For more information:**
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*www.heidenhain.com*

# Optical Measuring System

## ANALYZES DIMENSIONS

Digital Precision Corporation's OneTouch generation of optical measuring systems automates the measuring process and takes away the need for traditional gaging. Users can create part programs with the provided programming tools, and minimal computer experience is required. The system is capable of extreme measuring by combining standard and configurable screen overlay targets, a movable Crosshair/DRO and geometric edge acquisition tools. The OneTouch uses a pattern matching feature to make part orientation entirely automatic, so time-consuming part alignment is unnecessary.

High-quality digital images are made on a 20" LCD monitor by telecentric optics, a high-resolution digital camera and programmable episcopic and backlight illumination. There are several options for storing measuring results and images, including internal memory, internal CD-ROM and USB ports that can be used in an external source. With a slight footprint that provides space efficiency, the OneTouch is designed for the shop environment, according to the company's press release.

**For more information:**
Digital Precision Corporation

continued

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Fax: (714) 892-7451
*info@dpccorp.com*
*www.dpccorp.com*


# Haas Compact Mills

## FIT THROUGH MORE DOORWAYS

The OM series office mills from Haas Automation are more size efficient than average CNC machines. They are smaller and lighter, so they can fit through a 36" doorway and into most freight elevators, according to the company's press release.

Two versions of the machine are available. The OM-1 has a work envelope of 8"x 8"x 8" (xyz), and the OM-2's work envelope is 12"x 10"x 12", which allows a greater capacity with the same footprint. They both run on single-phase power of 240 VAC with a 20" x 10" T-slot table, and they are outfitted with a 50,000 rpm brushless micro-motor spindle, which is compatible with tools up to 1.25" shank size. The OM models function at a maximum cutting feed of 500 ipm. An ISO 20-taper spindle and 20-pocket automatic tool changer are features offered in the OM-1A and OM-2A models.

The customary equipment for the compact mills includes a 15" LCD color monitor with a USB port, 1 MB of memory, a coolant system, automatic lubrication and high-speed machining software. A pair of compact rotary tables fit into the work envelopes, so full 4th and 5th-axis operation is possible. Haas also offers a compact office lathe, the OL-1.

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Fax: (805) 278-8540
*www.haascnc.com*

# Houghton Cutting Oils

## BIODEGRADE, EXTEND TOOL LIFE

The Cut-Max V500 series of neat cutting oils from Houghton is biodegradable, vegetable based, lacks mineral oil and chlorinated additives, resists oxidation and offers high natural lubricity to extend the life of cutting tools, according to the company's press release.

This new oil line features a low viscosity, so fluid can be maintained longer and swarf dragout is minimized. They have higher flash points than other cutting oils, and they generate less mist and fumes that can lead to fires, meaning costly carbon dioxide fire blanket equipment is unnecessary. The Cut-Max V500 oils are best used for applications that use a higher level of tooling performance or where leaks and losses take place in the manufacturing process such as honing and superfinishing, grinding, cast iron gun drilling, general machining and gear machining.

**For more information:**
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Phone: (610) 666-4000
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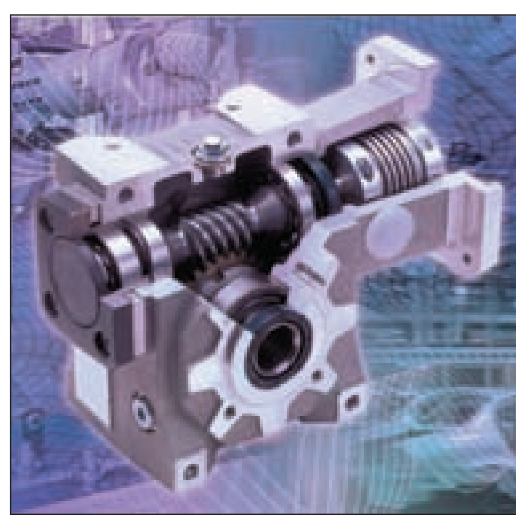
# ZF's High-Precision, Worm Gearboxes

## EMPHASIZE DURABILITY AND COST

New technology and designs allow ZF to offer a high-precision, right-angle servo gearbox, the SWG, emphasizing durability and cost-efficiency. The SWG technology features a computer-optimized profile that delivers 90 percent contact between worm and wheel, an increase of 50 percent more contact than conventional designs offer, according to the company's press release. The larger contact area reduces wear, so backlash levels are constant and predictable, and noise levels are kept under 55dB. Along with a wear-resistant bronze alloy the wheel is manufactured from, similar features throughout the gearbox serve to increase capacity, durability and precision with large diameter bearings that provide increased load bearing capacity. The worm wheel mounted to the shaft uses a press fit and pins instead of a keyed fit, which is less durable.

The SWG gearboxes come in three accuracy levels: the high precision unit with a backlash of less than 1 arc/minute, the precision box with 3 arc/minutes and the standard unit with 10 arc/minutes. They come in ratios from 5.2:1 to 90:1, in 10 sizes and with four output options. The 30-800 sizes are ideal for conveyors and handling systems in particular because of available dual output shafts. The units are capable of output speeds up to 6,000 rpm and output torques up to 6,900 Nm with service lives around 25,000 hours.



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# Online Calculator

## HELPS MANAGE ENERGY COSTS, $CO_2$ EMISSIONS

Dow Corning introduced an interactive Molykote Energy Savings Calculator, which serves as an online tool for plant managers and industrial maintenance engineers, to help them handle energy prices and carbon dioxide emissions by calculating the means by which these factors can be reduced. Dow Corning's energy savings calculator accepts input for the number of motors on gearboxes, pumps, compressors and fans, as well as the kilowatts they run on, the efficiency, hours per day and days per year. Once this information is computed, users view information such as possible reductions in kilowatt hours, efficiency, the carbon dioxide emissions and the subsequent cost savings available.

Without proper lubrication, drag and friction can result, which can waste money and damage equipment, but plant managers and industrial maintenance engineers can avoid some of these costs while saving energy and reducing carbon dioxide with appropriate lubrication. By increasing awareness about the importance of proper lubrication, plant managers and industrial engineers can benefit from implementing detailed maintenance programs.

"Optimized lubrication is more important than ever to increase reliability, lower emissions and reduce plant operation costs," says Phil Grellier, global solutions development manager for Dow Corning. "The Molykote Energy Savings Calculator can help manufacturers meet sustainability goals and fulfill their commitment to innovative, energy-efficient solutions by understanding where they may be wasting energy."

The calculator is found at *www.dowcorning.com/content/molykote/energysavingscalculator.aspx.*

continued

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# Accu-Lube LB4600

## LUBRICATES IN MINIMUM QUANTITY


A new member of the Accu-Lube product line from ITW Rocol North America, the LB-4600, is ideal for near-dry machining operations for sawing and machining aluminum materials. The lubricant is natural, environmentally friendly, non-toxic, biodegradable and suitable for any MQL operations in a non-ferrous machining process.

The LB-4600 is based from renewable vegetable resources without any mineral oil. Reinforced with additives that increase lubricity and performance, the purple colored, non-staining Accu-Lube LB-4600 is practically odorless and burns off during post heat-treat processes. The lubricant promotes longer saw blade and cutting tool life, safer working conditions and reduced machine maintenance. The product is available in one-gallon and 55-gallon containers, according to the company's press release.

**For more information:**
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# Before You Go—

## A CHINA GEAR MARKET UPDATE

Otis Edwards

It would not be an exaggeration to say that China is often the most-covered country in the news today. Many articles appear in newspapers and magazines each day, and just about every topic seems to be of interest—from the Dalai Lama to the Olympics, from bird flu to lead paint in toys. And the business press can't seem to find enough superlatives to describe the year-on-year growth for just about every sector of the country's economy. So what's going on in the Chinese gear industry?

***Market size***. It is not news that China has already become a major gear-producing country. According to the Chinese Gear Manufacturers Association, (CGMA), "With the development of the national economy, especially due to the automobile industry, total growth of the Chinese gear market in the last five years has increased by 150 percent. Meanwhile, China's total sales of gear products have increased by over 100 percent, reaching 70 billion yuan RMB (USD $9.8 billion), ranking third in the world and surpassing Italy" (Table 1).

Table 1— 5-Year Gear Market Size (automotive and non-automotive combined) Unit: Billion USD

| Year | Sales in Domestic Market | Net Value of Imports | Total Market Size |
|---|---|---|---|
| 2002 | 4.5 | 0.4 | 4.9 |
| 2003 | 5.4 | 1.1 | 6.5 |
| 2004 | 6.4 | 1.7 | 8.1 |
| 2005 | 7.6 | 1.8 | 9.4 |
| 2006 | 9.8 | 2.8 | 12.6 |
| Note: Net import = import – export | | | |

Table 2— Regional distribution of gear product sales

| Area | Eastern China | Northern China | West-Southern China | Middle China | West-Northern China | East-Northern China |
|---|---|---|---|---|---|---|
| Proportion (%) | 52.8 | 19.1 | 8.7 | 8.1 | 6.7 | 4.7 |

Table 3— Regional features of gear product export in 2006

| Value | Zhejiang | Shanghai | Jiangsu | Tianjin | Shandong | Beijing | Guang-dong | Hebei | Others |
|---|---|---|---|---|---|---|---|---|---|
| (%) Proportion | 20.1 | 19.8 | 13.4 | 10.0 | 6.6 | 4.7 | 4.7 | 4.7 | 16.0 |

Table 4— Application of gear products in different industries in 2006 Unit: Billion USD

| Category | Auto | Farm Machinery | Engineer-ing | Motor-cycle | Cement and con-struction materials | Crane and trans-portation | Mining | Metal-lurgy | Miscella-neous |
|---|---|---|---|---|---|---|---|---|---|
| Value | $4.62 | $1.30 | $0.72 | $0.67 | $0.56 | $0.53 | $0.53 | $0.22 | $3.40 |
| (%) proportion | 36.6 | 10.3 | 5.8 | 5.3 | 4.4 | 4.2 | 4.2 | 1.8 | 27.4 |

Table 5—Gear import and export for the last four years in the China automotive sector Unit: Billion USD

| Year | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|
| Value of Import | $1.44 | $1.99 | $2.25 | $3.37 |
| Value of Export | $1.06 | $1.53 | $1.66 | $2.60 |
| Value of Trade Deficit | $0.38 | $0.46 | $0.59 | $0.77 |

***Demographics***. In the West, we often speak of China as if it were one large, continuous market. Indeed, China is the size of the territorial United States, including the Gulf of Mexico. It's also as culturally, linguistically and economically diverse as Europe. About half of the Chinese gear industry is located in what is known as the Eastern Seaboard, and the provinces of Zhejiang and Jiangsu are where many of the larger gear enterprises are located. In 2006, for example, seven companies in these provinces had sales figures totaling over $70 million USD. We are also seeing very modern, well-equipped enterprises in Shandong Province, and the Shanghai area is becoming very important to exporters (Tables 2 and 3).

So what, exactly, is being manufactured in China, and where are the opportunities? Due to the great progress of China's automobile industry, its gear industry has witnessed a growth at an average annual rate of nearly 20 percent over the past five years. There are now around 1,000 gear enterprises in China, of which more than 50 have reached a scale of $70 million USD.

Basically, the manual automobile gearbox (including heavy, medium, light and mini gearboxes), sedan gearbox and motorcycle gearbox can now be locally produced to meet the demands of the Chinese domestic market. In 2006, 49 percent of all gearboxes were imported for the automobile industry, amounting to $228 million USD. And in addition to gearboxes, 60% of all other automotive-related gears—e.g., worm shafts for car seats, plastic gears for instruments, etc.—were imported.

The Chinese automobile sector is indisputably its leading industry in total gear market demand, occupying 36.6 percent, or $462 million USD (Table 4).

It is well worth mentioning that nearly one half of the Chinese automobile industry requires the supply of imported products, and the same applies for its gear industry as a whole. According to statistics gathered over the last four years, import and export activity for gear products have both been on the rise, while imports have outpaced exports (Table 5).

***A new movement toward quality***. We are beginning to see a rush of Chinese manufacturers moving towards higher-quality products, no more so than in the development of automatic transmission gearboxes. Much of China's needs remain dependent on imports—specifically, vehicle drivetrain axles, spiral-bevel gear sets and wheel redactors. These components serve to meet China's domestic demands, but quality levels for export are still maturing. Companies such as Shanghai Automotive, Jiangsu Aerospace and Shanxi Fast Gear are increasing their investment in gear machining quality and assembly to produce export-quality components.

***Basic views on the Chinese gear industry***. Nevertheless, the domestic gear industry here has seen great advances in the past years, mostly in the rapid increase of product quantity, if not quality. It is expected that 2007 figures will show that the entire market grew more than 15 percent, or approximately 10 billion yuan. But as shown candidly by the 2007 CGMA

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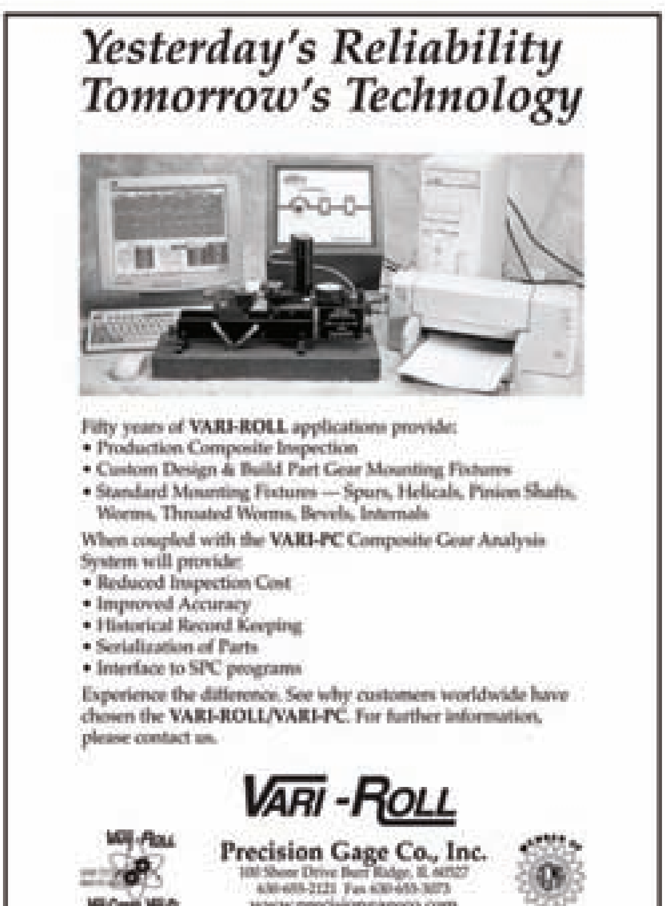


report, there are still obvious, sizable gaps, when compared with developed countries in the following respects:

- R&D—The research and development capability of many of China's gear manufacturers has not collectively improved.
- Backward Technology—Although a large number of new-generation equipment and machinery units have been imported from abroad, they are not being utilized to their capacity because the skill sets required to run them have not been appropriately learned and managed.
- Inferior enterprise management—Modern restructuring and processes have been carried out within many domestic manufacturers, but many enterprises still lack the will or ability to free up the enthusiasm and creativity of their employees.

This of course lowers the overall company efficiency, and results in inferior product quality and high turnover rate. The overall effect results in an industrial race-to-the-bottom competition, with price alone trumping quality products.

### Evaluating the Outsourcing Opportunities

Nevertheless, China represents a sizable market that—if pursued diligently and with the right support staff on the ground—can offer unique benefits to outsourcing. Sourcing gears from China can be an attractive way of increasing your company's capabilities without having to doing it yourself. Gears of various diameter, or gear types sourced, rather than made, broaden your product line without significant investment in machinery, tooling and technical know-how. Machine components, like cast or granite bases, improve your lead time and costs.

### Following Are Some Guidelines

***Know the manufacturing costs***. Try to view China's cost benefit from the point of view of reducing overhead and raw material costs. Of course, total overhead rates vary significantly by supplier, but keep in mind, they can be less than half of Western levels. Additionally, including hourly wage rates and benefits, Chinese wages are about 10 percent of the salaries of their counterparts in the United States and Western Europe.

***Some tips before you come***. Know the total labor content (direct and indirect) of your product. A target product for outsourcing to China would have a labor component in the area of 20 percent or more of the product cost structure. Where possible, look to add assembly processes to the machining projects you outsource.

***Design reengineering***. Reevaluate those products that run the risk of continual redesign or reengineering, or you could be left with significant risk exposure to obsolete inventory. Remember also that it takes time for reengineering processes to take effect on the Chinese manufacturing floor. A good guideline is any product requiring more than three redesigns per year should be reconsidered.

***Don't overlook the transportation factor***. Remember, in China a product must go from the factory to the port, onto a ship, and then to the U.S. or other major markets, where it is unloaded and trucked to its destination. Generally, prices are quoted F.O.B. Chinese port, with a transport time of four to six weeks. Calculate $0.06–$0.10 per pound for sea freight, and $1.50–$2.00 per pound for air freight.

***Don't bother surfing the internet to find suppliers.*** It is a truism here that the better suppliers have the worst websites, and that marginal suppliers have the slickest. Remember too, that, as with dancing, there is more involved than simply finding a partner. Once you decide upon a Chinese supplier, the real day-to-day work is just beginning.

***Some tips while you're here***. Don't be scared to look at locally sourced raw materials in China. It used to be the case just a few years ago that Chinese suppliers had to import materials, such as high-quality steel alloys, and those who thought they were locally available took a significant cost penalty to their procurement programs. Now, many international steel suppliers have established modern facilities here with foreign-trained staff management. Good cost savings are possible when these materials are locally sourced from competitive suppliers.

When hiring a local staff, ensure you have the ability to review references thoroughly, and that you are satisfied they are capable to do the work assigned. Don't make the mistake of hiring a person for their English language capability only. The Chinese government this year published a new labor law (Labor Contract Law) requiring all employers to enter into a contract agreement with their employees. It's designed to protect the employee from questionable employers, and streamlines the process for workplace litigation. Should an employer find the employee doesn't live up to the work assigned, the employer must keep a detailed account of his efforts to retrain or reassign the employee. In essence, you need to thoroughly understand whom you are hiring. Additionally, keep in mind equivalent levels of education in China differ from developed countries. In other words, a Chinese person with a masters degree from a Chinese university in mechanical engineering doesn't necessarily equate to his or her Western-educated counterpart.

**Selling into China—the Time is Now?**

There are several developments currently under way which make China particularly attractive for U.S.-made products. One, of course, is the weakening U.S. dollar. It currently trades with the Chinese RMB at $1 USD / ¥7.15—which gained 12 percent in value in the last year alone—and with the euro at $1 USD / € 0.65. Secondly, the perception of high quality rests with Germany, but German-made products are experiencing long lead times, thus impacting efficiencies the Chinese seek. Third, but more remotely, the Chinese retail banking sector, in complying with WTO scheduling, is undergoing an intense reformation. As more international banks relocate to the mainland, we may begin to see that loans for manufacturing equipment are more like years away, not decades.

While the Chinese gear manufacturers remain intent on buying international machinery, the Chinese gear market

continued

can be viewed by various capital structures—wholly owned foreign enterprises (WOFEs); JV manufacturers (JVs); and Domestic Private Companies (DPCs). All have their own purchasing preferences, but in general most WOFEs in China tend to remain national in their supply structures, aside from those of the United States—i.e., Germans stay with Germans, Japanese with Japanese. It's only the Americans, it is said, that seek to shop the world. The JVs seek to gain the highest technology transfer attainable, and therefore favor the Germans. On the other hand, while many domestic, private companies remain content to supply the low-quality domestic sector, they now seek to build higher-quality products in order to gain exporter status. If the U.S. dollar continues on its current pace, American manufacturers could begin to see all of these sectors of the Chinese market developing in their favor.

**Selling—Some Tips Before You Come**

***Rethink your concept of quality***. What you may advertise as your product advantages could be obstacles in the China market. Research what the market is buying over here and determine whether your company is willing to build a different product to gain entrée to a new market. Know your international competition's offerings, as they are likely over here as well.

***Guanxi rings rule***. Guanxi loosely translated means relationships, but more often than not it's viewed in the West as graft and underhanded dealings. This description doesn't quite complete the picture, however. When I think of a person's guanxi, I like to picture a circular target with the Chinese employee as the bulls-eye. The next guanxi ring surrounding the employee is the family ring, followed by a former classmates ring and then a past and previous workmates ring. This is where the employee has demonstrated credibility and trustworthiness. Beyond this ring (and guanxi influence), are the transactional relationships with tradeshow and other foreign contacts. A Chinese person, absent an English word to describe these various layers, will describe their relationships as simply "friend." (It's the reason there is no such thing as cold-calling customers in China). It is important to remember that, should your employee leave your company, he takes his guanxi with him. It isn't conferred upon the company he works for. Therefore, maintaining employee morale and the relationships they have maintained for you takes effort and sincerity on your part. In essence, both parties are gambling on each other.

Bidding in China is a lengthy, detailed process. Technical specifications for the bid opportunity are usually a reference target, with verbal details discussed before the bid opening ceremony, or sometimes after. In short, guanxi matters.

***Language***. It will take a good deal of your company's time and patience to cut through the verbal and written language barriers. And just because your Chinese employee nods his head at the right moments doesn't mean he understands what you are saying. Keep the discussions focused by using simple sentences and elementary vocabulary, directed to the business at hand. When your employees snicker at the creative, English e-mails received from their Chinese counterparts, encourage them to conceptualize the difficulty of replying back in Chinese. Don't expect your China staff to be a self-directed, autonomous entity. Build in daily or weekly conference calls with all pertinent staff available.

***Getting paid.*** Demand issuing a letter of credit. This is fairly common now with international purchases. In effect, the bank takes on the role of importer and exporter in handling documents and monies. The letter of credit vehicle is a guarantee that the bank will pay once all terms are satisfied by both parties. In the initial phase of commercial dealings with your Chinese partner, they are likely to request pre-payment terms. They'll make claims they need to purchase raw materials for your order and/or final payment before the goods are shipped. Unless you have visited them and feel absolutely comfortable that they are legitimate—and here's an example of how an appreciation of guanxi is crucial—I would advise against this method. And even though there are more services in China capable of determining credit worthiness (the U.S. Commercial Service among them), it remains true that the country lacks transparency.

### Wanted: Strategic Partnerships

Viewed in the context of a 5–10 year timeframe, perhaps the most attractive strategy now in play for U.S. manufacturers is establishing a strategic relationship with a Chinese partner.

On the one hand, the "graying" of the U.S. gear industry has been widely reported; it is an industry fact. It is also fair to say that machinists are more difficult to find than ever before, and that once they are on-board, it takes time and effort to train them. Even then there is no guarantee of retaining them. And of course fewer university students are attracted to the engineering departments of their colleges. (It is interesting to contemplate this point when you consider how many U.S. students these days, even in primary school, are studying Chinese).

Many Chinese manufacturers have some of the most modern equipment available, capital and labor. It is not uncommon to have job seekers lined up outside the factory gates, and technical colleges are continually graduating gear-specific technicians. But they lack the shop floor technology, management processes and knowledge of, let alone access to, new markets. At this point many Chinese factories are still in an "order taker," or commodity mentality, and it will take some time before they are capable of chasing after new markets on their own. But the day will come.

A strategic partnership with a Chinese manufacturer allows him to gain access to the necessary technology, management processes and access to new markets at a time when U.S. manufacturers are finding it difficult to create a long-term succession plan. A willingness to pursue this avenue for the American manufacturers would mean a shift of focus from solely manufacturing to export processes, as well as from maintaining in-house sales and marketing. Of course you can

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still maintain quality by performing all the finishing operations in-house.

This, admittedly, is a controversial topic. But it's an interesting way to conceptualize defending against a Chinese competitor—i.e., by using your Chinese partner. When your customer says they need to reduce costs, offer them your China price.

China represents an enormous but often little understood opportunity. Gone are the days when a wizened, grey-haired engineer arrived in China and taught the Chinese what they needed to buy. The Chinese are more aware of the rest of the world than we often give them credit for. They now expect agile, dedicated teams to work with them on a daily basis. The Chinese want to know you are more involved in this market than simply dipping a toe in the water. It helps to have a presence on the ground in China.

And an open mind back home.

*(Otis Edwards has lived and worked in China for nearly 15 years, beginning in the early 1990s familiarizing himself with the emerging Chinese consumer goods manufacturing environment. While in China, he has managed such processes as quality control, sales and sourcing for U.S.-, South American- and European-based companies. He studied Chinese at Nankai University (Tianjin), has a B.A. in Chinese Studies from the University of California, and an MBA from Ivey Business School (UWO). Edwards has completed the AGMA gear manufacturing training course, and has—quite unexpectedly—become fond of gears. Edwards lives in Hong Kong and is managing director of Red Rover Ltd., an export sales management and strategic sourcing company focusing on the gear and machine tool industries. Red Rover, an AGMA member, has offices in Hong Kong and Shanghai.)*





# Communication Breakdown

## OVERCOMING CULTURAL AND LANGUAGE BARRIERS IN THE GLOBAL GEAR MARKET

Matthew Jaster, Associate Editor

If you've read any business publications lately, chances are you've seen an article or two covering language and cultural barriers in the global marketplace. Buzzwords like "globalization" and "global supply chain" frequently come up in discussions on training, networking and economic growth. At least once a week, a headline triumphantly declares a company "lost in translation" due to language or cultural missteps.

According to *www.vistaworld.com*, the English language remains the most popular when conducting business abroad. It's the most widely published language, it has the most words and it's spoken by the most non-native speakers.

Many business professionals, however, are learning it will take more than the English language to remain competitive in the global market. While attendance for Spanish, French and German language courses has risen here in the United States, an increasing number of business professionals are also learning Arabic, Japanese, Russian and Chinese Mandarin.

As the manufacturing community gains prominence in countries like China, India and Korea, many are looking toward Asia for new business opportunities. Companies are working daily with partners, clients and customers around the world on joint business

continued

ventures, marketing agreements and sales opportunities.

Whether selling a grinding machine, marketing a software program or manufacturing components, companies would benefit from knowing the role language and cultural barriers play in today's business economy.

***Recruiting from the local talent pool.*** Companies like Gleason, Star-SU, Gear World and Ticona find that establishing localized sales offices or hiring commissioned representatives helps to eliminate potential language and cultural barriers. It's a simple solution, one that avoids getting caught in a situation where translation or alternative business practices cause confusion.

"We have sales directors at our technology centers in most of our major markets," says Kelvin Harbun, vice president of Asian sales at Gleason. "This helps to establish sales and support offices in all the major industrial regions. Typically, our sales and service offices are headed by representatives that know the environment, especially in countries like China and Japan, where knowing the culture is just as important as the language."

Gleason ships products to more than 40 countries around the world. According to Harbun, 75 percent of their products worldwide are shipped out of the U.S. market. He's fully aware of the challenges presented by working across several continents, but he can't imagine Gleason not doing this kind of international business on a daily basis.

"If we don't have a sales office in the country, we have commissioned representatives in place to work with our customers," Harbun says. "These reps have been working for Gleason for years in areas like Brazil, Argentina and Korea."

**To remain competitive globally, Ticona has factories around the world like this facility in Kelsterbach, Germany.**

Similar concepts are carried out at Star-SU. The company uses English as their business language, but will speak and correspond in German, Italian, Spanish, Portuguese and Chinese if necessary. Brian Cluff, vice president at Star-SU, says business practices differ from country to country, so their system is tailored to support experienced professionals from each and every culture.

"We do 50 percent of our machine tool business with companies overseas, doing business in Russia, Poland, all of the European Union, India, China, Japan, Korea, Brazil and Argentina," Cluff says. "Cultural differences are addressed by in-country personnel who are experienced with doing business in their native country."

Gear World S.p.A. is a manufacturing project launched by the Carraro Group in 2007. Headquartered in Padova, Italy, the organization manufactures cut-metal bevel and cylindrical gears, ring gears, powder metal gears and structural parts. The company has four plants in Italy and individual plants in the United States, China, Argentina and India.

Gear World utilizes local sales managers at their overseas plants and uses English internally for manufacturing, quality and technical issues. Any cultural differences are eliminated due to the "corporate culture" the organization has adopted over the years.

"Our corporate managers have a long, international experience; therefore, the understanding with the customers across the globe is always certain," says Dr. Ing. A. Scanavini, vice president of business development at Gear World. "We also pay close attention to communication in order to create a global presence with our customers."

Ticona Engineering Polymers employs 2,000 individuals at facilities in the United States, Germany, Brazil and throughout Asia. In order to accommodate their global clients, the company provides the right people with the pertinent language skills.

When Ticona collaborates on a


The international sales team at KISSsoft stands in front of the main office in Hombrechtikon, Switzerland.

project, the company provides the same brand experience whether it is in Frankfurt, Detroit or Shanghai. By insisting each facility adheres to the same performance characteristics and specifications, the company eliminates possible cultural or language hurdles.

While larger organizations have the time, resources and manpower to address these types of issues, smaller companies need a more creative approach.

***The right people, the necessary skills***. In the case of KISSsoft AG in Switzerland, communication is imperative in servicing its software to a global customer base. As a smaller organization, the company originally hired a single employee to address language issues in-house.

"It is important for us to have all the documentation and the software looked after and to have someone organize it all," says Dr. Stefan Beermann, vice president at KISSsoft. "The problem with translation is that you start from scratch again and again. As soon as you change a small percentage of the source text, someone has to translate it all. It doesn't matter if only two words or a complete sentence is changed; the translation effort is still the same."

As KISSsoft has expanded its customer base, the company has been able to hire a network of translators to address other language issues.

"We usually communicate with our customers in English, the current lingua franca," Beermann says. "Our business is very close to a consulting firm, so communication is the core of everything we do. Most of us here are in touch with several different customers each day by e-mail or by phone focusing on their demands and talking about language issues that have come up."

Unfortunately, these language and cultural obstacles can even occur in one's own backyard. Marswell Engineering Ltd., a small manufacturing company in Hong Kong, provides injection molding and small module plastic gears and gearboxes. More than 80 percent of Marswell's customers come from companies overseas.

"There's not only a significant difference between the West and the East, but also within the south and east Asian countries like China, Japan and India," says Wing Lam, sales executive at Marswell.

Lam says the diet and religious habits of Marswell's customers are just as important as the terms of a business deal. Food and drink, for instance, are an important first step for several cultures

continued

before business can even begin. Many Asian cultures believe a person's family and religious background help determine their business practices. When dealing specifically with countries like China, Japan and India, Lam says Marswell employees take the extra steps necessary to make their customers comfortable.

"It helps to know the background of our customers," Lam says. "If we can provide a close and friendly relationship, the customer feels mutually respected."

In order to continue to grow in the global market, Marswell plans to improve their sales and service techniques and become more flexible. While they use English to communicate with overseas customers, they see languages such as French, Japanese and Mandarin as vital to the front line of the organization.

***It pays to do your homework***. Regardless of the size and scope of the operation, some research can go a long way in establishing international relationships. Learning as much as you can about the traditions, beliefs and business practices of the host country is a great advantage.

The website *www.communicaid.com*, a global communication/consultant firm, has detailed information on conducting business in India. The website recommends companies make appointments at least a month in advance with Indian counterparts, as the culture appreciates punctuality and scheduled appointments. Deadlines should not be rushed or aggressive, as Indian culture sees this as rude and disrespectful. Final decisions rest with the highest ranking executives; therefore maintaining strong relationships with senior executives is essential.

In India, a cultural disagreement is

Star-SU's facility in Jundiai, Brazil.

KISSsoft communicates daily with its global customer base from its main office in Hombrechtikon, Switzerland.

very rarely expressed directly, and the word "no" is avoided if at all possible. Negotiations will not begin until a well-established relationship is in place. Meetings begin with small talk and normally involve personal questions as a way of building rapport between the individuals involved.

Titles are a very important part of business etiquette, and the website recommends using professional titles such as "Professor" or "Doctor" at all times, if the person does not have a title be sure to use "Mr.", "Mrs." or "Miss." Above all else, the website stresses the importance of sincerity and honesty, traits sometimes overlooked here in America when conducting business.

In the Chinese market, language remains a vital part of communication between both parties. Xiaoqing Diana Lin, associate professor of history at Indiana University Northwest, with an expertise in Asian studies, says more and more Chinese speak fluent, technical English, which helps facilitate communication. More Americans study Chinese in China with the explicit purpose of finding a job. (*Editor's Note: Please see our feature on the Chinese gear market on page 30 for additional information.*)

Lin believes American and Chinese companies can benefit greatly by doing some research into what kind of criteria, both explicit and implicit, the companies are using for potential business deals.

"Americans are used to legal contracts and work by the book, while Chinese are used to tacit or oral agreements rather than fixed, written agreements," she says.

Lin suggests some know-how on the business practices and cultural traditions of the company might be beneficial in moving the relationship forward.

"On the part of the Chinese, they should be persuaded to follow established rules and guidelines in order to continue working with the United States and Europe. For Americans, it helps to be immersed in Chinese culture, hold regular meetings with Chinese staff; learn a little bit of the language and be open minded," Lin says.

Some knowledge of a country's language and cultural background can go a long way in establishing relationships that will thrive in this new, borderless economy. While it's not the only role, Lin believes it's nice to have some insight moving forward.

"In general, culture and language play a very important role in business because they often provide the intuition to sense whether the business relationship

continued

is moving in the right direction. Culture shocks, rather than language gaps, are more difficult to overcome."

## For more information:

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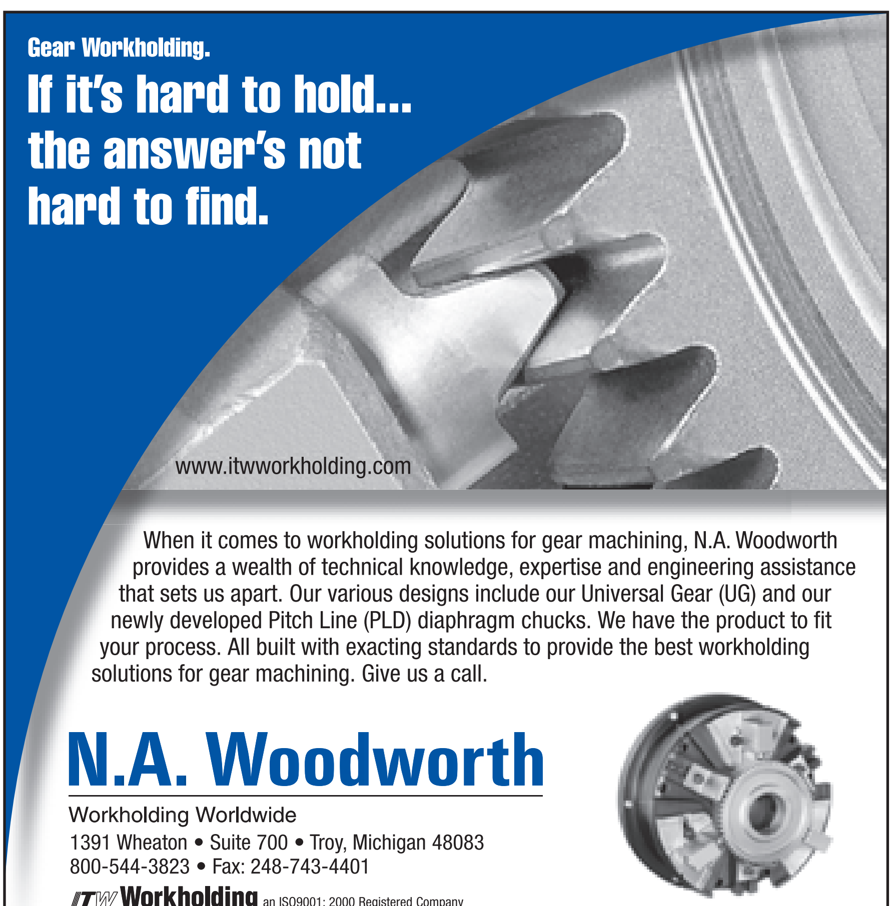

# Pitting Load Capacity of Helical Gears

## Influences of Load Distribution and Tooth Flank Modifications as Considered in a New, DIN/ISO-Compatible Calculation Method.

Bernd-Robert Höhn, Peter Oster and Gregor Steinberger

| Nomenclature | | |
|---|---|---|
| $a$ | [mm] | center distance |
| $b$ | [mm] | face width |
| ß | [°] | helix angle |
| $c_y$ | [N/mm•µm] | mean value of mesh stiffness per unit face width |
| $\varepsilon_\alpha$ | [-] | transverse contact ratio |
| $F_{bt}$ | [N] | normal transverse load in plane of action |
| $F_{bn}$ | [N] | load, normal to the line of contact |
| $F_t$ | [N] | transverse tangential load at reference cylinder per mesh |
| $f_{Ca}$ | [-] | component of equivalent misalignment |
| $K_A$ | [-] | application factor |
| $K_{H\alpha}$ | [-] | transverse load factor |
| $K_{H\beta}$ | [-] | face load factor |
| $K_v$ | [-] | dynamic factor |
| $T_1$ | [Nm] | torque at pinion |
| $p_C$ | [N/mm2] | Hertzian contact stress at the pitch point |
| $u$ | [-] | gear ratio |
| $\sigma_{H0}$ | [N/mm2] | nominal contact stress |
| $\sigma_{H1}$ | [N/mm2] | contact stress on pinion |
| $v$ | [m/s] | tangential velocity |
| $Z_{B/D}$ | [-] | Single-pair tooth contact factor for pinion wheel |
| $Z_E$ | [-] | elasticity factor |
| $Z_H$ | [-] | zone factor |
| $Z_\beta$ | [-] | helix angle factor |
| $Z_\varepsilon$ | [-] | contact ratio factor |

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**Management Summary**

In experimental analyses, the pitting load capacity of case-carburized spur and helical gears is determined in back-to-back test rigs.

Included for testing are one type of spur gear and eight types of helical gears, with tests for the determination of influences of varying load distribution, overlap ratio and transmission ratio. The test results are presented and evaluated on the basis of the pitting load capacity calculation methods of ISO 6336-2/DIN 3990–Part 2.

A new DIN/ISO-compatible calculation method for pitting load capacity is presented. This new calculation method analyzes helical gears more adequately than ISO 6336-2/DIN 3990–Part 2, and has the ability to consider tooth flank modifications. The new calculation method is applied to test results and gears of a calculation study. It shows better agreement with the experimental test results than the present ISO 6336-2/DIN 3990–Part 2.

### Introduction

Modern gears are designed with helical teeth to improve their noise behavior and the pitting load capacity. Therefore, a verified calculation method to determine the pitting load capacity of helical gears is essential.

ISO 6336-2 and DIN 3990–Part 2 calculate a higher-endurance torque for helical gears than for spur gears of the same size and material, but experimental research on the pitting load capacity of helical spur gears is lacking (Refs. 2, 3).

Thus the research project FVA 284 I/II "Helical Gear" (Ref. 10) was initiated to analyze the pitting load capacity of helical gears, theoretically and experimentally. Spur and helical gears of the same size and material batch were tested to determine the influence of the helix angle. The endurance contact stresses were calculated according to ISO 6336-2/ DIN 3990–Part 2, based on the experimentally determined fatigue-endurable torques. The results are shown in Figure 1, which shows that the expected pitting load capacity of $\sigma_{H0}$ = 1,500 N/mm$^2$ is only reached by the spur gears, not by the helical gears. Consequently, the calculation methods according to ISO 6336-2/DIN 3990–Part 2 determine the pitting load capacity of spur gears more accurately than for helical gears.

In order to confirm these results, additional tests (Ref. 12) were conducted. These tests prove the main result of FVA 284 I/II (Ref. 10)—i.e., the calculated pitting load capacity for helical gears is too high. Consequently, the calculation of helical gears according to ISO 6336-2 has to be reconsidered.

Optimum tooth flank modifications for uniform pressure distribution result in maximum pitting load capacity. Hence the research project FVA 284 Ic analyzed the influence of several tooth flank modifications on the pitting load capacity of helical gears.

The theoretical part of this research project included the development of a new DIN/ISO-compatible calculation method to determine the pitting load capacity of gears, especially helical gears. This new calculation method analyzes helical gears more accurately than the existing ISO 6336-2/ DIN 3990–Part 2 and includes the influence of tooth flank modifications.

### Test Program and Test Gears

One spur and eight helical gears were ground with different tooth modifications for varying load distribution. Table 1 summarizes the main geometry and details on tooth modifications of spur gears Gk and the helical gears S0, Slk and Stk.

The gear type Gk corresponds to the gear type of FVA 284 Ib (Ref. 12) and, except for a small lengthwise crowning on the pinion, the reference gear of FVA 284 I/II (Ref. 10). Hence this gear type is used to verify the results with the spur gears of FVA 284/I and 284 Ib. The helical gear type S0 has no modifications, except for a small lengthwise crowning on the pinion. Type Slk has a long tip relief on the pinion and wheel to achieve uniform pressure on the line of contact. The gear type Stk is modified with a generated relief and a short tip relief for optimally uniform pressure distribution. The necessary modifications were determined according to the calculation method in Reference 11, which is based on the pressure distribution calculated with the program *RIKOR G* (Ref. 8). The whole calculation is included in the program *RIKOR H* (Ref. 7).

The test gears are made from case-hardened steel 18CrNiMo7-6. The gears were case-carburized and ground after the teeth were cut. The case depth conformed to Eht ≈ 0.15·$m_n$ according to DIN 3990–Part 5.

### Measuring Gear Quality

The test gears were measured on a Höfler/Klingelnberg EMZ 402 3D-coordinate measuring machine. The quality was determined according to DIN 3960 by measuring the profile along the involute and across the flank, as well as measuring the pitch deviation and the true running. The quality of all test

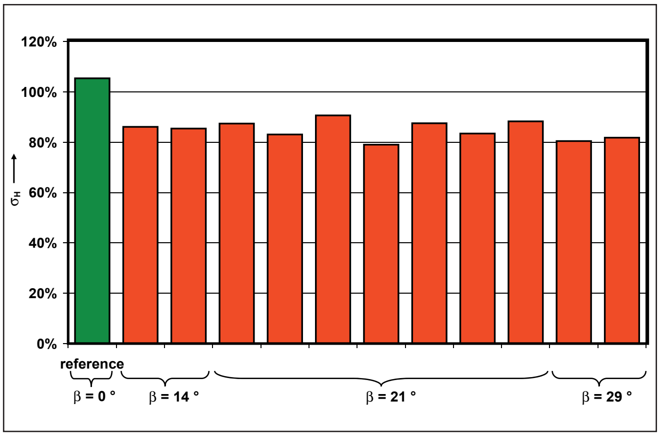


**Figure 1—Endurance contact stress of the spur and helical test gears according to ISO 6336-2/DIN 3990–Part 2 (Ref. 10).**

**Table 1: Gear geometry of the test gears type Gk, S0, Slk and Stk**

| Test Type | | | Gk | S0 | Slk | Stk |
|---|---|---|---|---|---|---|
| center distance | $a$ | mm | 112.5 | | | |
| normal module | $m_n$ | mm | 4.5 | | 4.25 | |
| number of teeth | $z_1/z_2$ | - | 24/25 | | 22/24 | |
| face width | $b$ | mm | | | 27.6 | |
| helix angle | β | ° | 0 | | 29 | |
| addendum modification factor | $x_1$ | - | 0.270 | | 0.100 | |
| | $x_2$ | - | 0.266 | | 0.077 | |
| tip diameter | $d_{a1}$ | mm | 119.4 | | 117.7 | |
| | $d_{a2}$ | mm | 123.9 | | 127.3 | |
| working pitch diameter | $d_{w1}$ | mm | 110.2 | | 107.6 | |
| | $d_{w2}$ | mm | 114.8 | | 117.4 | |
| normal pressure angle | $\alpha_n$ | ° | 20 | | | |
| transverse contact ratio | $\varepsilon_\alpha$ | - | 1.5 | | | |
| overlap ratio | $\varepsilon_\beta$ | - | 0 | 1.0 | | |
| tooth flank modification | | | | | | |
| generated relief | - | - | no | no | no | yes |
| tip relief pinion/wheel | - | - | short/ short | - | long/ long | short/ short |

gears averaged a value better than DIN 5.

All test gears had a flank roughness of $R_a = 0.2 \ldots 0.3$ µm. Such a smooth flank roughness minimizes micropitting risk and its influence on the pitting load capacity.

**Test Rig**

All pitting tests were run in FZG back-to-back test rigs with a center distance $a = 112.5$ mm (Fig. 2). These test rigs have a closed-power circuit with helical slave gears. Both test rigs are equipped with a speed controller in a range of $n = 50 \ldots 3{,}100$ min$^{-1}$. The helical hand of the slave and test gears is designed to cancel the axial forces on each shaft.

**Test Conditions**

According to the test conditions in Reference 4, the tests were run with constant load until the pitting area exceeded 4% of the active flank area of one tooth, or until a maximum running time of $50 \cdot 10^6$ load cycles on the pinion. All test gears were run in for 6,000 load cycles on the pinion, with a normal contact stress of $\sigma_{H0} = 1{,}000$ N/mm$^2$, and 18,000 load cycles on the pinion with $\sigma_{H0} = 1{,}200$ N/mm$^2$. The pinion speed was $n_1 = 100$ min$^{-1}$. Test lubricant was the FVA-referenced oil No. 3 mixed with four percent Anglamol 99. Table 2 shows the lubricant viscosity. The lubricant was injected in the gear mesh with a temperature of 60°C and a volume flow of $Q_e = 2$–3 l/min. All tests were run with a driving pinion and driven wheel. The pinion speed was $n_1 = 3{,}000$ min$^{-1}$. Consequently, the circumferential speed at the pitch point was $v_t = 17.3$ m/s for type Gk and $v_t = 16.9$ m/s for S0, Slk and Stk.

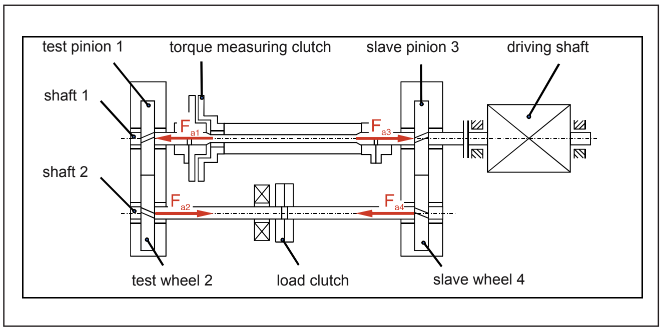


**Figure 2—FZG back-to-back test rig with $a = 112.5$ mm.**

| Table 2: Main lubricant data of FVA reference lubricant no. 3 + 4 % Anglamol 99 | | |
|---|---|---|
| viscosity | | |
| kinematic viscosity | at 40 °C: ν40 | 96 mm²/s |
| | at 60 °C: ν60 | 39 mm²/s |
| | at 80 °C: ν80 | 20 mm²/s |
| dynamic viscosity | at 40 °C: η40 | 85 mPas |
| | at 60 °C: η40 | 34 mPas |
| | at 80 °C: η40 | 17 mPas |

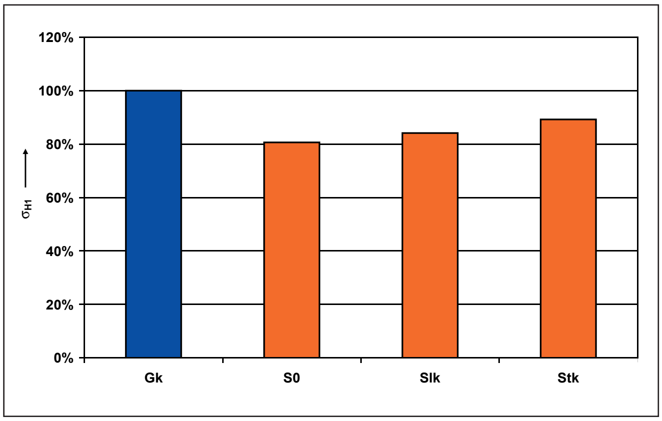


**Figure 3—Experimentally determined endurance contact stress $\sigma_{H1}$ for 50% failure probability, according to ISO 6336-2.**

**Evaluation of the Test Results**

Figure 3 shows the contact stress $\sigma_{H1}$ calculated according to ISO 6336-2 and based on the fatigue-endurable torque for 50% failure probability. The results are shown in Figure 3. Figure 4 shows the fatigue-endurable torques on the pinion of the four gear types—Gk, S0, Slk and Stk—which have the same transverse contact ratio of $\varepsilon_a = 1.5$. In comparison to the referenced spur gear Gk, the best modified helical gear type Stk transmits approximately 32% higher torque, while the endurance contact stress according to ISO 6336-2 is 11% lower. Without flank modifications (gear type S0), the increase of torque is about eight percent compared to the spur gear reference; the endurance contact stress according to ISO 6336-2 is 19% lower.

**Summary of test results:**

- Helical gears with equal transverse contact ratio transfer a higher torque than spur gears.
- For helical gears, the experimentally determined endurance contact stress $\sigma_H$ is smaller than the value calculated according to ISO 6336-2.
- Tooth flank modifications that give uniform stress distribution increase the pitting load capacity.

**New DIN/ISO-Compatible Calculation Method**

Following is a practical calculation method. This method is independent of a calculated pressure distribution, and compatible with the actual ISO 6336-2/DIN 3990–Part 2. Since the maximum contact stress is approximated with simple equations, the pitting load capacity can be determined. It is planned to consider this calculation method in the new ISO 6336-2 as method B.

In FVA 284 I/II, a calculation method was developed, based on the knowledge of the local contact stresses. This method is described in Reference 11.

The modernized calculation method presented here is called RV II (Rechenverfahren II), and uses double-signed variables like $\sigma''_{H0}$. The actual ISO 6336-2 uses no signed variables; e.g., $\sigma_H$.

***Nominal contact stress $\sigma''_{H0}$.***

See Equation 1 on page 49.

defines the basic value $\sigma''_{H0}$ used in calculation method II (RV II):

The factors $Z_H$, $Z_E$ and $Z_\varepsilon$ are identical to the same factors in ISO 6336-2.

**Factor $Z''_\beta$.** According to ISO 6336-2, $Z_\beta$ is calculated with:

$$Z_\beta = \sqrt{\cos\beta}$$

Based on the results of the research projects 284 I/II (Ref. 10), 284 Ib (Ref. 12) and the present research program, the factor $Z''_\beta$ is redefined as

$$Z''_\beta = \sqrt{\frac{1}{\cos\beta}} \qquad (2)$$

$Z''_\beta$ is an empirical factor, which takes the research results for helical gears and theoretical thoughts into account. For gears with only a small helix angle, the factor $Z''_\beta$ should be similar to the factor $Z_\beta$, according to ISO 6336-2. This factor is valid for helix angles between 0° and 35°. The factor $Z''_\beta$ is shown in Figure 5.

**Contact stress $\sigma''_H$.** The contact stress $\sigma''_H$ is calculated according to Equation 3. Compared to the nominal contact stress $\sigma''_{H0}$, the contact stress $\sigma''_H$ considers stress increasing influences resulting from non-uniform load distribution, additional dynamic force and so on.

$$\sigma''_{H\,1/2} = Z'_{B/D} \cdot \sigma''_{H0} \sqrt{K_A \cdot K_v \cdot K_{H\beta} \cdot K_{H\alpha}} \qquad (3)$$

The load factors $K_A$, $K_V$, $K_{H\beta}$ and $K_{H\alpha}$ are the same as in the actual ISO 6336-1.

**Factor $Z''_{B/D}$.** The single-pair tooth contact factor $Z''_{B/D}$ considers that the relevant contact stress for pitting is not necessarily that of the pitch point. With Equation 4, the factor $Z''_{B/D}$ can be calculated to estimate the maximum contact stress.

$$Z''_{B/D} = Z_{B/D} \sqrt{f_{ZCa\,1,2}} \qquad (4)$$

With $Z_{B/D}$ according to ISO 6336-2 and $f_{ZCa1,2}$ according to equations 5,6,7,8 or 9 (Table 3).

The factor $Z_{B/D}$ is from ISO 6336-2. The contact stress of point B (inner point of single contact) is important for spur gears. So for spur gears the factor $Z_{B/D}''$ is the same as the factor $Z_{B/D}$, according to ISO 6336-2. In this case the factor $f_{ZCa1,2}$ is 1.0 (Table 3). Thus the calculation method for spur gears remains unchanged.

**Factor $f_{ZCa}$.** The tooth flank correction factors $f_{ZCa1,2}$ for pinion and wheel consider the higher contact stress at the beginning and the end of the path of contact for helical gears, for the case where there are inadequate tooth flank modifications. Table 3 describes the determination of the tooth flank correction factor.

The tooth flank correction factor $f_{ZCa}$ depends on the load and considers inadequate tooth flank modifications through comparison of the existing and required tooth flank modifications. Here only the amount of profile modifications is taken into account, but an adequate length of the modifications

$$\sigma''_{H01/2} = p_C \cdot Z_\varepsilon \cdot Z''_\beta = Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z''_\beta \cdot \sqrt{\frac{F_t}{d_1 \cdot b} \cdot \frac{u+1}{u}}$$

Equation 1.

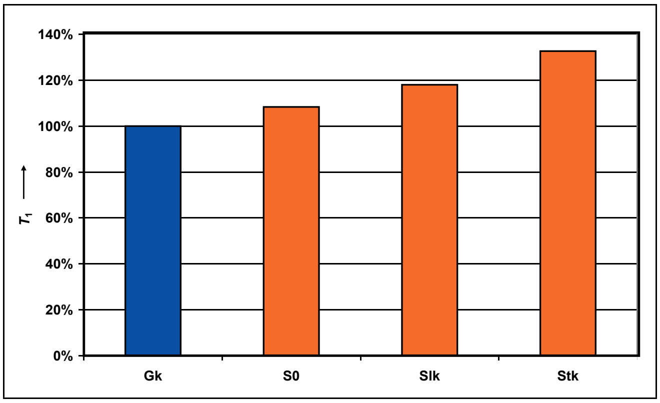


Figure 4—Fatigue-endurable torque on pinion $T_1$ of the tested gear types Gk, S0, Slk and Stk.

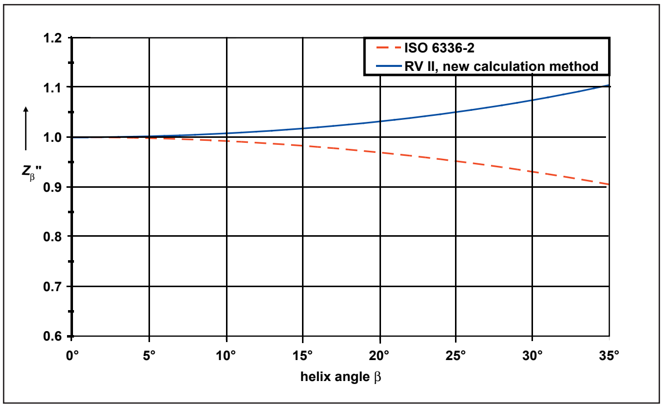


Figure 5—Helix angle factor $Z''_\beta$ according to Equation 2 in comparison to $Z_\beta$ according to ISO 6336-2.

| Table 3: Determination of the tooth flank correction factor $f_{ZCa1,2}$. | |
|---|---|
| spur gears (β = 0 °), with and without modifications: | $f_{ZCa1,2} = 1.0$ (5) |
| helical gears (β > 0 °), with and without modifications (tip relief, root relief): | $f_{ZCa1,2} = \sqrt{1+\left\lvert\frac{Ca - Ca_0}{Ca_0}\right\rvert}$ (6)<br>$1.1 \le f_{ZCa\,1,2} \le 1.2$<br>*Ca*: effective amount of profile modification<br>$Ca_0$: tooth deflection |
| helical gears (β > 0 °), with profile and lengthwise modifications, calculated with a 3D-load distribution program for working load and operated at this load: | $f_{ZCa1,2} = 1.0$ (7) |
| helical gears (β > 0 °), with profile modifications, designed for working load and operated at this load: | $f_{ZCa1,2} = 1.1$ (8) |
| helical gears (β > 0 °), without modifications and without calculating $f_{ZCa\,1,2}$ according to equation (6): | $f_{ZCa1,2} = 1.2$ (9) |

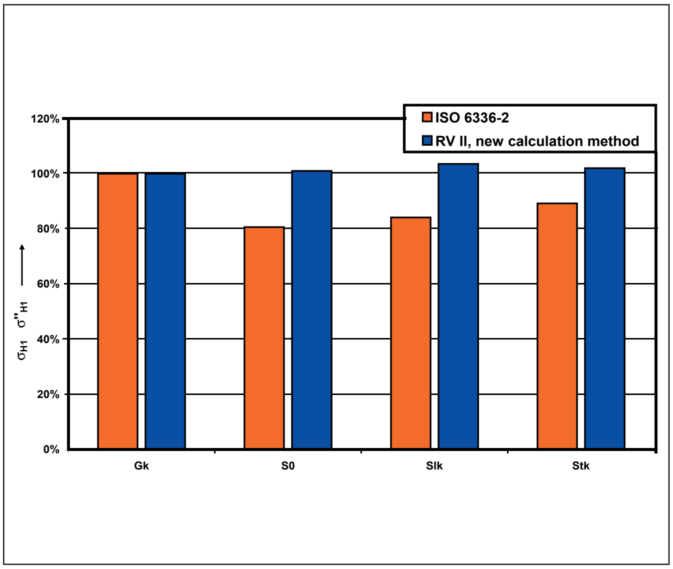


Figure 6—Contact stress according to ISO 6336-2 and to the new calculation method RV II.

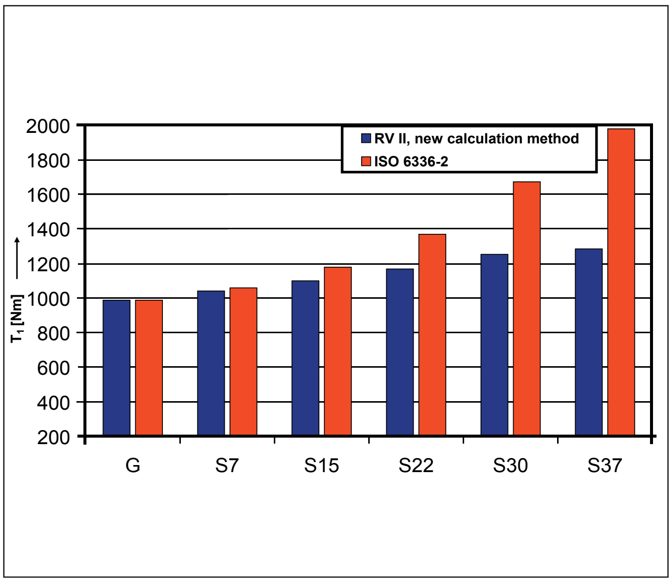


Figure 7—Permissible torque according to ISO 6336-2 and to the new calculation method RV II.

Table 5: Permissible torque for $\sigma_{HP}$ = 1500 N/mm² according to ISO 6336-2 and to the new calculation method (RV II)

| gear type | $f_{ZCa1}$ | $Z_B$ | $Z_B''$ | $T_{1,ISO6336}$ [Nm] | $T_{1,RVII}$ [Nm] |
|---|---|---|---|---|---|
| G | 1.0 | 1.02 | 1.02 | 991 | 991 |
| S7 | | 1.01 | 1.01 | 1062 | 1044 |
| S15 | | 1.01 | 1.01 | 1182 | 1103 |
| S22 | | 1.0 | 1.0 | 1372 | 1171 |
| S30 | | 1.0 | 1.0 | 1675 | 1256 |
| S37 | | 1.0 | 1.0 | 1981 | 1287 |

is required. If the whole flank topology is to be considered, the calculation method according to Reference 11 can be used.

For spur gears, the tooth flank correction factor $f_{ZCa1,2}$ is 1.0. Hence it is assumed that the contact stress of the inner point of single contact (B) is higher than the contact stress of the starting point (A) with double-tooth contact, which is the usual case for practical spur gears.

If helical gears have no tooth modifications or only standard modifications—like tip or root relief—the factor $f_{ZCa1,2}$ is calculated according to Equation 6.

The value ranges from 1.1 to 1.2. For helical gears with adequate tooth modifications, which cause maximum contact stress near the pitch circle, the factor $f_{ZCa1,2}$ is 1.0. These adequate tooth modifications are normally generated. For helical gears with tooth modifications designed for the working load and operated at working load, the factor $f_{ZCa1,2}$ is 1.1. For helical gears without modifications a tooth flank correction factor $f_{ZCa1,2}$ = 1.2 can be estimated.

***Existing and required profile modifications***. The amount of profile modification $C_a$ in Equation 6 is the actual profile modification on the tooth flank in microns. $C_{a0}$ is the required amount of profile modification in microns for having the maximum contact stress around the pitch point, not at the beginning or the end of the path of contact. The required profile modification can be calculated according to the manufacturer's experience or recommendations, according to Niemann/Winter (Ref. 6), Sigg (Ref. 9) or Equation 10.

$$Ca_0 = \frac{F_t / b}{c_\gamma} \qquad (10)$$

The factor $C_{a0}$ depends on the load for all recommendations. According to Equation 10, the required profile modification is calculated by the nominal tangential load $F_t$, the face width $b$ and the stiffness $c_\gamma$, according to ISO 6336-1.

## Applying the New DIN/ISO-Compatible Calculation Method

The following contact stresses are calculated from the fatigue-endurable torque. Figure 6 shows the contact stresses on pinion $\sigma_{H1}$ of the test gears according to ISO 6336-2, as well as the contact stress $\sigma''_{H1}$, as determined by the new ISO-compatible calculation method RV II. Obviously the calculation method RV II gives the same contact stress for the spur gear as ISO 6336-2. However, for helical gears a higher contact stress is calculated.

The contact stresses of the different gear types $\sigma_{H1}$ according to ISO 6336-2 range in a spread of ± 11% of the mean value. According to RV II, the contact stresses $\sigma''_{H1}$ range in a spread of ± 2% of the mean value. Especially for the helical gears with practice-relevant modifications (Slk and Stk), the calculated contact stresses (RV II) are nearly the same as the contact stress of the spur gear.

Consequently the new calculation method RV II corresponds better to test results than the ISO 6336-2 calculation method.

**Theoretical Study to Determine the Influence of Helix Angle on the Endured Torque**

The following study estimates the permissible torque as a function of the helix angle according to the new calculation method. Therefore the contact stresses according to RV II for six different gears (Table 4) were calculated. All gears have the same center distance, face width, transverse pressure angle, transverse module, number of teeth, transverse contact ratio and constant tip diameter. The permissible contact stress is the same as in ISO 6336-2.

The maximum endurable torque can be determined for the condition where the contact stress according to the new calculation method is equal to the permissible contact stress according to ISO 6336-2:

$$\sigma''_H = \sigma_{HP} \quad (11)$$

A permissible contact stress of $\sigma_{HP}$ = 1,500 N/mm² is assumed for all gears. The load factors and $f_{ZCa1}$ are set to 1.0 ($K_{ges} = K_A \cdot K_v \cdot K_{H\beta} \cdot K_{H\alpha} = 1.0$ and $f_{ZCa1} = 1.0$).

Consequently, it is assumed that all helical gears have uniform load distribution, resulting from adequate flank modifications.

The calculated torque $T_1$ on the pinion and the main factors according to the new calculation method are printed in Table 5, and the permissible torques are shown in Figure 7. Obviously, the permissible torque increases with increasing helix angle. In comparison to the spur gear (G), the helical gear S30, with a helix angle of 30°, has a 30% higher calculated torque.

**Conclusions**

The results of the experimental part of this research project prove that the calculation of the contact stress according to ISO 6336-2/DIN 3990–Part 2 isn't accurate for helical gears.

Hence a new calculation method to determine the pitting load capacity was developed. This calculation method is compatible with ISO 6336-2/DIN 3990–Part 2. It takes the maximum contact stress into account and can be used as a new method B. This calculation method, called RV II, treats helical gears more precisely than ISO 6336-2, and is capable of accounting for tooth modifications. For spur gears the new calculation method is equal to ISO 6336-2.

**Acknowledgments**

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# Manufacturing Net-Shaped, Cold-Formed Gears

Dr. Dennis M. Engelmann

**Management Summary**

A net-shaped metal forming process has been developed for manufacturing quality, durable, high-yield and cost-efficient gears for high-volume production. In this article, the development of net-shaped cold-formed gears (CFG) by using the divided flow method will be presented, along with their suitable applications. The manufacturing technique and equipment will be introduced, as well as the advantages and limitations. Applicable materials and heat treatment practices will also be discussed. Gear tooth inspection charts will be presented and compared to conventional manufacturing methodologies.



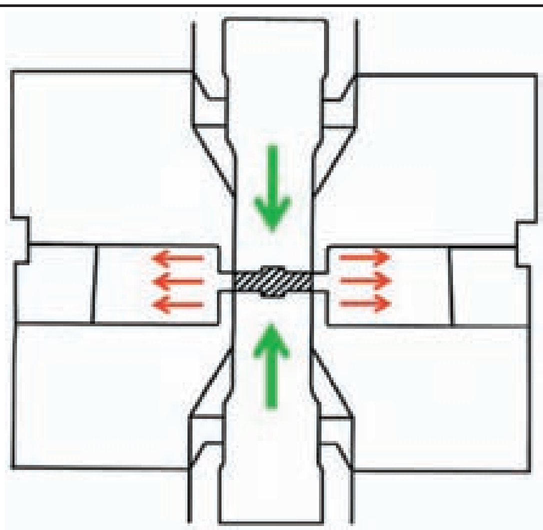

Figure 1—Cold forming by the divided flow method.

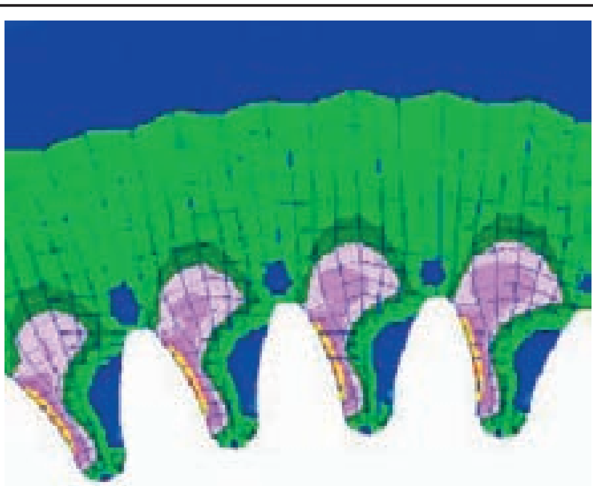

Figure 2—Gear die stress distribution.

## Introduction

Cold forming/cold forging is a bulk metal forming process where a metallic workpiece is plastically deformed into a tool by a press. The workpiece and tooling are at room temperature—i.e., they are not pre-heated, as in the case of hot forging.

The advantages of using a cold forming process to manufacture parts are: 1) there is less material waste since material is being displaced and not removed; 2) the parts can be made at very high production rates; 3) the parts are strong due to the work hardening of the material; 4) the parts have tight tolerances; and 5) the parts have excellent surface quality.

Cold forming by the divided flow method is a process where a workpiece is simultaneously pressed from an upper punch and a lower punch, allowing the material to flow radially outward into the die cavity (Fig. 1). This process is typically used for forming rotational symmetric components.

A net-shaped or near-net-shaped forming process is one where no or minimal secondary and/or finishing operations are necessary. A net-shaped gear is a gear where the teeth do not need to be machined or finished.

## Development

To begin development of cold forming gears, finite element analysis (FEA) was used to determine how much forming load is required, how the material will flow, and how much the tools will deflect (Fig. 2).

Since metal forming involves movement of large amounts of material, a plastic deformation (non-linear) finite element software program is required. Today there are over a dozen commercially available FEA software packages capable of simulating metal forming processes, cold or hot.

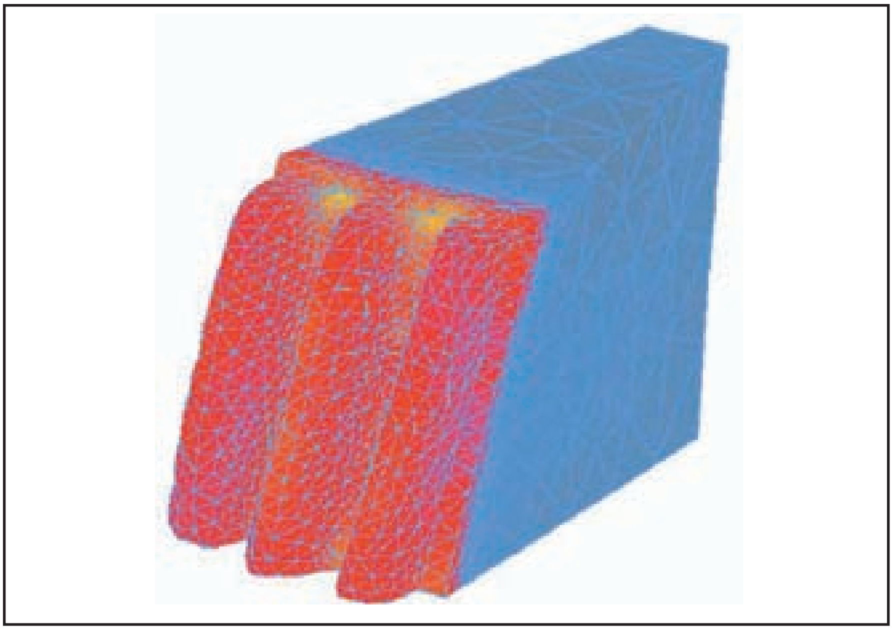

Figure 3—CFG strain distribution.

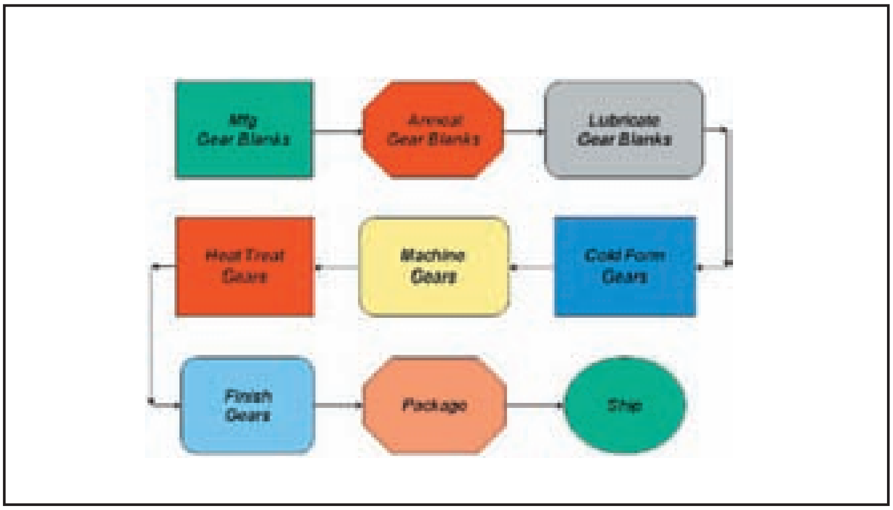



Figure 4—CFG process flow chart.

An advantage of using FEA simulation during the development phase is to be able to determine the overall effects of parameters on the results; e.g., the effects of the punch geometry on the material flow, the effects of the material alloying and processing on the forming load, etc. (Fig. 3). As a developmental tool, FEA simulation allows the user to test several "what if" scenarios without having to manufacture expensive "hard" tools. FEA simulation can also be used to help determine what type and size of manufacturing equipment is required to cold form a family of gears.

The FEA simulation results were used to conduct an initial feasibility analysis to determine the process limitations and manufacturing equipment requirements, and to estimate if the process yields a competitive product.

## Processes and Equipment

Net-shaped cold forming of gears does not require any additional manufacturing processes over the traditional gear manufacturing process. Simply put, the gear cutting process is replaced by a metal forming process. Furthermore, conventional pre- and post-processing operations are applicable. Figure 4 illustrates a typical cold-formed gear process flow.

***Gear materials***. The cold formability of steel is dependent primarily on the amount of carbon in the steel. The lower the amount of carbon content—e.g., 8620 vs. 8640—the smaller the forming load and the less the tools will be stressed. The alloy content and the raw material processing also play a role in how the material will flow—e.g., 1040 vs. 4140. For most gear configurations, the common gear materials ranging from low carbon steels (1020) to medium carbon-alloyed steels (4340) can be formed. If the carbon content is above 40 points, it is better to consider hot forging, which will improve the metal flow and reduce the forming loads.

***Gear blank manufacturing***. As with many manufacturing processes, it is important to start with an inexpensive blank, whether it is a blank turned from bar stock or a blank cold-formed from coiled wire. The optimal blank manufacturing process depends on the size and shape of the blank required.

If a gear blank is under 50 mm, then the blanks could be cold-formed using coiled wire on a cold header at speeds ranging from 60 to 180 parts-per-minute. If a gear blank is larger than 50 mm, then it could be turned from bar stock or in some cases hot-formed.

In order to cold-form gears, it is generally better to anneal the gear blanks to remove the residual stresses and any "work hardening" effects from prior processing of the material. Annealing softens the gear blanks and makes them more formable, which reduces the forming load required to deform the material.

Since the gear blanks will be cold-formed in a tool cavity, lubricants and coatings must be used in order to avoid galling. Forming oils and/or zinc phosphate coatings are typically used to coat the blanks. PVD (physical vapor deposition) coatings such as TiCN (titanium carbo-nitride) are used to coat the tools.

***Forming press***. In order to plastically deform the workpiece into the die cavity, a forming press is required. For the divided flow method, the press can be either a mechanical or hydraulic forming press, depending on the complexity of the part and accuracy required. The main advantage of a single-action mechanical press is the high productivity rates. However, a hydraulic press can have


Figure 5—Triple-action hydraulic press.

Figure 6—Gear-forming tools.

more than one action and deliver desired forming loads and speeds at specific points throughout the stroke of each action with precision.

For the development and production of cold-formed gears, a 1,200 ton, triple-action CNC hydraulic press is used (Fig. 5).

**Gear Tooling**

Since cold forming processes occur at room temperature, the forming loads required to plastically deform steels are very high. Hence, the stresses in the tooling are also very high, which can lead to premature tool failure. Advancements in tool steels and the development of more formable steels has enabled cold forming processes to be applied to more complex, precise components that were not possible earlier.

Cold form gear tooling consists of a die set, gear die, punches and die clamping rings (Fig. 6). Since these tools touch the workpiece, they are unique for each gear. These tools have a limited tool life due to the high stresses (fatigue) and frictional contact (wear), and as such are considered to be "perishable" tooling.

The die set that holds the perishable tools is considered to be durable tooling. The durable tools are not unique for each gear and have a much longer tool life because they typically are not as highly stressed and do not experience as much wear.

Standard tool steels such as shock-resistant (S); molybdenum (M) and tungsten (T) high-speed; water (W), oil (O) and air (A) hardening; and high-carbon/high-chromium (D) tool steels can be used for cold forming gears.

Due to the high forming loads during cold forming, the gear tooling elastically deflects. When the tool deflection is consistent from part to part, it is possible to compensate for the elastic deflection during the manufacturing of the perishable tools. Generally, a gear die should be manufactured a few quality levels better than the final product.

***Machining operations***. After the gear teeth are cold-formed, the gears are said to be in the "green" state because they have not yet been hardened. In this state, features on the gear that could not be cold-formed—such as chamfers, grooves, clutch face features, etc.—can be machined using standard CNC equipment.

***Heat treatment***. The heat treatment of cold-formed gears, as with conventional gear manufacturing processes, depends on the base material. Cold-formed gears of lower carbon content can be case hardened, while medium carbon content gears can be through hardened. The use of heat treat baskets aids in the handling of the gears and the uniformity of the hardening results (Fig. 7). Cold-formed gears can also be induction hardened inline.

***Finishing operations***. After hardening of the gears, the center hole can be honed, the faces or any bearing surfaces can be ground and, for high quality gears, the gear teeth can be ground, all using standard production equipment.

## Gear Quality

The gear quality, like in all conventional gear manufacturing methods, is dependent on the manufacturing process tolerances and consistencies. Since a gear blank is formed in a closed die, the volume (weight) of the gear blank is important. If there is not enough material, there will be underfill in areas of the gear. If there is too much material, the die cavity will be overfilled, causing excessive tool stresses and eventually breaking the die.

The forming press is more than just a big hammer to smash the gear blank. In fact, the more accurately the press can be controlled, the more accurate the gears will be. The more consistently the press can apply the forming load, the more consistent the gears will be from part to part.

The gear die has the largest influence on the gear quality. As stated earlier, the gear die tooling will be made a few quality classes better than the desired gear quality. In addition, the elastic deformation of the tooling must be compensated for and incorporated into the tool design. The selection of tool materials, coatings, and manufacturing methodologies is very important in making a high-quality gear die.

Figure 7—Gear heat treat baskets.


Figure 8—Material savings.

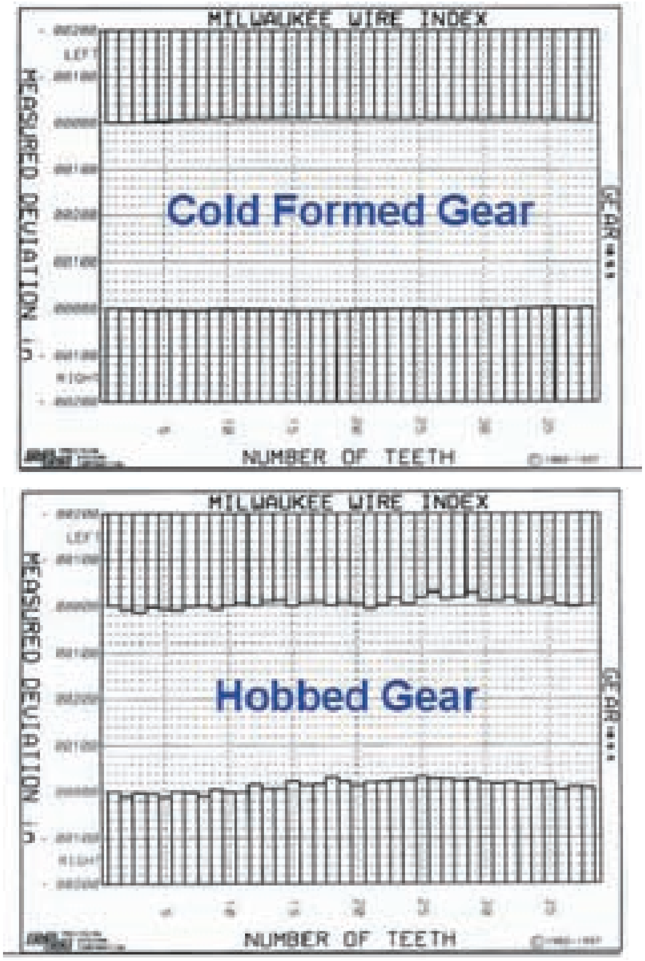


Figure 9—Comparison of tooth-to-tooth variation for a cold-formed gear and a hobbed gear.

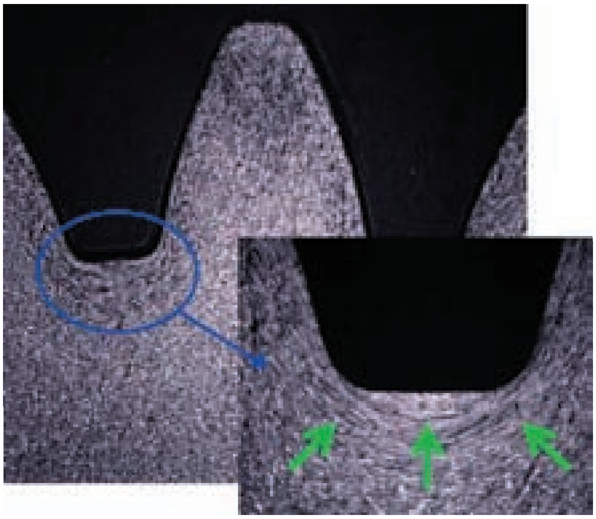

Figure 10—Strain hardening.

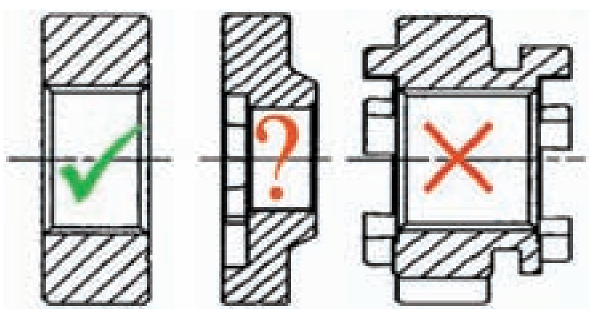

Figure 11—Gear configurations.

Machining, finishing and heat treatment affect a cold-formed gear's quality as much as and in the same ways as they do for a cut gear.

Depending on the gear configuration, a net-shaped, cold-formed gear will typically yield an AGMA Q8–Q9 finished quality gear.

### Advantages of Cold-Formed Gears

The advantages of manufacturing gears by cold forming are: 1) high production rates; 2) effective material usage; 3) small tooth-to-tooth variation; and 4) high strength and high durability.

***High production rate***. Since all of the teeth are formed simultaneously, the time it takes to fill the die cavity is only a few seconds. Cycle time varies based on the size and configuration of the gear, but most gears can be cold formed at rates of 2–10 parts per minute.

***Effective material usage***. An advantage to the closed die forging process is that material is not being removed, but displaced. This typically results in a 5–10% material savings just from forming the gear teeth as opposed to cutting them.

An additional material savings of 10–30% is possible by designing a thinner web (Fig. 8). The forming punches can be designed so that a thinner symmetrical web can be formed without "putting chips on the ground." Hence, a lighter blank can be used with shaped forming punches.

***Small tooth-to-tooth variation***. As can be seen in Figure 9, a cold-formed gear has less tooth-to-tooth variation than hobbing, since all of the gear teeth are formed simultaneously in a precise gear die. This could result in a smoother, quieter and longer-running gear.

***High strength and high durability***. Cold forming steel induces local work hardening into the material which will yield a stronger product. As can be seen in Figure 10, most of the work hardening occurs in the root. Durability tests have shown that cold-formed gears can also withstand higher impact loads than powder metal gears.

### Applications and Limitations

To be competitive with conventional gear manufacturing processes, a cold-formed gear must be manufactured so that it can economically replace an existing gear. Some potential applications of cold-formed gears are in the automotive, recreational vehicle, power hand tool, lawn & garden, appliance, and gear motor industries.

As with any process or product, there are physical and economical limitations to its applications. Loose, flat spur and helical gears are good candidates for net-shaped cold-forming by the divided flow method (Fig. 11). Some gears with hubs or webs can be designed for cold forming. Gears with large, asymmetrical protrusions or pockets cannot be net-shape cold formed. These types of features are best done by machining.

The size limitation of cold-formed gears is dependent primarily on the manufacturing equipment. The larger the gear and the less the material is form-able, the larger the forming press required. The smaller the gear, the higher the tool stresses.

Medium- to fine-pitch gears are good candidates for cold forming, but large-pitch gears should not be excluded, depending on the configuration. The larger the pitch diameter to face width ratio (PD:FW), the easier it is to form the gear. The closer the PD:FW ratio is to one, the more difficult it is to form the gear teeth uniformly. The higher the helix angle, the more the tooling will be stressed and deflect. The higher the gear tolerances, the lower the tool life.

Even after compensating for the elastic tool deflection, it is not possible to consistently cold form gears above AGMA Q9 class. It is, however, possible to grind a cold form gear to improve its quality class while capturing the other advantages of a cold-formed gear stated in the previous section. In other words, a near-net-shaped, cold-formed gear could be ground to yield an AGMA Q10 or higher quality gear.

Lastly, due to the large capital investment for the forming press and the high-quality gear die required, it is normally not economical to cold form gears for low annual volume productions. In addition, since the gear die cannot be easily modified, the process is best for long-term programs where the gear tooth geometry does not change often.

**Closing Remarks**

The process of net-shaped cold-forming gears by the divided flow method was introduced. The manufacturing processes and equipment, the advantages and limitations, were discussed.

High-volume, loose, flat spur and helical gears with large pitch-diameter-to-face-width ratio in the AGMA Q8 to Q9 quality classes are good candidates for this technology.

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# Calibration of Two-Flank Roll Testers

Richard L. Thoen

**Management Summary**

The presence of significant errors in the two-flank roll test (a work gear rolled in tight mesh against a master gear) is well-known, but generally overlooked. Of the various sources of error, one is the attenuated response of a two-flank roll tester to gear defects. In this article, it will be shown how to design and inspect a device for measuring this particular error.

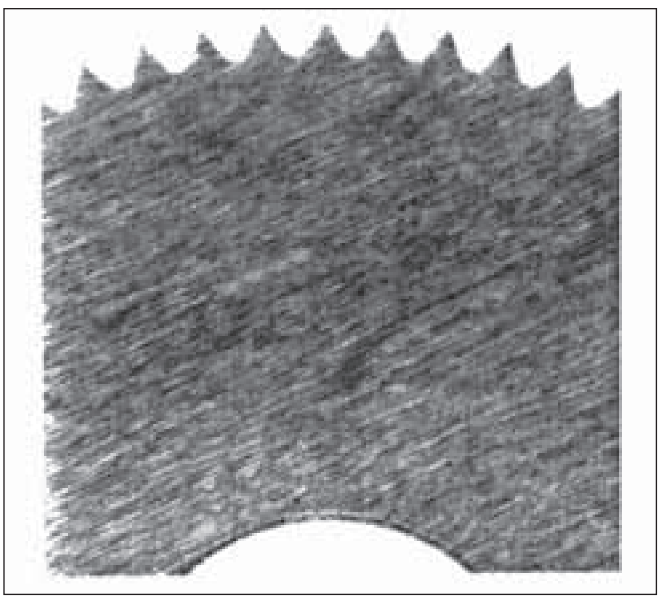

Figure 1—Pointed-tooth gear.

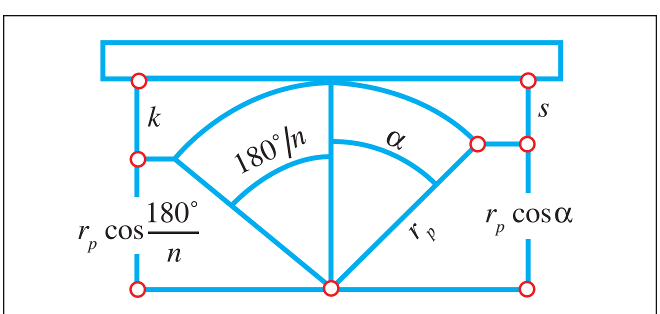


Figure 2—Calculation of pointed-radius and carriage displacement.

## Introduction

Historical evidence shows that measured values for kickout (also known as tooth-to-tooth composite error; terminology rarely used by shop personnel) on the same gear can differ from one two-flank roll test to another. For example, Michalec and Karsch conducted a correlation study (Ref. 1) wherein an assortment of 100 fine-pitch precision gears was inspected at 20 different facilities for total composite error, tooth-to-tooth composite error (kickout) and testing radius. In their final report, in addition to finding "a wide variation of measurements among companies," they "decided to eliminate" the study of kickout, because "the readings contained considerable uncertainty."

If a similar correlation study were to be conducted today, the discrepancies probably would be similar, since there has been no marked improvements in inspection practice and test equipment. This article deals with a method of calibrating the response of two-flank roll testers to a known kickout.

## Basic Geometry

One way to generate a known kickout is with a pointed-tooth gear (Fig. 1), where the points contact a flat (not an arbor) mounted on the floating carriage of the roll tester.

From Figure 2 it is seen that, for a given kickout ($k$) and tooth number ($n$), the pointed-radius ($r_p$) is:

$$k + r_p \cos \frac{180°}{n} = r_p \qquad (1)$$

so that…

$$r_p = \frac{k}{1 - \cos \frac{180°}{n}} \qquad (2)$$

Another way to generate a known kickout is with an eccentric disc. However, the carriage motion would be sinusoidal, unlike the abrupt reversals seen in practice.

Likewise, for a specified pointed radius ($r_p$) and rotation angle ($\alpha$),

$$r_p \cos\alpha + s = r_p \quad (3)$$

so that the carriage displacement ($s$) is:

$$s = r_p\,(1-\cos\alpha) \quad (4)$$

From Figure 3 (a plot of Eq. 1), it is seen that the pointed radius ($r_p$) increases with both kickout ($k$) and tooth number ($n$). And from Figure 4 (a plot of Eq. 2 for $n$ = 72 and $k$ = 0.0008"), the carriage undergoes an abrupt reversal at $\alpha = 180°/n$.

From Figure 5 it is seen that the tooth thickness ($t$) that corresponds to a specified pointed radius ($r_p$) is

$$\mathrm{inv}\varphi_p = \mathrm{inv}\Phi + \frac{t/2}{r} \quad (5)$$

where…

$$t = \frac{\pi}{2P} + \Delta t \quad (6)$$

and…

$$r = \frac{n}{2P} \quad (7)$$

$P$ is the diametral pitch and $\Phi$ is the profile angle, so that…

$$\Delta t = \frac{\left[(\mathrm{inv}\varphi_p - \mathrm{inv}\Phi)n - \frac{\pi}{2}\right]}{P} \quad (8)$$

where…

$$r_p \cos\varphi_p = r_b = \frac{n}{2P}\cos\Phi \quad (9)$$

so that…

$$\cos\varphi_p = \frac{n}{2P}\,\frac{\cos\Phi}{r_p} \quad (10)$$

Also, from Figure 6 it is seen that the clearance ($c$) between the pointed tip and the root of a topping hob is

$$r + \Delta C + \frac{1}{P} = r_p + c \quad (11)$$

so that …

$$c = \frac{n+2}{2P} + \Delta C - r_p \quad (12)$$

where, from the well-known equation for a rack (Ref. 2),

$$\Delta C = \frac{\Delta t}{2\tan\Phi} \quad (13)$$

## Numerical Example

A pointed-tooth gear (Fig. 1) can be inspected with a micrometer by measuring over diametrically opposite tooth

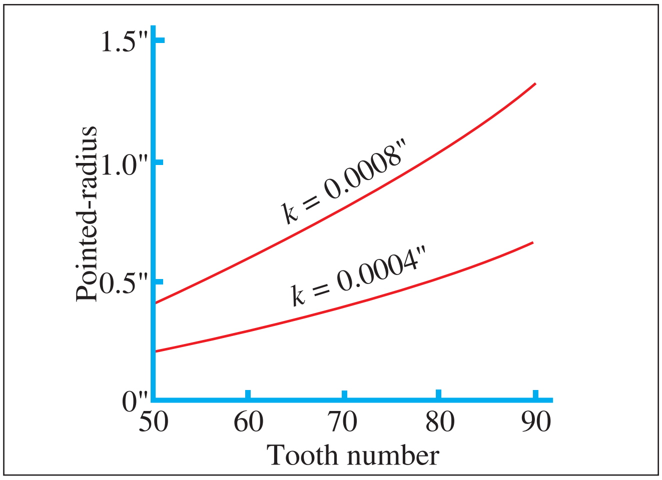


**Figure 3—Pointed-radius versus kickout and tooth number.**

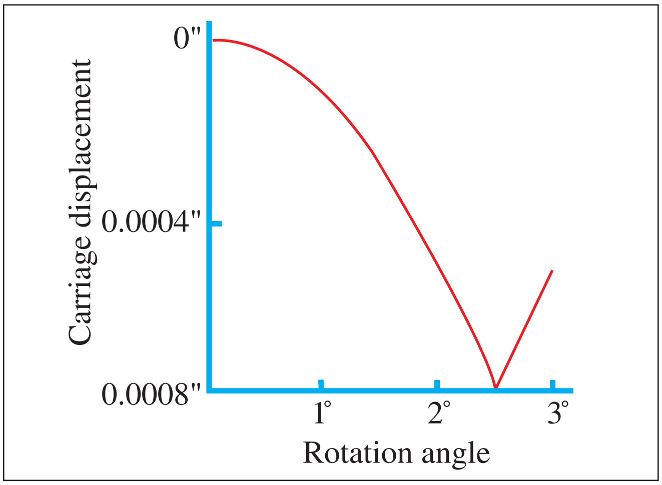


**Figure 4—Carriage displacement versus rotation angle.**

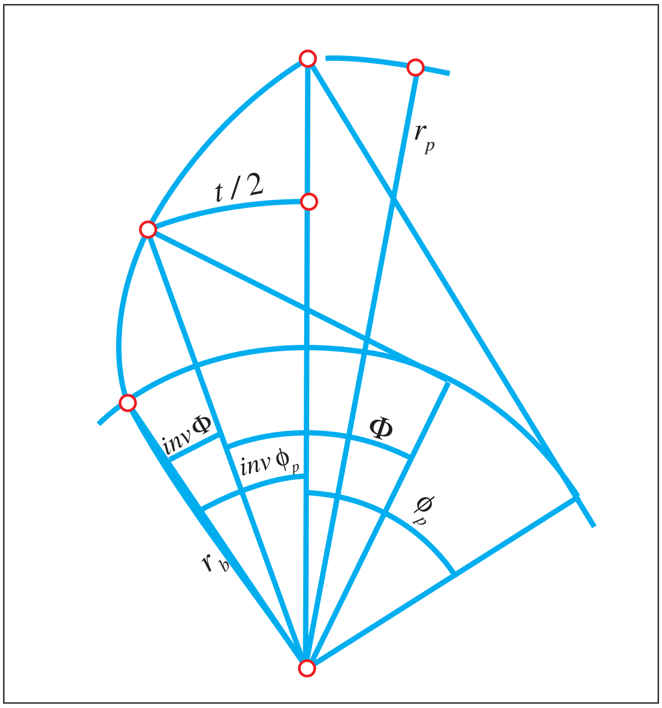


**Figure 5—Calculation of tooth thickness for a specified pointed-radius.**

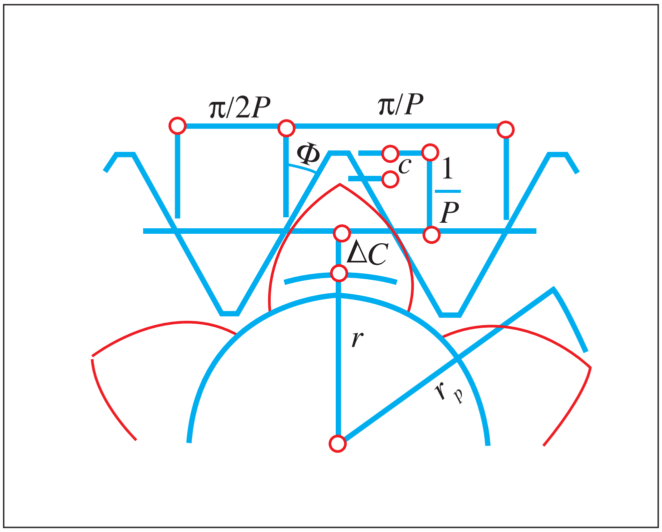


**Figure 6—Calculation of clearance between pointed tip and root of topping hob.**

| Table 1—Calculated Data For Tip Clearance | | | | | |
|---|---|---|---|---|---|
| $n$ | $r_p$ | $\varphi_p$ | $\Delta t$ | $\Delta C$ | $c$ |
| 70 | 0.7945" | 30.4106° | 0.02747" | 0.0377" | -0.007" |
| 72 | 0.8405" | 33.0167° | 0.05528" | 0.0760" | 0.006" |
| 74 | 0.8879" | 35.3337° | 0.08649" | 0.1188" | 0.023" |

spaces (contact on four tooth tips, which requires an even tooth number), and over diametrically opposite tooth tips, the difference being double the kickout.

For a pointed-tooth gear of about 1.5 inches diameter (for ease of turning by hand) and a 48*P*, 20° topping hob, feasible tooth numbers are: 70, 72 and 74.

For $k = 0.0008"$, the values for $r_p$ (Eq. 1), $\varphi_p$ (Eq. 4), $\Delta t$ (Eq. 3), $\Delta C$ (Eq. 6) and $c$ (Eq. 5) are tabulated in Table 1, wherein it is seen that the 70-tooth gear is topped, and that either the 72- or 74-tooth gears are applicable.

When hobbing a pointed-tooth gear, it is convenient to obtain size via a span measurement. For the 72-tooth gear, the span dimension over 14 teeth is 0.9032" (Ref. 3), which can be measured with an ordinary micrometer.

## Conclusion

It should be noted that widespread calibration of two-flank roll testers is not likely to occur in the near future. For example, Darle Dudley was asked if "gear development has been evolutionary or revolutionary." He replied (Ref. 4):

"I think gearing evolves. Historically, 10 to 40 years may pass from when a new idea is first heard of to when it becomes an established trade practice."

Likewise, the National Bureau of Standards set up a Gear Metrology Laboratory (Refs. 5 and 6) in 1961, only to terminate it in 1970 due to lack of demand. (Editor's note: The national gear metrology lab was reborn in 1994. See our article on page 62 for details.)

Also, for more than 50 years it has been known that measured values for kickout and tooth thickness can vary with the number of teeth on the master gear (Refs. 7 and 8), a phenomenon ignored by one and all.

And George Grant, inventor of the hobbing machine (Ref. 9), encountered apathy during the transition from cycloids to involutes. He wrote (Ref. 10):

"There is no more need of two different kinds of tooth curves for gears of the same pitch than there is need for two different threads for standard screws, or two different coins of the same value. The cycloidal tooth would never be missed if it were dropped altogether. But it was first in the field, is simple in theory, has the recommendation of many well-meaning teachers and holds its position by means of 'human inertia,' or the natural reluctance of the average human mind to adopt a change, particularly a change for the better."

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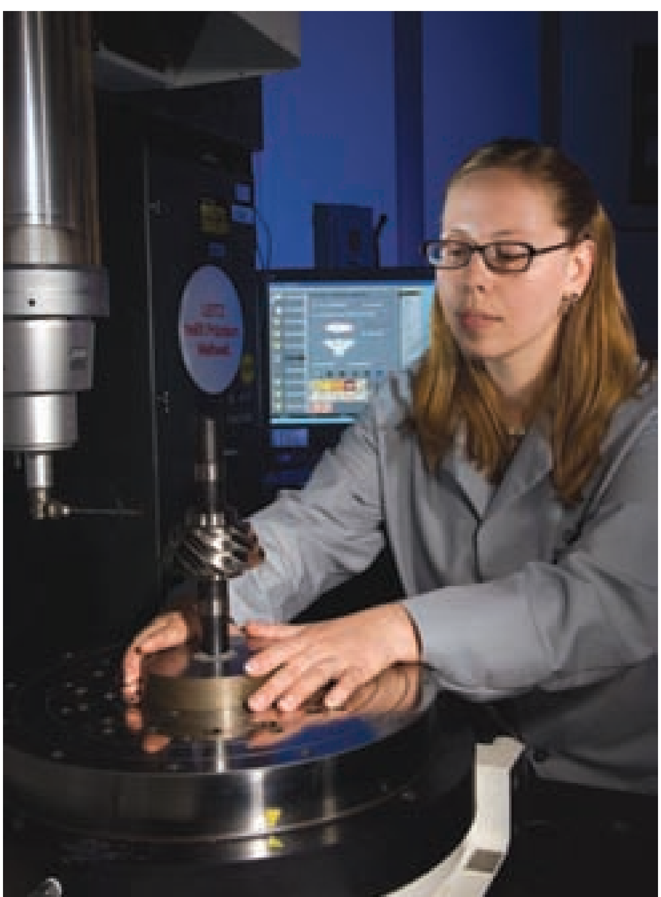
Kevin Martin measuring length artifact on a Moore M48 CMM.



Suzanne Canning measuring a bevel gear artifact on a Leitz PMM.

# Update on the National Center for Gear Metrology

Bruce L. Cox

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## Introduction

The National Center for Gear Metrology (NCGM) was established in October 1994 as a result of $3-million stipend awarded through the Department of Defense's Technology Reinvestment Program. A partnership was formed between the American Gear Manufacturers Association, the American Society of Mechanical Engineers, National Institute of Standards and Technology, Pennsylvania State University and Department of Energy National Nuclear Security Agency (NNSA) Y-12 National Security Complex to establish the NCGM. The center, located in Oak Ridge, Tennessee, contains state-of-the-art coordinate measuring machines (CMM) for the calibration of all types of gear artifacts.

## Capabilities

The NCGM is climate controlled to a temperature of ± 0.1° C. It has two Leitz 866 PMM CMMs, a Federal Formscan 3200 circular geometry instrument and a Moore M32 CMM. Also located in a nearby laboratory is a Leitz 866 PMM CMM with an optical head, a Moore M48 CMM, two super micrometers and a Talyrond roundness instrument. Types of gear artifact calibrations performed include involute profile, helix, index, pin and master gears. Involute profile and index of fine pitch master gears can be calibrated on the Leitz 866 PMM CMM with the optical head. The types of gear artifacts that have been calibrated include Fellows, ITW, Höfler, Klingelnberg, Koepfer and Maag. Special types of artifacts can be calibrated upon request.

### Uncertainty

The NCGM is the only laboratory accredited for gear artifact calibration by the National Voluntary Laboratory Accreditation Program (NVLAP). The uncertainties for gear artifact calibration were co-developed by the NIST. Traceability to national or international standards is provided under the guidelines of ANSI/ISO/IEC 17025-2005. Stated uncertainties are as follows:

| | |
|---|---|
| • Involute profile | 0.9 micrometers |
| • Helix | 0.8 to 1.4 micrometers |
| • Pin offset | 0.7 micrometers |
| • Pin diameter | 0.5 micrometers |
| • Pin roundness | 0.3 micrometers |
| • Index and runout | 1.6 arcseconds |

### Future Plans

The controllers for the Moore M32 and M48 CMMs are being upgraded. The new controllers will provide expanded capability and hopefully lower uncertainties to be developed. Plans also include expansion into bevel gear calibration. Intercomparisons with other international metrology institutes will continue to be conducted to ensure that the calibration uncertainties are equivalent with other laboratories worldwide.

## For more information:

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**Gear Technology Correction**:

Correction: In the March/April 2008 issue of *Gear Technology*, paragraphs were omitted from Timothy Krantz and Brian Tufts' technical article, "Pitting and Bending Fatigue Evaluations of a New Case-Carburized Gear Steel" (Page 57). For the full technical article with references please visit *www.geartechnology.com*/issues/0308


RESCUE
ONE

# International PM Community Converges in North America

## AT 2008 WORLD CONGRESS

Technical sessions offer opportunity for technology exchange on a host of topics.

"If you are involved with the PM industry or interested in it, this is the place to be," says Jim Dale, vice president, member and industry relations for the Metal Powder Industries Federation (MPIF).

The 2008 World Congress on Powder Metallurgy and Particulate Materials is sponsored by the MPIF and APMI International with the cooperation of various international organizations involved with the powder metallurgy industry. MPIF includes six separate trade associations aimed at prominent sectors of the PM business. APMI is a technical society for people working in PM technology or interested in growth related to the industry.

The world congress is a larger, more inclusive version of the MPIF's International Conference on Powder Injection Molding of Metals, Ceramics and Carbides, which meets annually and attracts fewer international representatives. Attendance at this year's world congress is expected to exceed 1,500 people from 45 countries with 425 technical papers in 133 sessions.

The world congress is hosted in North America once every six years because the event alternates locations with two other major international PM organizations: the European Powder Metallurgy Association and the Japan Powder Metallurgy Association. In 2006 the world congress was held in Korea, and the next one is slated for Florence in 2010. Attendance at the event jumps 40–60 percent from the smaller PIM world conference because of the substantial international participation, according to Dale.

The nation's capital was an ideal location choice for the world congress's planners. "Washington was chosen for the event this year because it is the kind of city that draws a good international crowd as a sort of gateway city to the U.S.," Dale says.


Equipment on display at the exhibit provides hands-on opportunities for attendees.

The Gaylord National Resort and Convention Center, the event site, is a brand-new, inclusive facility scenically located on the Potomac River. MPIF organizers jumped at the opportunity to hold the event's meetings, technical exhibit and convention in the same place as the hotel, so attendees have more chances to network and interact with each other. The world congress audience includes buyers and specifiers from a wide array of industry specialists including manufacturers of injection molding equipment and processes, tooling and compacting presses, furnace belts, sieving machines, lubricants and sealers and monitoring equipment.

A 150-booth trade exhibition attracts 100 companies from North America, Europe and Asia to feature displays of process equipment, raw materials, powders, services and PM products. Open Monday, Tuesday and Wednesday, the exhibition is scheduled to avoid conflict with the major events, general sessions or program luncheons.

The technical program features six special interest programs on topics of broad interest to the wider marketplace. One such program is titled "Gears—The Next PM Frontier." The focus is development in gear technology, which will deal with advances in gear rolling, fatigue, gear specifications, material options and compaction technologies. Another special interest program is devoted to fatigue design, noting the frequent subjection to fatigue loading in many PM applications. The program will look at the latest design methods, materials and process techniques that may be used to improve the fatigue behavior and durability of PM elements.

Some other highlights of the congress include a general session about the global PM industry and a general session about energy concerns in the industry featuring representatives from the U.S. Department of Energy. The annual PM Metallography Design Excellence Competition will be awarded during an event luncheon, with a grand prize of $1,500. Entries feature photomicrographs of unique PM microstructures that demonstrate how the use of metallography is an analytical tool in research and development, problem solving and quality control areas of powder metallurgy, according to the competition brochure. Participants include manufacturers, users, researchers and suppliers of powders and powder-related equipment. Entries will be displayed in the exhibit hall daily.

The 2008 world congress is being held in conjunction with the International Conference on Tungsten, Refractory and Hardmaterials VII, which is sponsored by the Refractory Metals Association. The tungsten conference has been affiliated with MPIF for the last seven years, but this is the first year they will share the same location. The registration fee for the Tungsten conference includes admission to the world congress exhibition, luncheons and the opening and closing night dinners. To attend the technical sessions of both conferences, there is a small additional fee.

"The advantage (of holding the two events in conjunction) gives people involved with refractory metals the benefit to attend the world congress and visit the exhibit," Dale says. "One reason (they're being held in conjunction) is because a lot of Europeans are interested in coming to both. It is killing two birds with one stone. The technologies are interrelated, the difference is in materials."

The 2008 World Congress on Powder Metallurgy and Particulate Materials is being held June 8–12 at the Gaylord National Resort and Convention Center, National Harbor, Maryland. For more information, visit *www.mpif.org*, or email *jtamasi@mpif.org*.

**May 13–16—ESPRIT World Conference.** Grand Hyatt, Denver. The ESPRIT World Conference 2008 launches the latest version of DP Technology's flagship product, ESPRIT, a powerful, high-performance, full-spectrum pro-gramming system for milling, turning, wire EDM, and multitasking machine tools. During the 28-hour conference, technical product training, educational seminars, hands-on instruction and workshops for users of all ranges of experience take place. The intention is for attendees to streamline business on the machine shop floor. Representatives from every ESPRIT reseller will be in attendance, along with DP Technology representatives including all executive managers from the United States, Asia and Europe, in addition to product managers, research and development and applications engineering staff. End users are encouraged to attend to stay up to date on the latest software. A new feature to the conference this year is the ESPRIT Boot Camp, a three-and-a-half-day course for new users that introduces milling and turning programming.

**May 18–22—Conference on Lubrication and Wear.** Cleveland Convention Center, Cleveland. The Society of Tribologists and Lubrication Engineers also refers to this event as its Annual Meeting and Exhibition. The meeting includes panel discussions and the presentation of around 400 technical papers, in which 17 consider wear as a subject, including enhanced characterization techniques of wear processes under a variety of conditions or with a variety of materials, coatings and wear surfaces. Ten peer-reviewed courses are offered for basic to advanced levels covering the best lubrication practices available for members and nonmembers. Eighty exhibitors will feature new products and technology in hydraulic fluids, system controls and filtration and contamination control equipment. For more information, visit *www.stle.org*.

**May 21–22—Swiss Machining Fundamentals Course.** Kennametal Knowledge Center, Kennametal Inc. Headquarters, Latrobe, Pennsylvania. This two-day educational course is provided by a partnership between PartMaker Inc., Rem Sales LLC and Kennametal Inc. to advance skills in process optimization and tool selection, and application for micro-machining applications. The course will detail the metal cutting processes of ID and OD turning for micro applications, with emphasis in areas such as rotating tooling and quick-change tooling for micro machines. The curriculum is aimed towards addressing the needs of process engineers, CNC programmers and tool engineers. Ted Woodward, manager of education programs for the Kennametal Knowledge Center, will be the instructor. Rem Sales' contribution to the course is a Tsugami SS-20 Swiss-type lathe, which handles cross and face milling, drilling, tapping, angular drilling, thread whirling and polygon turning. PartMaker is supplying the SwissCAM software for automating the programming of the Tsugami SS-20. For more information, contact PartMaker, at (215) 643-5077, or visit *www.kennametal.com*.

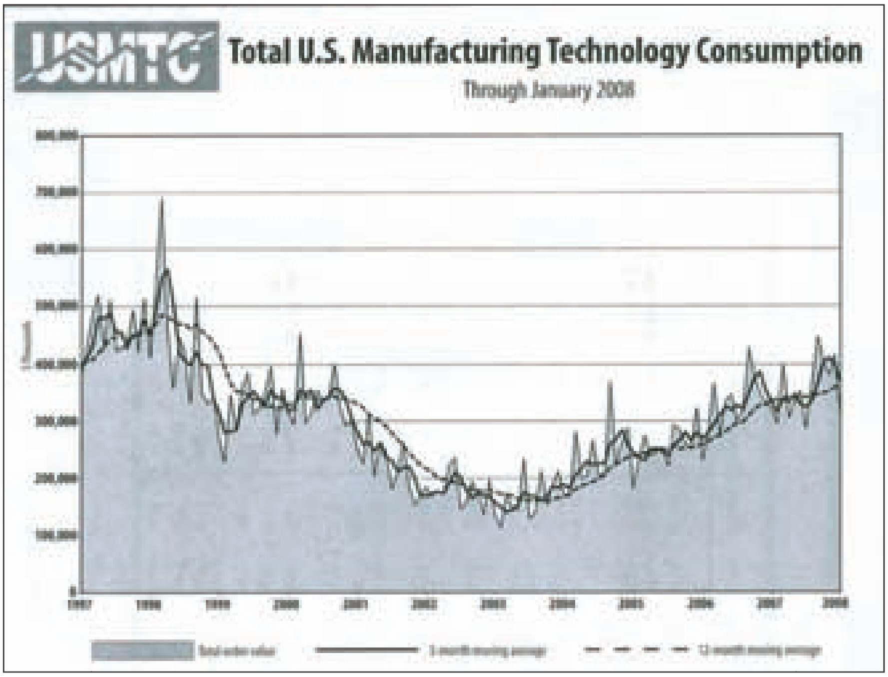
**May 22—Dallas and South/Southwest Regional NFPA Luncheon.** The Womack Machine Supply, Farmers Branch, Texas. The National Fluid Power Association is holding this roundtable luncheon for all members, but especially for the Southwest region members who are encouraged to invite customers, suppliers or distributors as guests. The 2008 series of regional roundtable meetings, the first of which was in Detroit and another of which will take place in Chicago later this year, all focus on the economic forecast and feature well-regarded economists as presenters. The Texas lunch event's speaker will be Laila Assanie, an economist who has been with the Federal Reserve Bank of Dallas since 2003, where she conducts research on regional economic issues. The event is free and intended to be a casual and effective means to meet other fluid power colleagues in the region. For more information, visit *www.nfpa.com*.

**June 4–6—Gear Manufacturing Technology Course.** Liebherr America, 1465 Woodland Drive, Saline, Michigan. The Gear Consulting Group offers this three-day AGMA course to teach theory and practical aspects of gear manufacturing. Participants will learn about everyday problems and appropriate responses to troubleshooting. Instructors Geoff Ashcroft and Ron Green of the Gear Consulting Group will cover material including gear theory, inspect-ion, manufacturing, hobbing, shaping, tools, production estimating, hard finishing and gear shaving. The course's tuition includes all necessary materials, an AGMA reference manual and a certificate of completion. Two other versions of the course will take place later this year in California and North Carolina. For more information, contact the Gear Consulting Group at (269) 623-4993.

**June 16–17—Gear Failure Analysis Seminar.** Big Sky Resort, Big Sky, Montana. The American Gear Manufacturers Association presents this 17th annual Gear Failure Analysis Seminar designed to help manufacturers avoid gear failure by knowing what causes to be aware of and how to fix problems. This technical education seminar looks at specific types of gear failure like macropitting, micropitting, scuffing, tooth wear and breakage, and methods to avoid these issues. Expert Robert Errichello, of the GEARTECH consulting firm, will be leading the seminar using lectures, slide presentations, hands-on workshops and Q&A sessions to educate attendees about the reasons for gear failure. Participants will also receive Errichello's Failure Analysis Textbook and Gear Failure Analysis Atlas. Another version of this seminar is scheduled to take place in September, also at Big Sky. For more information, visit *www.agma.org*.

# Manufacturing Technology Consumption

## GREW IN 2007, DOWN IN JANUARY




U.S. Manufacturing technology consumption (USMTC) totaled $400.31 million in December, according to the Association for Manufacturing Technology (AMT) and the American Machine Tool Distributors' Association (AMTDA). This indicates a 7.5 percent increase from November 2007, a 20.9 percent increase from the total reported for December 2006 and a year-end total of $4,261.47 million, an increase of 8 percent compared to 2006. The data these numbers are based on come from reports made by companies contributing to the USMTC program.

"Exceptionally strong December results have driven 2007 manufacturing technology orders to a level eight percent above 2006," says AMT president John B. Byrd III in a press release. "This is the fourth complete year in the current growth cycle as U.S. manufacturers continue to apply innovative manufacturing technologies to improve productivity."

The USMTC December statistics are broken down into five regions: Northeast, Southern, Midwestern, Central and Western; with respective consumption totals of $54.87 million, $52.95 million, $154.53 million, $83.72 million and $54.24 million. The largest manufacturing technology consumption came out of the Midwestern region, of which the December total was 31.9 percent higher than from the previous month and 112.6 percent higher than the December total from 2006. The year-end total was $1,422.48 million in the Midwestern region, which was 15.4 percent higher than the closing total from 2006. The year-end total for the Northeast region was 10.5 percent higher than the closing total for 2006, and the Southern region's total was 7.8 percent above 2006. December manufacturing technology consumption fell in comparison to the value from November 2006 in the Central region but still posted a year-end total above 2006's by 5.6 percent. December's total also fell in the Western region, where the year-end total was 5.1 percent less than the comparable figure for 2006.

Manufacturing technology consumption in January 2008 declined 26.1 percent from December, totaling $308.73 million. This is down four percent from the total reported for January 2007.

On a regional basis, in comparison to December's figures, manufacturing technology consumption was down in every area of the country: 7.5 percent in the Northeast, 17.2 percent in the Southern region, 36.9 percent in the Midwestern region, 13.6 percent in Central states and 41.8 percent in the Western region.

"Despite the publicized concerns about the U.S. economy, we anticipate that first quarter machine tool consumption numbers will improve as manufacturers start to implement 2008 capital budgets and use the potential savings available from the new economic stimulus package enacted last month," says Peter Borden, AMTDA president.

# Zebra Skimmers

## OPENS DISTRIBUTOR TRAINING CENTER IN OHIO


The full-line manufacturer of oil skimmers and coolant maintenance equipment, Zebra Skimmers Corporation, is opening a distributor training center in Solon, Ohio. Distributors can benefit from participating in the training center's program by learning fluid dynamics and preventative maintenance protocols, Zebra product lines and appropriate application selection and alternative web-based training.

"We are pleased to offer our distributors the opportunity to visit our facility in Solon, Ohio to gain experience with our product lines. We truly enjoy spending personal time with them and helping them understand fluid dynamics as well as utilization of our equipment," says Meg Grant, sales and service manager.

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# Kasputis

## NAMED PRESIDENT OF HOEGANAES CORPORATION


David Kasputis

David Kasputis succeeds Robert Fulton as president of Hoeganaes Corporation after spending the past year as executive vice president and chief operating officer.

Kasputis received his bachelor's degree in chemical engineering from Bucknell University. After working seven years at Bethlehem Steel Corporation, he became manager of quality control and laboratory services for Hoeganaes in 1984. He joined the executive staff when he was appointed director of quality assurance. In this position, Kasputis helped obtain the company's first ISO quality management certification.

Kasputis became the gen-eral manager of operations for Hoeganaes' powder production facility located in Gallatin, Tennessee before working in the sales and marketing department, and eventually he was appointed vice president of sales and marketing for North America.

Hoeganaes Corporation produces ferrous metal powders for the sintered component, chemical and welding industries worldwide.

# Northstar Aerospace

## WELCOMES NEW PRESIDENT AND CEO

Glenn E. Hess is now president and chief executive officer of Northstar Aerospace, Inc., as appointed by the company's board of directors. Hess has a widespread background in the global aerospace sector.

Hess is coming to Northstar from Alabama Aircraft Industries, Inc., where he served as president of the Birmingham company that deals with maintenance, repair and overhaul of military and other aircraft.

Hess also served as president and CEO of Bell Helicopter Textron. He oversaw the manufacturing facilities in Fort Worth and Amarillo, Texas and Mirabel, Quebec. Serving as vice president and general manager of the maintenance and modification business unit at The Boeing Company, Hess was responsible for military aircraft operations in San Antonio and Wichita, Kansas. Prior to his employment at Boeing starting in 1997, Hess worked in a number of senior manufacturing and program management positions at McDonnell Aircraft Company, which he joined following an honorable discharge as an active duty aviator for the U.S. Navy.

Hess received a master's degree in business administration from Washington University, a Master of Science in aerospace systems engineering from the University of West Florida and a Bachelor of Science in mechanical engineering from Northwestern University.

"Glenn's extensive experience in the aerospace sector, specifically in the manufacture and maintenance, repair and overhaul of rotary wing aircraft, is an excellent fit for Northstar," says Donald Jackson, executive chairman of Northstar. "Our focus is converting record backlog into shipments with a goal of continuously improving customer satisfaction."

## Platinum Research

### WELCOMES INTERIM CFO

David A. Hart was appointed interim chief financial officer, effective March 7, taking over the position previously held by Michael D. Newman, the former vice president and CFO who announced his resignation in January. Newman stepped down to pursue other interests, but he agreed to a consulting position with Platinum Research for a limited period.

Hart, a certified public accountant (CPA), has worked for public and private companies for over 20 years. He has experience supplying financial leadership, employing financial systems and managing accounting regulations that simplify processes and help comply with Sarbanes-Oxley, public company accounting reform law.

Platinum Research designs, develops and commercializes high-performance additives for lubricants and coatings. According to the company's press release, they are going through a transitional development stage seeking to produce more effective, efficient, commercially viable and environmentally friendly compounds. Their most recent product launch is TechroBond, which provides economic, performance and environmental advantages.

Hart commented, "I feel that we are at an important crossroads with Platinum Research, and I look forward to participating in the advancement of this new proprietary technology."

# MDM, QCA

## AGREE TO SELL, SUPPORT GEAR INSPECTION MACHINES IN N. AMERICA

After more than 40 years manufacturing CMM and gear inspection machines exclusively in Europe, MDM Mecatronics of Bologna, Italy is expanding its market to North America via an agreement with QC American (QCA) of Ann Arbor, Michigan.

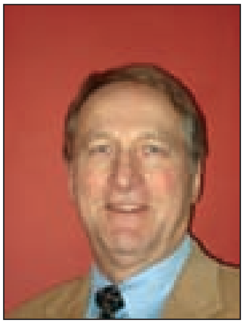

MDM constructs a line of gear inspection equipment ranging from 10 mm to 2.5 m inspection capabilities, in addition to producing retrofit packages used for older mechanical inspection machines. MDM machines are used extensively in Italy, and they are used by Italian companies to produce gear machines for U.S. machine manufacturers that provide final assembly and customer acceptance. The company also supplies artifacts to NIST, all according to MDM's press release.

Beginning in May 2008, QCA will display a GMM 40 in the company's new show room in Ypsilanti, Michigan. In September 2008, the GMM 40 will be exhibited by QCA at IMTS in Chicago along with other machines from QCA's sister company, American Broach and Machine Co. QCA distributes CNC and manual gear grinders for worm, cone and form wheel type applications, shaving cutter grinders, OD/cylindrical grinders and other CNC applications.

The GMM products are CNC-driven coordinate multifunction machines that execute fully automated inspection cycles while minimizing the work operators are required to perform. These machines have an optional, rotating fourth axis for complicated data components, which compensates for potential interpretation mistakes that occur while only using three axes. They have a high resolution for measuring gearing with involute tooth profile, free form profiles and other features that aid reverse engineering, according to product information posted on MDM's website.

# Richard R. Kuhr

## JOINS ABA-PGT SALES AND APPLICATIONS ENGINEERING TEAM


Richard R. Kuhr

Offering over 30 years of gear design and manufacturing background to ABA-PGT in his new position as a member of the sales and applications engineering team, Richard R. Kuhr graduated from the University of Illinois at Urbana-Champaign, with a degree in mechanical engineering, and he started his professional career manufacturing metal gears of all sorts—spurs, helicals, worms, worm gears, straight, spiral and hypoid. He has managed capital plans, arranged departments and designed tools in departments of production control, purchasing, manufacturing engineering and heat treating, serving in positions of management, chief engineer, director and vice president.

Kuhr moved from the manufacturing sector to software development and gear design consulting spanning various industries such as aerospace and automotive markets. Plastic gear design training and consulting eventually occupied his greatest interest considering the distinctive features plastic gears can offer and having provided training in North America, Europe and Asia. Kuhr is a published author of many technical papers and other magazine articles, including for *Gear Technology*.

Kuhr will be based in ABA-PGT's

Lombard, Illinois location where he can be reached at (630) 495-5646 or *rkuhr@abapgt.com*.

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# McNeil

## APPOINTS EXECUTIVE VICE PRESIDENT, BUSINESS DEVELOPMENT

Randall J. McNeil, president and CEO of McNeil Industries, announced Jordan L. Owens' appointment as executive vice president of business development. In his new position, Owens will guide McNeil's global sales, marketing and distributor support programs, as well as help strengthen the strategic accounts program and identify and evaluate new product and acquisition prospects, according to the company's press release.


Jordan L. Owens

Previously, Owens served two years as president of Vanguard National Trailer Corporation, and he was president of Danly IEM for six years. While working for the Cleveland-based producer of die sets and components for the metalworking industry, Owens conducted an acquisition and integration of Anchor Lamina, and his initiatives for plant consolidation and improvements minimized operating costs and lead times but improved service levels for major product lines at Danly IEM. Owens also held a general management position for SPX Corporation and a position in business unit management for Sulzer Bingham Pumps, a company that makes industrial pump systems.

Owens earned a bachelor's degree in engineering technology from the California Polytechnic State University, San Luis Obispo before doing graduate work in business administration at Pepperdine University and in technology management at the University of Phoenix. Owens is on the board of the National Institute for Metalworking Skills (NIMS), and he was an international director of the Society for Automotive Engineers.

continued

McNeil Industries, based in Ohio, manufactures and distributes MAXAM bearings, guide systems, deburring systems, industrial seals and precision manufactured products.

## Marposs

### PURCHASES GAGE MAKER KERN S.A.S

Kern S.A.S, recently bought by Marposs S.p.A, supplies high precision mechanical gages and assemblies used primarily by manufacturers in the aerospace and automotive industries. The company is located in the Paris suburb of Chelles and will continue producing tailor-made, robust gauging solutions, mechanical assemblies and measuring equipment from simple hard gauges to automatic measuring machines, according to a press release from Marposs. In its 54th year of business, Kern S.A.S has 40 employees.

The Auburn Hills, Michigan-based company, Marposs, supplies precision metrology equipment to improve productivity and reduce costs in manufacturing. Marposs intends to continue a commitment to the French market with this acquisition in combination with the 2006 purchase of Trace, a French company that manufactures leak testing machines used in assembly applications. Marposs also recently acquired Control Gaging Inc. of Ann Arbor, Michigan, and the company expects to make additional acquisitions in the near future, according to Stefano Possati, Marposs president.

"Our goal is growing in a solid and continued way both in our traditional and new markets," Possati says. "Purchasing quality companies with products that are complementary to those of Marposs is a tool that we will continue using in addition to our strong activity in research and development inside the company."

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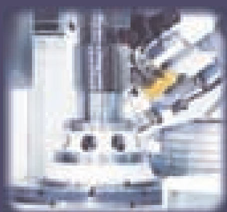

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Internal grinding with dressable grinding wheels and measuring probe arm.

Measuring

## NILES Profile Grinding Machine ZP40

| | |
|---|---|
| Tip Diameter | 157” |
| Grinding face | 60” |
| Modul | 1.7” |
| Rotary table dia. | 89” |
| Bore of rotary table (dia & depth) | 54” x 10” |

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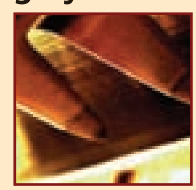



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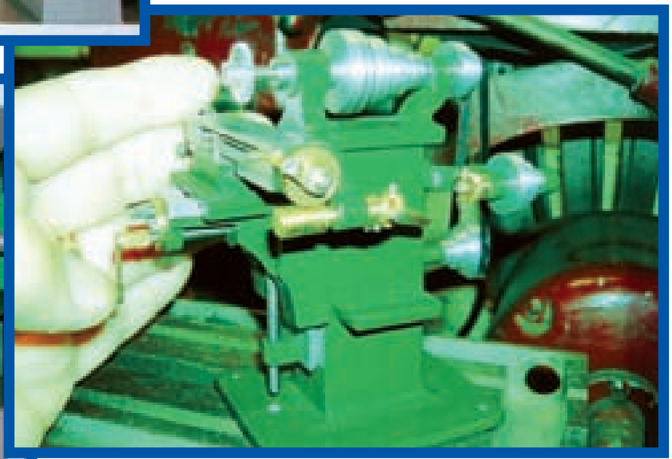

# Micro-Machined *Memories*

Dollhouses may be toys for children, but an old-time working miniature machine shop is the ultimate toy for a self-proclaimed hobby machinist like Greg Bierck.

Bierck has spent the last decade—1,500 hours he estimates—building a fully-functional machine shop about 16 inches tall that models a traditional pre-1950s era shop. The machine "dollhouse" is filled with gears—straight cut, bevel and worm gears predominately—and pulleys throughout that Bierck handcrafted.

The "GB Machine Works Co." includes the usual suspects: a shaper, drill press, mill and stand grinder to name a few; every machine has gears except the grinder. Bierck built the model in his basement using Atlas machines and jeweler's lathes with typical screws sized 0-80, 1-72 and 4-40. Most of the parts he made from castings supplied by P.M. Research Inc., along with blueprints the company provides. The biggest challenge he cites came in studying the blueprints and castings alongside each other. The blueprints don't provide any tools or how to use them. Lucky for Bierck he has been machining for 37 years, and he grew up watching his grandfather machine next door. "Half the fun is figuring out how to machine a part to print with the tools and machines that one has to work with," he says.

Bierck built the model in memory of Bruce, an old friend who first envisioned the working model but tragically died from liver disease before he was able to lay the foundation. The project is almost finished, pending one machine's completion, and set to appear at the Museum of Miniatures in Carmel, Indiana in May, for guests traveling to the area for the Indianapolis 500 activities.

Working with tiny tools has brought a significant strain to Bierck's eyes, which is pressuring him to finalize the long-term project. "The lathe (over in the corner) is the last machine to be built, and so far only the bed and legs have been machined," Bierck says. The lathe requires a great deal of gears, and he expects the process to take another 600 hours over two years. "I saved the most challenging machine for last."

Bierck did experience a few blunders along the way. At one point, he couldn't make any of the worm gears right because he forgot that the left-handed machine he was using must run backwards. He was also set back for a while by an error with the mill. "I broke the main casting in half," he says, "It came out fine. You can't tell I broke it."

If he had to do it all over, Bierck says he would try to work more often instead of building a little bit at a time. His longstanding knowledge of machines and tools were critical to the project's success. He advises anyone considering a similar endeavor that "This is not a project for someone who likes things done quickly."

For further reminiscing, other machine shops from this era can be seen in full scale at the Henry Ford Museum in Dearborn, Michigan (www.hfmgv.org ), or view this model, anticipated to display through Labor Day, at the Museum of Miniatures (*www.museumofminiatures.org*).

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