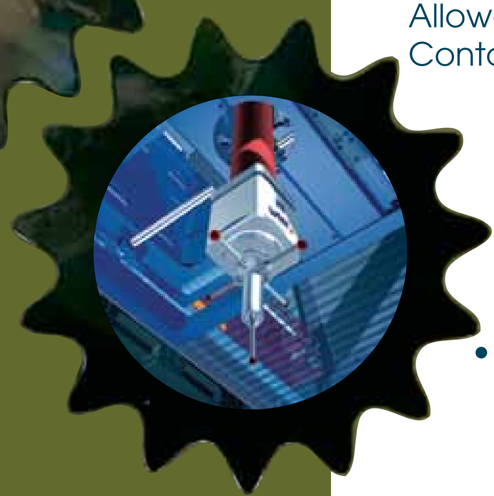
May 2010

GEAR TECHNOLOGY

www.geartechnology.com

The Journal of Gear Manufacturing



The Global Gear Industry

Feature Articles

- Ask What Your Country (USA) Can Do for You
- Counterfeit Parts a Global Menace

Technical Articles

- ISO 18653—Making it Work
- Software-Enabled Gear Finish Hobbing
- Offshore Jacking Gear Units Allowable Contact Stresses

Plus

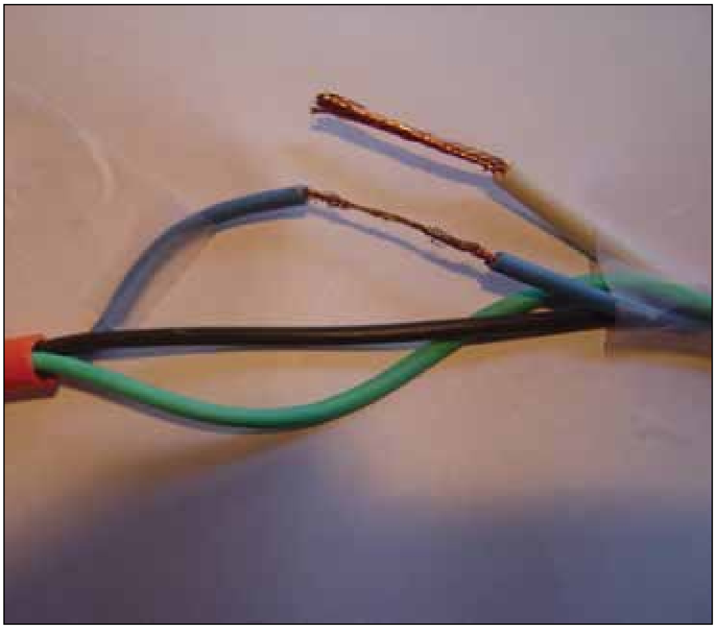
- Addendum: Elementary, My Dear Watson

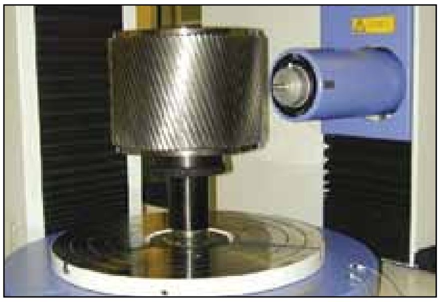
THE GEAR INDUSTRY'S INFORMATION SOURCE

grinding in one

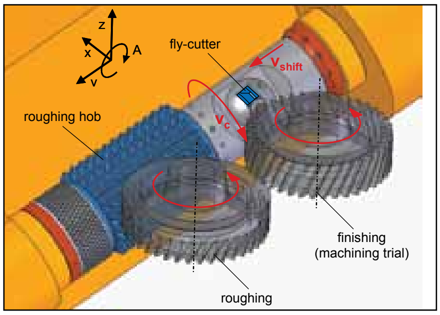
CONTENTS

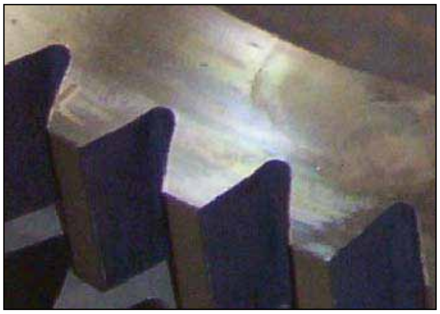
FEATURES





TECHNICAL ARTICLES





Vol. 27, No. 3 GEAR TECHNOLOGY, The Journal of Gear Manufacturing (ISSN 0743-6858) is published monthly, except in February, April, October and December by Randall Publications LLC, P.O. Box 1426, Elk Grove Village, IL 60007, (847) 437-6604. Cover price $7.00 U.S. Periodical postage paid at Arlington Heights, IL, and at additional mailing office (USPS No. 749-290). Randall Publications makes every effort to ensure that the processes described in GEAR TECHNOLOGY conform to sound engineering practice. Neither the authors nor the publisher can be held responsible for injuries sustained while following the procedures described. Postmaster: Send address changes to GEAR TECHNOLOGY, The Journal of Gear Manufacturing, P.O. Box 1426, Elk Grove Village, IL, 60007.

May 2010

CONTENTS

DEPARTMENTS

ONLINE

GEARTECHNOLOGY.com
www.geartechnology.com

- **BUYERS GUIDE**
  Search for gear industry products and services and communicate with the industry's leading suppliers
- **SUBSCRIPTIONS**
  Sign up for subscriptions to ***Gear Technology*** and the ***geartechnology.com*** e-mail newsletter
- **E-GT**
  Subscribers get access to back issues of ***Gear Technology***

PTE powertransmissionengineering
www.powertransmission.com

- ***Power Transmission Engineering***
  Read the April 2010 issue online. Sign up for a free subscription.
- **NEWS**
  The latest products, industry news and calendar items.
- **BUYERS GUIDE**
  Search for power transmission products and services and communicate with the industry's leading suppliers

GEAR TECHNOLOGY

VOL. 27, NO. 3

Randall Publications LLC
P.O. Box 1426
Elk Grove Village, IL 60007

Phone: (847) 437-6604
Fax: (847) 437-6618

Small Gear Photo
Courtesy of
Carl Zeiss.

BPA WORLDWIDE

Building on Your Foundation

When you graduated from school and made your way into the world, you probably thought you'd learned everything you needed to know to be successful. But those of us who've been out in the workforce for some time know that you never stop learning. What you graduated with was just a foundation. Over the years, I've found that one of the best ways to build on that foundation both as a professional and as an individual—is by volunteering and becoming involved in an industry association.

Most of you are familiar with the AGMA and its significance to the gear industry, not only in the United States, but throughout the world. But how many of you are actually involved with this or any other association? Not only could your association use your knowledge, your expertise and—frankly—your man-hours, but the fact is that the vast majority of you are missing out on a terrific opportunity for yourselves and your companies.

As a used machinery dealer, I have participated for 35 years as a contributor to the Machinery Dealers National Association (MDNA), having served on the board of directors from 1976-1993 and the executive committee from 1980-1993. I was also president of the MDNA's for-profit subsidiary that published the *Locator*. In addition, for 21 years, I've served on the council of the European Association of Machine Tool Merchants (EAMTM).

I've always looked at my role in association affairs as an opportunity rather than an obligation or burden. Volunteering with these associations has provided me with the opportunity to hone my people skills, helped me develop a broader and more complex vision of the worldwide marketplace and given me insight into how different people with similar business problems have looked at and solved those problems. This exposure to different problem-solving approaches has broadened my perspective and given me more tools to work with, both in my own machinery business and right here at *Gear Technology*.

Because of my involvement with these associations, I've also been in a position to volunteer for tasks I wouldn't otherwise have been exposed to. In the late 70s and early 80s, I was involved with buying mainframe computers and computerized typesetters. I've gone to visit printing plants and negotiated printing contracts. In fact, I credit my work in these associations with giving me the experience, knowledge, insight and confidence to launch *Gear Technology* in 1984.

Although you're aware of the AGMA and you know that it serves the gear industry, many of you probably don't know about all of the activities the association is involved in and the many ways you *could* become involved.

With that in mind, we're launching a series of *Voices* columns, beginning with this issue. Through these columns, we're going to give various leaders in the gear industry a forum in which to talk in-depth about some of the activities they're involved in. The first column is by Joe Franklin, AGMA president. My hope is that if you're not involved with AGMA or other industry associations, you'll see the value of membership, and if you're already a member, you'll see the value of participation.

Whether you're the owner of the company, a department manager or a new hire to the gear industry, participation in association activities will provide you with a wealth of experience and knowledge that you'd have a hard time gaining any other way. I encourage you not just to read the upcoming *Voices* columns, but also, to consider how you can add your "voice" to the gear industry.

Michael Goldstein,
Publisher & Editor-in-Chief

Herman Pfauter Responds

Hi Michael: What a surprise to see me in such illustrious company in your fine magazine! A great picture—though I regret not having removed my sunglasses...

You said it very nicely—the Pfauter company indeed had influenced the gear industry in the U.S.A. more than its relatively small size would have warranted.

At the AGMA convention there were quite a few who had been associated in one way or another with Pfauter, and it was wonderful to see them all again. I am proud to have been a small part of this special fraternity, but I am still disappointed today that a majority of the Pfauter owners, in 1997, decided to sell the company my grandfather had founded in 1900. That is all history now—but at least the company is still in existence and doing well in its original post-World War II location.

One little correction: I did drive a school bus in California while pursuing graduate work at the University of California in Santa Barbara. But it was not a psychedelic bus, but a regular 79-passenger Crown Coach! (I am sure glad you didn't mention my 1965 bus trip to a nudist convention in the Sierra Nevada foothills—but then, I was only their driver...)

Thanks again for your "reflections." I hope our paths will cross again—long before another 15 years will have passed. If you are ever in California, let me know, and we will get together again, especially since the time in Tucson was so short!

Kind regards,
Herman Pfauter

(*Editors' note: Herman Pfauter spoke at the 2010 AGMA annual convention about his grandfather, Robert Hermann Pfauter, who founded the Pfauter Machine Tool Company in 1900. A summary of his presentation follows below.*)

Robert Hermann Pfauter,
Inventor And Entrepreneur
by Herman Pfauter

My grandfather, Robert Hermann Pfauter, one of the pioneers of the machine tool industry in Saxony, was born January 30, 1854, in the village of Goeltschen, near Leipzig. The farm where he grew up doesn't exist anymore today. The entire village was destroyed not by war but by open-pit mining.

I never knew my grandfather. He died suddenly and unexpectedly at his desk, October 14, 1914.

I was born June 2, 1935 in Chemnitz, the first son of his second son, Michael, born 1899, also in Chemnitz.

As the oldest grandson of Robert Hermann Pfauter, I "inherited" a collection of interesting documents that allowed me to get better acquainted with my grandfather.

Robert Hermann Pfauter (RHP) was in many ways an exceptional personality. I was especially impressed by his strength, his courage and his unfaltering belief in his abilities. He possessed a brilliant technical mind and great business acumen—a rather rare combination, then as now…

Studying his documents, I also learned that he was a man of vision. Many of his thoughts and ideas were implemented later by his successors.

While growing up on a farm in the midst of the industrial revolution, he developed at an early age a deep interest in all things technical. After apprenticing as a mechanic, he studied engineering. Upon graduating, he worked for several machinery builders, advancing rapidly through the ranks and finally becoming the technical director of the knitting machine works of Biernatzki & Co. in Chemnitz.

Sundays and evenings he spent working on his project of a "Universal Hobbing Machine." A first prototype was constructed by Biernatzki, but their owners were not interested in pursuing the further development of his machine. After a protracted struggle with the German Patent Office, he finally received the German patent #112082 in July 1900 for a "method and machine for generating helical gears by means of hobbing."

Not quite six months later, my grandfather founded the Hermann Pfauter Company on Christmas Eve, December 24, 1900, based on his invention.

continued

ADDENDUM

Old Friends and Gear Machine Memories

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

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

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

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

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

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

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

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

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

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

Continued on page 79

84 GEARTECHNOLOGY March/April 2010 www.geartechnology.com

His invention was indeed revolutionary. In his patent application, he had claimed that the method invented by him "could be considered as not being able to be improved further."

Gears were produced in those days by indexing the gear blank and cutting one gash after the other with a milling cutter. Often this method was not sufficiently accurate due to indexing errors and a lack of high precision cutters.

RHP did not invent the hobbing machine. His great contribution to the advancement of the "art" of cutting gears was the integration of a differential in the gear train between the workpiece and the cutter. Workpiece and cutter are continuously engaged during the generating process, thus avoiding the shortcomings of the indexing method.

His new "Universal Hobbing Machine" could also cut helical gears.

Today all universal hobbing machines are still based on this principle of his invention—even though the differential consists no longer of gears but of electronic components.

The first years of the new company were accompanied by extreme hardships and difficulties. Lack of capital forced RHP to accept a partner, a wealthy coal merchant. When the difficult economic situation around the turn of the century produced only meager returns, the partner pulled his investment, and the firm collapsed.

But RHP was not a man to give up easily. Even after his bank went bankrupt and he lost the rest of his savings, he was determined to try again. My grandmother Clara, who by this time had born three sons, supported him in his determination—even though he had several offers from leading machine builders to join them as technical director.

In cooperation with a large machine tool distributor, a new beginning was made. This relationship proved very profitable and endured for over 20 years. Several key employees had stayed with RHP, and others returned. By 1903, he had 14 hourly employees and one salaried office manager on the payroll.

Several moves into larger quarters finally led to the purchase of an industrial lot in a Chemnitz suburb, and in 1906, a new factory was built and occupied. At that time, the company employed 65.

By 1913, total employment had increased to 310, and 2,000 machines had been built and delivered, many of them to the United States.

The original factory building is still standing today and is protected as a historical industrial site.

Also in 1913, my grandfather and grandmother sailed from Bremen to New York, aboard the German steamer Prinzessin Cecilie—after his first trip in early 1909 had led to profitable orders and many new experiences.

He was not only the inventor, designer and salesman of his machines; he could also operate, service and repair them!

While I have not found much information on this second trip, I have letters he sent back home from his earlier trip. They are dated January 28 to February 26, 1909 and were mailed from New York, Boston, Cleveland, Chicago, Buffalo and other cities. He visited customers, dealers and competitors.

He was excited by what he saw, and his letters contained detailed instructions for the factory in Chemnitz to follow. For example, he noticed the castings were cleaned, primed and painted before being machined. He was very impressed in general by the "great American machine tool industry" and the quality of their products. He noted that "they work slowly, but well organized," after a visit to the Acme Company in Cleveland.

But he also made some critical observations. For example, when visiting Gould and Eberhardt in New Jersey—a competitor—he noticed a violation of his patent. But he concluded that he was not concerned because "they did not know about the differential." And he mused about the effects of a possible U.S. embargo of machine tool imports to protect the domestic industry.

"We must ultimately build our machines in America" was his conclusion…

I am sure RHP would have traveled again to America if his untimely death a year and a half later—at age 60—would not have intervened. But his sons did, among them my father. One of my uncles sadly fell to his death in 1928, in Yosemite Park, in California.

But it was my good fortune, after immigrating to America in 1959, to be able to assist in realizing one of my grandfather's visions: building Pfauter hobbing machines in the United States of America—almost 60 years later—by establishing the American Pfauter Corporation in Chicago, on July 28, 1971.


The SECRET Is Out...
GearInspection.com
ND300
NEXT DIMENSION®
NEXT DIMENSION

AGMA—
AMERICAN NAME, INTERNATIONAL ASSOCIATION

AGMA Voices *is a new feature brought to you by* Gear Technology *in cooperation with the American Gear Manufacturers Association.* **AGMA Voices** *will give you opinions, insight and information presented by various AGMA staff members, board members, committee heads and volunteers. In this column,* Gear Technology *will bring you guest editorials from the gear industry's leading association. If you are involved with AGMA and you'd like to contribute a guest editorial, please e-mail* publisher@geartechnology.com.

I'd like to thank Michael Goldstein and the staff of *Gear Technology* for offering us the space in their magazine for AGMA Voices. I am confident this forum will serve the industry well as the *Gear Technology* editors communicate with the gear industry leaders on the many great programs, activities and resources made available through the American Gear Manufacturers Association. Since this is the inaugural AGMA Voices column, as well as *Gear Technology*'s "Global Gear Industry" issue, I thought it would be appropriate to give an overview of the association, as well as some information about the association's global reach.

In the first quarter of 2010, individuals from 118 countries clicked onto the AGMA website. Fifty-seven percent were from the United States, leaving 43 percent from the rest of the world. This level of international activity is astounding and clearly reflects the recognition around the globe that AGMA is the association for the international gear and mechanical power transmission industries.

Founded in 1916, the American Gear Manufacturers Association had nine members that first year. In 1973, the Board of Directors authorized a membership category for international gear manufacturers—those with no manufacturing in the United States. And today, we have a total of 427 members in 34 countries; 110 of AGMA's members are outside of the United States.

We commonly hear that the world is smaller today. True, we can communicate by phone and e-mail at the speed of light. Air travel, for all the discomfort and bother, gets us face-to-face in a matter of hours no matter where we are when we start out.

But, I think the reason for AGMA's success and international success is that our industry is more complex and more demanding than it ever has been. Complex and demanding means that fewer companies have the capability to compete successfully in these products. Expertise is thinner and suppliers more difficult to find.

The solution is global manufacturing, and that means being connected to the best technical information and most knowledgeable experts. AGMA is the focal point for many of these activities.

AGMA's Gear Expo allows specialized manufacturers to come together for a few days to meet with manufacturers who need their products, services and knowledge.

AGMA's leadership in the development of technical standards complements experts in the other counties as we all work toward global solutions and global standards that become international standards under ISO's TC-60. AGMA is Secretariat to TC-60, the international committee charged with developing technical standards for the world's gear industries. (AGMA was first elected Secretariat in 1993 and has been reelected every three years since.)

AGMA's Annual Meeting of members is becoming the place for industry executives from the world's key players to come together to learn and to network with their peers.

And, AGMA's education programs, especially the newer offerings of advanced-engineering seminars, frequently draw attendees from around the world. Leading engineers do not hesitate to come from Europe, Australia and India to be part of these learning opportunities.

When we look at all of the members and participants outside of North America, does any country stand out as more active than others? Yes, India is growing rapidly in the AGMA as a source of members and of interest in AGMA programs and activities. Of our total international membership, 10 percent is located in India; internet traffic follows the same pattern, as 11 percent of visitors from outside the United States are also in India.

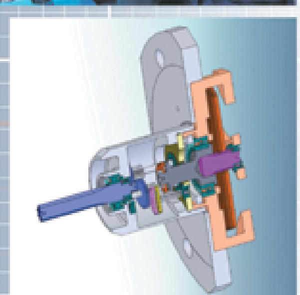
Interest is not restricted to a few of the large cities; internet users for the first quarter of this year came from 79 cities in India.

AGMA is planning to take a delegation of members to visit Indian manufacturers in February 2011. This May 2010, AGMA is exhibiting at the International Power Transmission Exposition (IPTEX 2010) in Mumbai.

And, the association is always available no matter where you are, at *www.agma.org*.

Sincerely,

Joe T. Franklin Jr., President
The American Gear Manufacturers Association



Future Demands
Next Generation of Standards and Practices in Gear Industry

Graeme Walford
Chief Operations Officer, Romax Technology

Gear manufacturers are moving into an era that will see changes in both engineering practices and industry standards as new end-products evolve. Within the traditional automotive industry, carbon emission reduction legislation will drive the need for higher levels of efficiency and growth in electric and hybrid vehicles. Meanwhile, the fast growing market of wind turbines is already opening up a whole new area of potential for gearbox manufacturers, but this industry is one that will demand reliability, high levels of engineering excellence and precision manufacturing. Over the coming years, these changes will require new techniques and approaches that will quickly become accepted industry standards.

Efficency has become one of the most important factors in the design process for hybrid and electric vehicles. However, optimizing gear designs to be more efficient without compromising other design targets, such as NVH and durability, can be challenging.

Having recognized this problem of conflicting design requirements, Romax has carried out significant research and development into simultaneous optimization, so engineers are able to consider efficiency, durability and NVH in the same environment and optimize the system performance to meet all the targets.

Another major challenge facing hybrid and electric vehicle designers is that gear noise becomes much more prominent and can be at a high frequency—which is much more noticeable to end users. This makes gear noise in electric vehicles harder both to predict and to solve. Potentially, the gear noise in hybrid and electric vehicles needs to be lower over a much wider range of operating conditions than the traditional vehicle. This can be achieved with computer aided optimization of design.

As quieter and more efficient automotive gearboxes are required by the end user, this also means that manufacturing standards need to be raised to meet these higher demands. By using advanced computer-assisted design optimization combined with virtual prototyping, you can give the HEV and ZEV drives of the future the quietest and most efficient experience possible, but this must be combined with tighter and more precise manufacturing techniques and a good standard of quality control.

The wind turbine industry is growing and providing a route for many companies to diversify and find new revenue streams. However, whilst component suppliers are welcomed, many are discovering that the wind energy industry demands both quality as well as quantity.

The mechanical parts of the wind turbine have to be robust enough to deal with extraordinary forces and stresses, and for this reason, the industry demands exceptional technical ability, as well as high quality from its component manufacturers.

Within the area of gearbox transmissions, in particular, reliability problems are widespread, and these issues have to be addressed if the industry is to develop to its full potential.

Manufacturers looking to enter the wind turbine industry can turn to design platforms to support their needs. Design platforms enable manufacturers to decrease design time by allowing a variety of concepts to be reviewed quickly and easily, considering all permutations. It also allows different components to be tested in the design stage and the impact on performance, weight and manufacturing to be measured, for example investigating the effects of switching a helical gear for a spur gear. Having the ability to understand the forces and material capabilities enables design decisions to be made before expensive prototyping is performed, ensuring quiet, durable and long-lasting components.

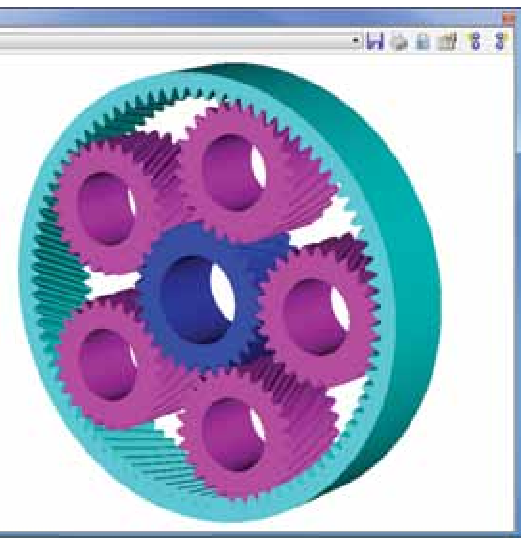
For suppliers entering the wind energy market, design platforms can provide a valuable reduction in time and costs to meet the demands for turbine component manufacture, particularly drivetrain elements such as gearboxes and bearings. For those companies already supplying the wind energy industry, design platforms can offer an opportunity to develop capabilities and improve results.

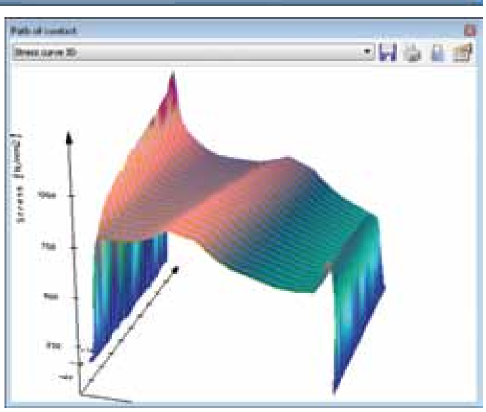
As we move into the future, a new generation of opportunities awaits the gear industry.

Going forward, the gear industry will need to utilize and embrace new and developing technologies to ensure that it remains as competitive as possible. The gear industry has a bright future, one that will carve out new practices and standards as we seek to meet the challenges this future brings with it.

KISSsoft Update

INTEGRATES PARASOLID CAD CORE





The machine element package by KISSsoft for the design and optimization of components like gears, shafts, bearings and others is now available in the new version *04/2010*. "There are currently two strong trends for the computer based calculation of machine elements like gears, shafts, bearings and so on: one is the combination of Finite Elements with the standardized methods, the other is the tighter combination of the software tools in the machine design process by interfacing or even combining software for different tasks in this process," says Dr. Stefan Beermann, vice president at KISSsoft. "In the current version of *KISSsoft* there is a CAD core (Parasolid) and a Finite Element library included, to take this fact into account. The standards defining calculation methods still remain their importance, but seem to be no longer sufficient for a competitive product design: the methods must be extended for practical application."

Improvements to the software package include the integration of the parasolid CAD core into the software, so exact 3-D models are directly available for most gear types. Users can also utilize the generated model for load distribution analysis and stress and deformation analysis using FEA. The model can also be used for any kind of post-work such as local modification of the tooth surface for optimal load distribution and transmission error. Due to the STEP interface and the native parasolid format, these models can be exported to other software packages. For the most common 3-D CAD packages in machine design, however, the direct integration of KISSsoft into these packages provides fully parameterized models, according to the company's press release.

A second section with major improvements is the tooth contact analysis for cylindrical gears. The stiffness model was extended to better take the load distribution in the width direction into account. For this purpose, the gear is split up into a number of slices. Each slice has a contact stiffness function assigned that is dependent on the meshing position, according to the model of Peterson. The single slices are then connected by springs with a stiffness value derived from the contact stiffness of the neighboring slices. Based on this model, the real contact between the flanks is determined, considering deformation of the teeth, modifications, misalignment and manufacturing errors. As a consequence, the user gets graphs and numerical results for forces, stresses, transmission error, power loss and temperature—and for dry running plastic gears, even the wear on the flanks. The *KISSsoft* material database now incorporates material properties of 17 additional LNP specialty compounds from the SABIC Innovative Plastics portfolio for gear design. This data is now available for *KISSsoft* and includes temperature-dependent values for Young's modulus, static bending strength as well as characteristic wear values at dry-run.

In the draft of the planned ISO/CD TR 6336-7, for the calculation of the lubrication gap and the analysis of the risk of micropitting, the calculation of the permissible lubricant film thickness lGFP was not covered. In the meantime, it was decided that the calculation will not be a part of the 6336-standard, but it will become the Technical Report ISO/TR 15144. According to the latest proposal for the Committee Draft, the ISO/CD TR 15144, the permissible lubricant film thickness is included. So, a reliable evaluation method of the safety against micropitting could be implemented in *KISSsoft*. With the AGMA 925, not only the determination of the permissible lubricant film thickness is possible, but also the probability of scuffing and wear can be calculated. Furthermore, the latest method for scuffing calculation, the ISO/TR 13989, is now available.

There are two more standards for cylindrical gears newly implemented: The AGMA 6011 for open gears and AGMA 6014 for speed increasers. For the configuration of steel worm with plastic gear, the guideline VDI 2736, the successor of the old VDI 2545 plastic gear guideline, contains a method calculating the worm gears root strength based on the shear stress in the root. The new *KISSsoft* version implements the current state of this method. It should be noted, however, that this standard is still under development, and significant changes might still occur.

Another highlight of *KISSsoft 04/2010* is the possibility to determine the transmission error directly in the fine sizing. This allows the comparison of the different variants according to noise rating. Several standards were added regarding bevel gear calculation. The Klingelnberg standards have been implemented for spiral and hypoid gears with palloid method. Furthermore, the draft for ISO/TR 10300, with the calculation of hypoid gears, is implemented too. Parallel to the standards, a *KISSsys* functionality was developed in order to calculate the relative position of pinion and ring gear under load, considering the deflections of bearing and shafts.

There are several more improvements in the software like the addition of splines according to DIN 5481 and DIN 5482, the extension of the calculation of interference fits to the plastic range, implementation of strength classes for bolts according to SAE J429, for bolts, nuts and washers according to ASME 18.2.1-1996, 18.2.2-1987 and B18.22.1-1965 (R1998), the calculation of the relaxation of garter springs, and the generation of 3-D shaft models in several CAD packages.

In *KISSsys*, the GPK Model used for sizing of one- to five-stage gearboxes is enlarged by some significant improvements. The main functionality is the automatic transfer of the relative position of gears, considering the shaft and bearing deflections. Together with the previously mentioned tooth contact analyses, the user is able to optimize and analyze the gear modifications under real conditions. Other functionalities are the import of housings and the collision check with the gear elements. In the field of the precision mechanics, the automatic shaft and bearing sizing is optimized, and proposals for smallest designs are calculated. The free test version of the new release *04/2010* is available for download at *www.KISSsoft.com*.

For more information:

KISSsoft USA, LLC.
3719 North Spring Grove Road
Johnsburg, IL 60051
Phone: (815) 363-8823
Fax: (815) 363-8832
info@kisssoft.com
www.kisssoft.com

Gerlach

TURNS POWDERED METAL INTO PROFIT WITH TURNING CELLS

By using the new Eurotech-Famar Pronto 5 Turning Cells, as well as CNC lathes and various machining centers, Charles Gerlach, president of Gerlach Machine and Tool, located in St. Henry, Ohio, is turning powdered metal into profit. Gerlach does high-volume machining, plus bead blasting and honing of various powdered metal and cast aluminum parts. Their customers include major suppliers of automotive components such as timing sprockets, engine/drive line components and auto body parts. Gerlach frequently does the final machining on near-net-shape products for subsequent delivery to Tier One automotive vendors.

The purchase of two Eurotech-Famar Pronto 5 Turning Cells with a Siemens CNC control, drive and spindle package onboard each was necessitated by the unique machining characteristics inherent in powdered metal work. "We're machining very high quantities of powdered metal automotive components, which causes excessive tool wear and therefore requires constant offset adjustments," Gerlach says. "The Eurotech-Famar representative trained us on the set-up, programming and the time-saving features for our particular operation.

"The machines had been put into action almost immediately after delivery, to meet current customer production schedules, so we'd had less time than expected to test run the cells. What we learned was that the Siemens control package allowed us to add separate sets of electronic pushbuttons at the operators' worktables, each wired into the machine, to make offset changes by the

Eurotech-Famar CNC Pronto 5 Turning Cells features Siemens controls, drive and spindle package.

push of a button, rather than keying in the change on the control panel's offset page. Within the cutting program, each pushbutton controls a tool offset and is assigned a specific positive or negative numerical value," Gerlach says. "Then, each time a button is pushed by the operator while the machine is running, the offset assigned to that particular button will change by the given numerical value. This basic capability saves time and simplifies tool adjusting, which in turn increases our productivity substantially."

Additionally, Gerlach cites other benefits of the machines, including the capability of assigning offsets a maximum value the control will accept per adjustment, thereby preventing machine "crashes," which occur when an offset

Powdered metal automotive parts machined at Gerlach's 25,000 square foot facility in St. Henry, OH.

value is changed to an incorrect large number. He also notes the programming as an added upside of the machine control package, which features the Siemens Sinumerik 840D CNC, Simodrive 611D and spindle as original equipment on the Eurotech-Famar Pronto 5 Turning Cells. Axis and spindle motion are all controlled by the Siemens CNC, with Gerlach storing all data/programs on the hard drive with floppy disk back-up.

President Charlie Gerlach (right) and general manager Terry Fisher (left) assess a powder metal gear.

For more information:

Gerlach Machine & Tool, Inc.
512 N Eastern Ave.
St. Henry, OH 45883
Phone: (419) 678-4217
Fax: (419) 678-3615

Siemens Industry, Inc.
Drives Technologies
Motion Control, Machine Tool Business
390 Kent Ave.
Elk Grove Village, IL 60007
Phone: (800) 879-8079
Fax: (847) 952-4278
John.meyers@siemens.com
www.siemenscnc.com

Power Honing Machine

FINISHES HARDENED CYLINDRICAL GEARS IN HALF THE TIME

The next-generation 150SPH Power Honing Machine from Gleason uses the latest patented Spheric Honing process to finish hardened spur and helical gears up to 150 mm in diameter in half the time required by existing machines.

continued

The 150SPH is appropriate for production environments that require higher volume finishing of high precision gears with low noise characteristics, like those typically found in modern transmission applications. With a high-speed, direct-drive honing head, the 150SPH can hone at speeds almost twice as fast. Gleason's patented Spheric Honing process uses a combination of Gleason software and Siemens 840D CNC to allow users to produce quieter gears faster by improving tooth geometry, reducing concentricity and indexing errors while optimizing overall tooth flank contact characteristics.

The Spheric Honing process was first introduced by Gleason with the ZH 125 and ZH 250 honing machines. The process allows for tooth trace and crowning modifications generated by machine movements only, making change unnecessary to the dressing master when modifications are required or when changing over from one workpiece type to another. This reduces tooling costs and non-productive changeover time. When dressing is required, a patented process is used that can extend honing tool life by up to four times. The process also improves compressive stress in the surface of the tooth flanks to prevent early wear and extend gear durability and life.

Siemens 840D CNC combined with Gleason's Windows-based Intelligent Dialogue software makes setup and operation simpler. Other standard features include a fully integrated, high-speed automatic loading system that cuts workpiece changeover by up to 70 percent. Also the loading system was designed to make it easy to interface with a customer's existing factory automation systems.

For more information:
Gleason Corporation
1000 University Avenue
P.O. Box 22970
Rochester, NY 14692
www.gleason.com

Grind Burn Detection Capability Developed

The Wenzel WGT 500 gear measuring machine is equipped with Stresstech Rollscan R500 Barkhausen noise analyzer System integrated with a horizontally-mounted Renishaw SP80 probe.

Wenzel GmbH and Stresstech GmbH have developed a gear measuring machine feature that detects the presence of grind burn or pits on gears. The sensor technology applied uses the Magnetic Barkhausen Noise Method, which is based on inductively detecting a noise-like signal generated when a magnetic field is applied to a ferromagnetic material. Barkhausen Noise can be used to analyze the micro-structure of a material's surface in terms of hardness and its microstructural condition.

The Stresstech Rollscan R300 is the digital Barkhausen noise analyzer system being applied to Wenzel GearTec machines. It includes the instrument, sensor and software. The sensor has been integrated into the probe plate of the Wenzel InovaGear, WGT series and LH Gear CMM bridge style machines. The Barkhausen probe can be stored in the integrated change rack. The software is also integrated into the GearTec controller.

"Because gear measuring machines utilize very sophisticated programming software to inspect all geometrical features of gears and gear teeth, it's logical that a sensor adapted to the same measuring arm, making many of the same inspection movements, should be able to inspect for grind burn and pits that can occur on the flanks of ground gear teeth," says Chris Pomm, Wenzel technical director. "Typically chemical acid baths and optical methods are used to check for grind burn. With our new method, grind burn on gear flanks can be analyzed at the same time inspection occurs, eliminating the need for additional processing."

continued

For more information:
Xspect Solutions, Inc.
47000 Liberty Drive
Wixom, MI 48393
Phone: (248) 295-4300
Fax: (248) 295-4301
emills@xspectsolutions.com
www.xspectsolutions.com

Northfield Precision

RELEASES THE MODEL 1000 PITCH LINE CHUCK

Northfield Precision Instrument Corp., a designer and manufacturer of precision workholding chucks, introduces its Model 1000 10 inch diameter Pitch Line chuck. This chuck grips the outside diameter of 9 inch diameter helical gears. The pins are mounted in a loose-fitting housing so they can float. They pick up the pitch diameter and the jaws grip the outside diameter of the pins. The pitch is measured over pins, so it is gripping the same way it measures.

The Model 1000 has two "pin cages," one for a left-hand helix and one for a right-hand helix. The pin cages are changed out by removing three mounting screws. Northfield Precision designs and manufactures air chucks for any lathe, boring machine, grinder or VMC. Models include through-hole, high-speed and quick-change and are available in SAE or metric, in sizes from 3 inches (76 mm) to 18 inches (457 mm). Accuracies of 0.001 inches (0.0254 mm) to 0.00001 inches (0.000254 mm) guaranteed. Custom workholding chucks and jaws are available, and free engineering assistance is offered.

For more information:
Northfield Precision Instrument Corp.
Phone: (800) 810-2482
sales@northfield.com
www.northfield.com

Ondrives

LAUNCHES CROSSED HELICAL GEARS

A precision range of crossed helical gears was released from Ondrives Ltd. These 45 degree crossed helical gears have already been specially manufactured to several customers' specifications for the standard range. "We believe this is because we make all our precision gears in-house, and ultimately, this gives us complete control over the finished quality of the parts as well as enabling us to offer quick turnarounds to meet customer's just-in-time requirements where needed," says Amanda Laughton, marketing manager for Ondrives.

This range of helical gears is available as standard from sizes 0.5 module to 3.0 module, and a right-hand helix runs with another right-hand helix. They are manufactured to 7e25 DIN 58405 (AGMA Q10) with other quality grades available on request.

Standard materials are 817M40T (28 HRC) steel and 805M20 (58 HRC) case hardened steel. Tapped holes, pin holes, different bore sizes, different numbers of teeth and keyways are all available to quote on request. Discounts are available for quantity purchases.

For more information:
Ondrives Ltd.
Foxwood Industrial Park
Chesterfield, Derbyshire S41
9RN United Kingdom
www.ondrives.com

ONLINE
Visit
www.geartechnology.com
for the latest Product News

Profiling Machine

CAPABLE OF NINE STARTS

The PM280T from Burri Werkzeugmaschinen GmbH was developed to profile threaded grinding wheels for gear grinding machines and honing rings for gear honing machines. It is also capable of processing straight-sided wheels for generative grinders and profile wheels for form grinders

with the correct adaptors and diamond dressing wheels. The machine is also capable of processing threaded wheels with multiple starts for the latest generation of threaded wheel grinders using the electronic control the machine is equipped with.

In the past, gear companies that were processing threaded wheels with an AM10 dresser were restricted to one or possibly two starts on the grinding wheel. This dramatically restricted how the gear could be processed and the time it took to grind it. Operators also needed to manually run the AM10 dresser, which tied them up for the time this took, according to a press release issued by JRM International, the machine's North American distributor.

The PM280T can profile up to nine starts depending on the size of the wheel and the diametral pitch, with an unattended machine. Once the program is generated in the machine control in a few minutes, the operator starts the cycle and can leave. The machine runs automatically, and after 10 to 12 minutes, for a one start wheel, it shuts itself off at the end of the cycle.

For more information:
JRM International, Inc.
5701 Industrial Avenue
Loves Park, IL 61111
Phone: (815) 282-9330
Fax: (815) 282-9150
www.jrminternational.com

Magnetic Chucks

ENGINEERED FOR HEAVY DUTY HOLDING FORCE

SAV North America introduced a line of magnetic chucks that deliver heavy duty holding for accurately cutting parts. The Radial Pole High Power Electro-Permanent Chucks hold parts while allowing full access in a single set-up, to reduce labor costs and increase throughput of finished work.

The chucks are engineered with heavy-duty holding force of 245 pounds per square inch. The surface area of the chucks allows for hard turning without sacrificing speed and feed capabilities of machine tools. Part size is unrestricted, and those with limited surface areas can be held securely, reducing the chance of slippage, inferior cuts and wasted materials.

The solid body construction allows for high balance and stability of a workpiece, which provides flexible mounting options. Top tooling raises workpieces to be turned or cut, so they are more accessible with quick changeovers. A separate top plate is fully sealed for preventing short-circuiting that could occur with coolant leaks. Custom mechatronic part centering is an option for error-free workpiece placing.

These chucks have a greater clamping force than other magnets due to electro-permanent magnet technology. A programmable release cycle is activated to fully demagnetize the chuck and release workpieces. The chucks operate on standard North American voltages.

For more information:
SAV North America
250 Nutmeg Road South,
Suite N
South Windsor, CT 06074
Phone: (888) 628-8796
www.sav-workholding-na.com

Emuge

EXPANDS SOLID CARBIDE THREAD MILLS

An expanded line of Solid Carbide Thread Mills was introduced to Emuge Corp.'s Threads-All program. The new thread mills require minimal tooling and adapt quickly to a range of threading requirements to machine with high thread quality and tool life.

The thread mills require eight standard tool sizes, numbers 10–1/4–5/16–3/8–7/16–1/2–5/8–3/4, so it is possible to make over 100 commonly produced screw thread designations, including UNC–UNF–STI UNC–STI UNF–UNEF–UNS–UNJC–UNJF–M–MJ. The tools also provide total control over pitch diameter limits, including 2B, 3B, 3BG and all oversize variants.

The Threads-All program is designed for difficult-to-cut materials, up to 58Rc—including stainless steels, titanium and Inconel—that are often used in demanding industries, such as aerospace, defense and medical.

The Threads-All program also includes miniature tools in 10 sizes from 0 to STI 8. "Emuge recognizes the need to continually deliver new tooling solutions to help manufacturers cut costs, improve delivery times and produce world-class products," says Mark Hatch, thread milling manager at Emuge. "With the new Threads-All program, we offer manufacturers a high quality threading solution, which maximizes profitability and minimizes tool inventories."

For more information:
Emuge Corp.
1800 Century Drive
West Boylston, MA 01583
Phone: (800) 323-3013
www.emuge.com

Your Tax Dollars at Work

U.S. COMMERCE DEPARTMENT: YOUR BOOTS ON THE GROUND OVERSEAS

Jack McGuinn, Senior Editor

Easily one of the central issues affecting U.S. manufacturing is what one might call the exports deficit—the inability of American companies to sell products to, for instance, Asian markets, developing countries and other ports of call—due to what they perceive to be unfair trade agreements and or policies. Once trusted trading partners such as Mexico, Canada and the United Kingdom are accounted for, the going gets rough for selling to—much less opening—overseas markets. The U.S. Commercial Service (USCS), a branch of the U.S. Commerce Department's International Trade Administration, provides perspective: fifty-eight percent of all U.S. businesses sell to only one country (all, as noted, in North America).

Perhaps that is why, again citing

USCS figures, less than *one percent* of this country's businesses export their products. And that's something that has to change.

"In today's global economy, businesses can't afford to miss out on international opportunities," says Joseph J. English, senior international trade specialist/global trade programs, for the U.S. Foreign Commercial Service. "Ninety-five percent of the world's population and nearly 70 percent of the world's purchasing power is outside of the U.S. If you're not exporting, it's highly likely that your competitors are or will be selling internationally.

"One of the most important things about exporting is that it enables firms to diversify their portfolios and help weather changes in the domestic and world economies. So, by spreading the risk, it helps them boost their competitiveness and bottom line."

And while it may be something of a well-kept secret, the USCS—through its International Partners Search (IPS) program and other efforts—is here to help.

In essence, the program has access to a number of overseas "trade specialists" charged with finding "suitable partners" for existing and would-be U.S. exporters. But there's much more.

"Using client-provided marketing materials and background on the client's company, we use our strong network of international contacts to interview potential partners and provide the client with a list of up to five prescreened partners in the overseas market of its choice," says English. "IPS is used to determine the marketability and sales potential for a client's products and services in that market and provides complete contact information on key USCS officers; potential partners interested in the client's product—along with information on their size, sales, years in business and number of employees; and a statement from each potential partner on the marketability of the client's product or service. The IPS is normally delivered in about 30 business days, or as negotiated with the overseas office."

How effective is the program?

It and the USCS "team" include a network of offices around the world hooking up U.S. businesses with international buyers—109 offices across the United States and locations in American embassies and consulates in more than 77 countries.

"Different companies have different needs, and the value of our assistance is tailoring to the individual needs of that company," says English. "Commercial specialists at post are assigned responsibilities by industry sectors, and the specialist working on a service will be responsible for the industry sector appropriate to the client's company. As such, the specialist is familiar with industry trends and practices, potential buyers, ways of doing business in that home country and relevant industry trade events. For a gear manufacturer, the commercial specialist would be the person at the overseas post responsible for the machine tools and metalworking equipment industry sector.

"Last year, the (USCS) facilitated more than 12,000 export successes worth billions of dollars in U.S. export sales."

continued

According to English, there is a wealth of untapped opportunities overseas for U.S. companies—and that includes the gear industry. Citing figures from the Freedonia Group consultancy, English states that worldwide demand for gears and gear assemblies is forecast to climb by 4.7 percent annually through 2013, to $169.5 billion, with gains driven by rising motor vehicle production, greater manufacturing output and the potential for wind and solar energy. The report goes on to say that demand for gears used in all other applications will also grow—including aerospace, ships, motorcycles and energy systems.

The report also states:

- Demand in developing parts of the Asia/Pacific, Eastern Europe, Africa/Mideast and Americas regions will outpace product sales in the United States, Western Europe and Japan.
- China is expected to account for one-third of all additional gear demand through 2013 and will surpass Japan to become the second largest national market behind the United States. By 2018, total gear sales in China will exceed product demand in the U.S.
- Market growth is also expected to be healthy in Indonesia, Thailand, Iran and Russia.
- Although advances will be less robust than in developing countries, gear product demand in the U.S. and Western Europe will increase as well, spurred by renewed strength in motor vehicle output following a period of decline.

Even for those gear companies just dipping their toes in the trade waters, the IPS/USCS has a plan.

"For many U.S. new-to-export companies, Canada and Mexico are good first-time destinations," says English. "Businesses are also encouraged to take advantage of countries where the U.S. has free trade agreements." (For more information, visit *www.export.gov/FTA/index.asp.)*

And for those trepidacious export newbies, the USCS/IPS is there to bring them in off the ledge.

"First, let me emphasize that the exporting process may seem daunting for a new-to-export business, but there are ways these companies can overcome the initial challenges," English explains. "For many businesses, free trade, ease of transportation, the Internet and a range of government export programs have really helped to simplify the export process—that's true for even the smallest businesses. Many smaller companies mistakenly believe that exporting is too complicated, is just for larger firms or aren't aware of all the export and financing resources available to them.

"If a U.S. company can sell in the United States—one of the world's most open and competitive economies—it's a good potential candidate for selling internationally. This also applies to new startups that have a solid business plan. An export strategy is important, and we can help you develop one."

And that strategy will be executed dependent on a client's experience. Companies who have not exported or have infrequently exported in response to orders received from overseas buyers are recommended to consult the USCS publication, *A Basic Guide to Exporting*. The book, says English, treats exporting as a process, addressing export planning, shipping and documentation, and also includes case studies about small companies the USCS/IPS has helped, allowing them to systematically pursue and generate new sales. Another resource for companies starting out, or those with technical questions, is the USCS Trade Information Center (1-800-USA-TRADE).

There also exists within the USCS network a Manufacturing Team dedicated to meeting the key needs of U.S. manufacturers in their exporting efforts. This team works closely with the DOC's official liaison to the National Association of Manufacturers (NAM) to address the export needs of a variety of manufacturing groups. They develop programs for manufacturing trade shows, webinars for and with manufacturing associations (e.g., a recent program on the EU Machinery Safety Directive) and other activities to reach smaller U.S. manufacturers with the potential to sell internationally. (*For more information, contact Debbie Dirr at* Deborah.Dirr@trade.gov *or go to* www.buyusa.gov/manufacturing.)

Last, but certainly of great import and potential benefit to the USCS and U.S. manufacturing, is another new "government program"— the National Export Initiative (NEI). The program's goals are challenging, but English believes they are realistic, if not long overdue.

"President Obama's National Export Initiative (NEI) announced a goal of doubling exports over the next five years to support two million jobs in America," he says. "The NEI will help the country reach that goal—providing more funding, more focus and more cabinet-level coordination to grow U.S. exports. The NEI represents the first time the United States will have a government-wide, export-promotion strategy with focused attention from the president and his cabinet."

According to the USCS, the initiative is focused on three key areas:

1. A more robust effort by the Obama administration to expand its trade advocacy in all its forms, especially for small- and medium-sized enterprises. This effort includes educating U.S. companies about opportunities overseas, directly connecting them with new customers and advocating more forcefully for their interests.
2. Improving access to credit with a focus on small- and medium-sized businesses that want to export.
3. Continuing the rigorous enforcement of international trade laws to help remove barriers that prevent U.S. companies from getting free and fair access to foreign markets.

continued

English provides a brief summation for U.S. companies looking to export.

"Develop an export plan, and we'll help. It doesn't have to be lengthy but should include: a process for highlighting the business's strengths and why they may have a competitive edge; assessing and selecting best markets; pricing considerations; and how best to find qualified buyers.

"Since many U.S. businesses sell through their websites, the site should be international in scope and buyer-friendly, and we can help with that.

"Also, why limit your export business to web sales when, with some additional effort, you can move into other sales channels?"

For more information:

Joseph J. English
U.S. Department of Commerce,
U.S. & Foreign Commercial Service
Pennsylvania Avenue, N.W.
Suite M800, Washington, D.C.
Phone: (202) 482-3334
Fax: (202) 482-7801
Joseph. English@trade.gov
www.export.gov

Implementing ISO 18653—Gears: Evaluation of Instruments for Measurement of Individual Gears

Robert C. Frazer and Steven J. Wilson

Management Summary

A trial test of the calibration procedures outlined in *ISO 18653—Gears: Evaluation of Instruments for the Measurement of Individual Gears*, shows that the results are reasonable, but a minor change to the uncertainty formula is recommended. Gear measuring machine calibration methods are reviewed. The benefits of using workpiece-like artifacts are discussed, and a procedure for implementing the standard in the workplace is presented. Problems with applying the standard to large gear measuring machines are considered and some recommendations offered.

Introduction

Cylindrical, involute gears are precision components with a relatively complex geometry that must be made accurately to fulfill their specification in terms of noise, power density and reliability. It is common for gears to specify profile, helix and pitch tolerances in the 5–10 μm region, and many applications demand tighter tolerances. Modern machine tools, operated in a carefully controlled environment and correctly managed, can achieve these tolerances provided there is an appropriate independent method of measuring the geometrical accuracy of the gears and thus control the process.

Figure 1—CMM used for gear measurement.

The traditional Golden Rule for metrology is that the uncertainty of a measurement process should be 10% of the tolerance inspected. Measurement uncertainty is the term used to quantify the unknown random and systematic errors that occur in any measurement process. With tolerances of 5–10 μm, our measurement uncertainty should be 0.5–1.0 μm on the shop floor, which is still too difficult to achieve, and even national measurement institutes (NMIs) around the world can just barely achieve these levels. Thus the shop floor measuring instrument capability is an important consideration when interpreting measurement result conformance with specification.

In recent years, the range of gear measuring equipment available to the gear manufacturer has expanded. There is greater choice of dedicated 4-axis CNC gear measuring machines (GMMs) with three linear axes, a rotary table and tailstock. General purpose coordinate measuring machines (CMMs) are now equipped with gear measurement software where previously only the highest quality machines were considered for gear measurement applications. Recent improvements in error mapping to improve measurement performance and the introduction of scanning probe systems has meant that now even relatively modest-cost CMMs can be considered for gear measurement applications. The gear manufacturer has a wider choice of measurement solutions than ever before, but how should the appropriate solution be selected?

It is surprising therefore, that when ISO published ISO 18653 in 2003, *Gears: Evaluation of Instruments for the Measurement of Individual Gears* and a supporting technical report (guidance document) ISO/TR 10064-5, that the gear industry has not adopted the recommendations and applied the standard more widely.

The proposal to develop the ISO document came from AGMA using ANSI/AGMA 2010-A94, *Measuring Instrument Calibration, Part 1–Involute Measurement*, as the working document. Other documents are also used extensively throughout the gear industry. The VDI/VDE guidelines 2612 and 2613 (Refs. 1–2) propose limits on measurement uncertainty, depending on the DIN 3962 quality grade. They were first published in the 1980s but were revised in 2000. The guidelines also prescribe limits on runout of centers, machine alignment and instrument repeatability and, importantly, the uncertainty of the calibration data artifacts used to prove machine capability. The VDI/VDE measurement uncertainty limits are used to define the measurement capability of the instruments worldwide.

In the U.K. in the early 1990s, there was general acceptance of the philosophy of the VDI/VDE guidelines, but it was considered that more guidance on the procedure to assess measurement uncertainty was required. Also, more guidance on the routine testing of measurement instruments was required. The result of this was a series of codes of practice prepared by the U.K. National Gear Metrology Laboratory (NGML) and published by the British Gear Association (BGA) (Ref. 3).

One of the reasons that the guidance in ISO 18653 is not more widely adopted is that measurement uncertainty is seldom considered unless a dispute occurs, usually between customer and supplier. The supplier's measuring machine shows the gears are within tolerance and customer's machine indicates the gears are outside tolerance and thus rejects them. Sometimes the cause of the disagreement is simply the interpretation of the specification—a gear mounting error or a mistake in the measurement process—but at other times the cause of the differences is subtler. All measurement processes contain error, including NMI and shop floor machines. The only certainty is that the measurement result is wrong.

ISO 18653 addresses traceability; calibration intervals; sources of measurement uncertainty or errors; basic instru-

continued

Figure 2—Example GMM: the U.K. primary gear measuring machine.

Figure 3—Micrometer and M8-gauge block set used for functional micrometer calibration.

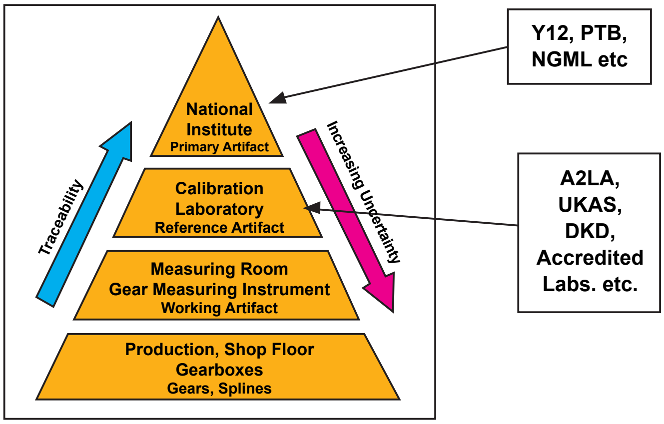


Figure 4—Example of traceability chain for gears using artifacts as transfer standards.

ment checks; environmental conditions; and calibration artifact design. It also provides a method for estimating measurement uncertainty, containing sound guidance on how to estimate gear measurement uncertainty using simple, robust methods. It allows users to assess the differences in measurement instrument capability and thus make informed choices. It minimizes the risk associated with high-accuracy gearing operating in safety-critical situations and allows manufacturers to focus on manufacturing gears rather than measuring them.

Calibration Methods—Micrometer Example

It is the experience of the authors that many gear manufacturers consider that they carefully maintain and calibrate their gear measuring machines. Compared to the care taken to calibrate a simple instrument such as a micrometer, shown in Figure 3, we do very few tests. A typical micrometer calibration procedure is as follows:

- Check that the micrometer spindle is free through its range of operation and the lock functions correctly.
- Verify the fixed anvil is flat within defined limits and free from damage with a calibrated optical flat.
- Verify the moving anvil is free from damage with an optical flat and then verify that the two anvils are parallel within limits with an optical parallel. It is usual to use five optical parallels with different thicknesses arranged to set the spindle at different angles to verify for spindle runout.
- Check that the zero point is within acceptable limits and adjust if necessary.
- Use a range of traceably calibrated gauge blocks to verify the measurement performance through the 25 mm range of operation. It is usual to use 8 gauge blocks (M8) set as a functional verification of the performance of the micrometer.
- If all the results are within acceptable limits, the calibration is complete and the micrometer is returned to the shop for use.

In addition, before use, every competent operator checks the zero point setting and ensures that it is within its calibration interval. We apply these thorough checks to a simple single-axis measuring instrument used to inspect simple lengths with tolerances of 15–100 μm.

Many users of gear measuring instruments do not calibrate them with this rigor. Most rely on the machine service engineer to perform a calibration with the gear artifacts supplied with the machine when it was originally installed. They may use a gear artifact to verify the machine at three- or six-month intervals and then use a mandrel to check alignment, but in general the measurement uncertainty is only considered when there is a problem, flagged by manufacturing machine operators or the customer.

ISO 18653—How it Works

The key concepts in the ISO 18653 standard are summarized below:

- Measurement uncertainty is assessed by performing a series of measurements on a gear or gear artifact that has been calibrated in an accredited calibration laboratory.
- It is a comparison process: the results from the calibration laboratory are compared with the results from a series of measurements on the subject measuring machine.
- All parameters that the machine will measure and evaluate (profile, helix, pitch and tooth thickness parameters) are analyzed.
- The gear or gear artifact should be of similar geometry to product gears inspected by the measuring machine (geometrical similarity implies the same size and weight, module, helix angle, face width and, where possible, the same measurement position and locating arrangement on the measuring machine). Artifact design is discussed in detail in ISO/TR 10064-5.
- It is preferable that data for the series of measurements is gathered over a long period of time so that effects from temperature variation, machine alignment and different operators are taken into account (reproducibility data). The ISO procedure uses the mean and standard deviation from these tests to estimate measurement uncertainty. The minimum number of tests is 10, but 30 is recommended.
- Guidance on other factors that are known to affect measurement results is given, such as temperature and instrument alignment (ISO/TR 10064-5 covers these in detail).
- It recommends minimum recalibration intervals for gear artifacts.
- The methods are consistent with those used for task-specific calibration in general metrology with CMMs.
- If the calibration artifact is significantly different to the product gear geometry, additional time-consuming tests are needed to establish an uncertainty budget for the product gear. This is why the standard recommends that the calibrated gear is similar to the product gears.
- The subject of fitness for purpose of the instrument is complex and is not covered in the standard, but is discussed in detail in ISO/TR 10064-5.
- An accredited calibration laboratory is one that complies with the requirements of ISO 17025, i.e.—laborratories accredited by A2LA, DKD, UKAS, etc. The calibration certificate states how the gear was measured, calibration data and its measurement uncertainty.

Care has been taken when preparing the document to make it applicable to dedicated GMMs and CMMs.

Traceability

The requirement that calibration data is supplied by an ISO 17025-accredited laboratory implies measurement traceability. Traceability implies that there is an unbroken chain of calibrations between the subject measurement result and the primary standards (of length, angle and temperature for the dimensional measurement of gears) at the NMI. Traceability is usually established or transferred by calibrated artifact and is illustrated in Figure 4.

Thus data from a properly accredited calibration laboratory is required to establish measurement uncertainty.

Estimating Measurement Uncertainty

It has long been recognized that measurement processes are subject to errors that are not known and therefore cannot be corrected. The results from any measurement process are thus incomplete without the statement of its associated measurement uncertainty. It is common practice to define a measurement uncertainty (U95) with a specific confidence interval of 95%, meaning that there is a 95% chance that the actual result lies within the upper and lower stated limits. There remains, obviously, a 5% chance the actual result is outside the upper and lower limits stated. This is illustrated in Figure 5. The measurement uncertainty statement is a statistical definition of how we quantify measurement uncer-

continued

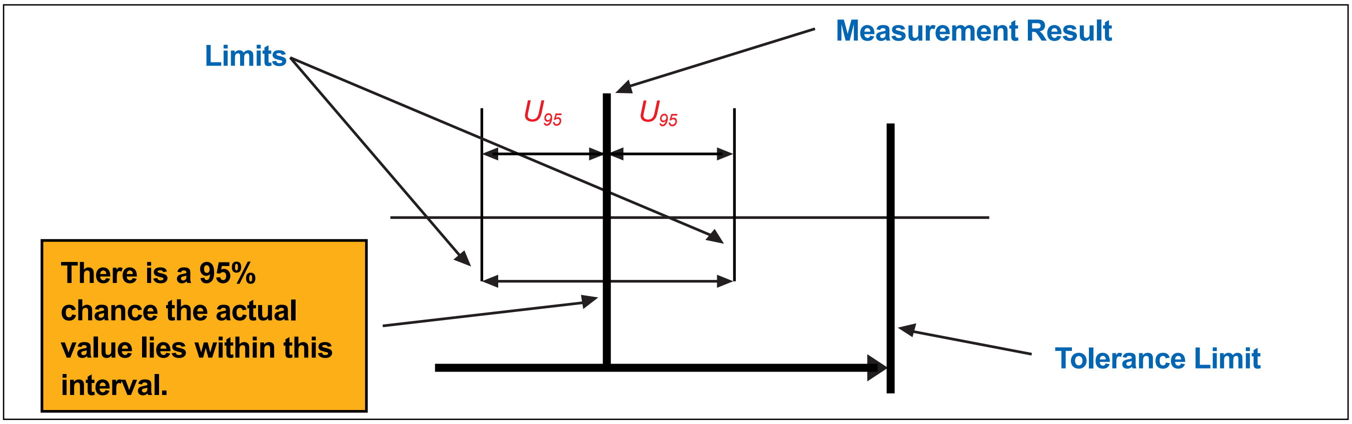


Figure 5—Definition of measurement uncertainty.

Figure 6—Traditional Fellows-type helix (lead) artifact.

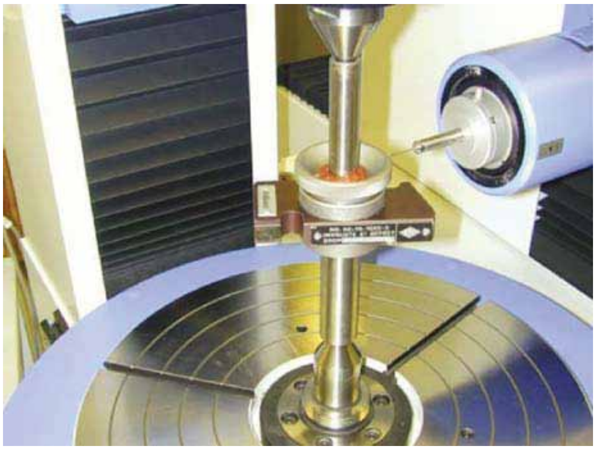


Figure 7—Traditional Fellows involute profile master.

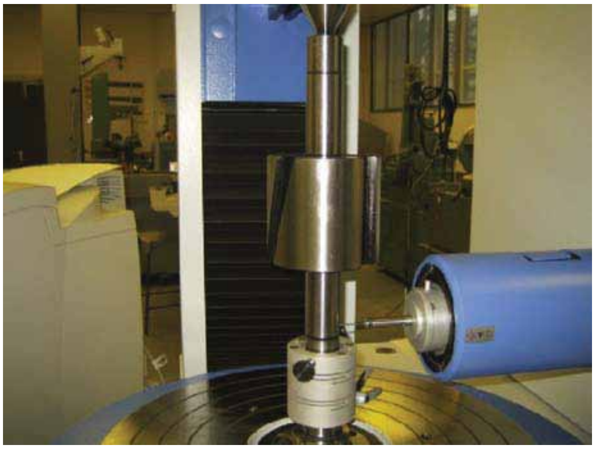


Figure 8—Traditional 100 mm-diameter helix and profile artifact (from Europe).

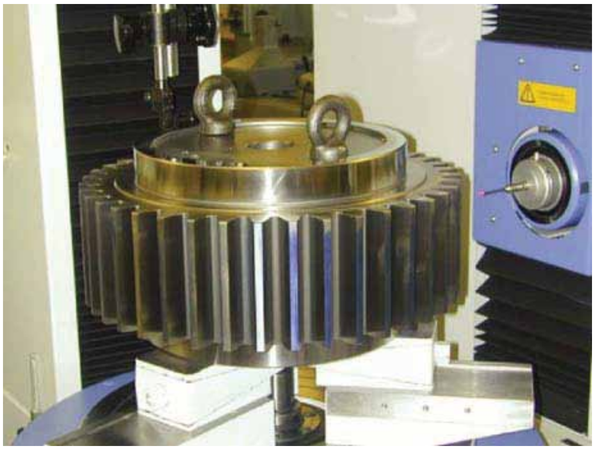


Figure 9—Workpiece-like artifact: master gear to verify a specific geometry.

tainty. The general calculation as defined in ISO 18653 is:

$$U_{95} = k\sqrt{(u_m^2 + u_n^2 + u_g^2 + u_w^2)} + |E| \quad (1)$$

where :

- K = a coverage factor is set to 2 to give an approximate 95% confidence interval, assuming the distribution is a normal distribution.
- u_m = standard deviation of the series of reproducibility tests of the subject machine (10–30 test results are required to comply with the standard).
- u_n = calibration artifact standard deviation. Assumed to $U_{95}/2$ where U_{95} is calibration certificate measurement uncertainty.
- u_g = geometrical similarity uncertainty to account for difference in geometry between the calibrated artifact and the product gears measured.
- u_w = workpiece similarity uncertainty, accounting for uncertainty due to the workpiece—e.g., it could be due to excessive workpiece deflection during measurement or poor datum surface quality, etc.
- E = bias or difference between the mean measured data (x_{mean}) and the calibration value (x_{cal}).

This relatively simple formula (Ref. 1) is very difficult to apply in practice without suitable experience in modeling measurement uncertainty, but ISO/TR 10064-5 provides information on applying it to common situations.

The easiest situation is to estimate the uncertainty of measurement taken on the calibrated gear artifact used to establish traceability. In this situation, U_g and U_w are zero, because the product gear we are measuring is the calibration artifact (or a near-identical copy of it). Thus the resulting formula is simplified to the standard deviation of the calibration data, standard deviation of the measurements on the subject measuring machine and the bias (difference) between the mean of the measurements and the calibration data values, as:

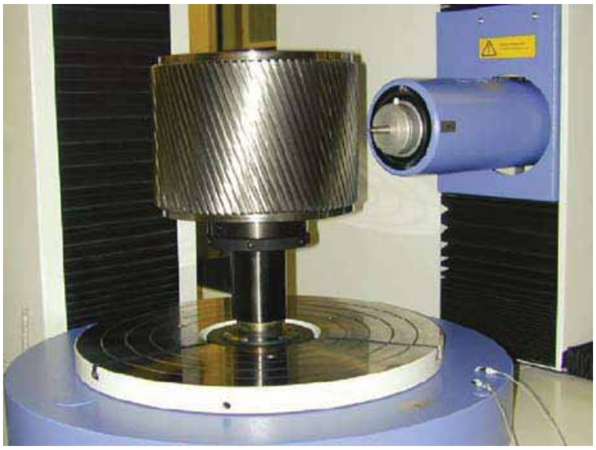


Figure 10—Workpiece-like artifact: 180 mm-face width master involute spline for aerospace applications.

$$U_{95} = k\sqrt{(u_m^2 + u_n^2)} + |E| \quad (2)$$

The procedures for estimating values of u_g and u_w are more complicated and discussed briefly in ISO/TR 10064-5 but the details, particularly for u_g when there are significant differences in gear geometry between the calibrated artifact, are beyond the scope of that document. Some methods to overcome this are discussed in the following sections, but the recommendation that users obtain workpiece-like artifacts to establish traceability avoids the difficulty of establishing the u_g uncertainty contributions.

Artifacts and Master Gears

ISO 18653 provides examples of different artifact designs, and ISO/TR 10064-5 provides further information on the design and specification of artifacts. Users should ensure they have artifacts that cover all the features that are measured on the measuring machine, including profile, helix, pitch, tooth thickness and other features such as datum axis runout correction.

Traditional artifacts are illustrated in Figures 6–8. These were originally developed to prove the performance of manual gear measuring machines, where base discs were used with a mechanical sine bar to set the base helix angle. In these cases, the range of helix angles was necessary to ensure that the sine bar was correctly set and no excessive play affected results when measuring left- or right-helix angles. The benefit of this artifact style is that a single artifact can test a range of geometries, and the source of any bias due to a machine setting can be established. As such, they are very useful for investigative work in calibration laboratories (Refs. 4–5). The disadvantage is that they often do not use the same software as standard gear measurement processes, and require manual intervention to measure them correctly. A further disadvantage is that many measuring machine suppliers use identical artifacts, calibrated by NMIs to error map the machine and, thus, when the user tests the machine with the same geometry artifact, the measurement results can give an overly optimistic assessment of measurement uncertainty.

Although the older style of gear artifacts is acceptable, ISO 18653 recommends that full workpiece-like artifacts or product gears are used for establishing industrial traceability of gears to perform a functional test on the machine performance. Matching the artifact geometry to the customer's product gears eliminates the complexity associated with the uncertainty due to geometrical differences u_g and thus minimizes the costs and additional costs with establishing the uncertainty associated with u_g. Examples of workpiece-like artifacts are illustrated in Figures 9–11.

Figure 9 shows a spur gear that was identical to a workpiece that had particularly stringent accuracy requirements, compared to the available measurement capability. Routine calibration with an identical artifact avoided measurement problems. Figure 10 is a helical involute spline used in an aerospace application. Its geometry is totally different from "standard" artifacts that would traditionally be used to prove instrument measurement performance, and is a functional test of machine performance. Figure 11 shows a large face width, left-hand helical master gear used to calibrate measuring machines for the wind turbine industry. The disadvantage with a full gear is that only a single helix is tested, so a right-hand helix master gear was also manufactured. Helix, profile and pitch errors, radial runout of tooth space, tip and root diameters and tooth thickness parameters are calibrated to meet a customer's requirements. The customer also defined the mounting arrangement and the datum surfaces.

Workpiece-like artifacts are more challenging to calibrate because of larger flank and datum surface geometry form errors. But the potential problems caused by this are avoided if the procedure used on the shop floor measuring instrument is identical to the procedure used by the calibration laboratory.

ISO 18653 Survey Results

The NGML carried out a survey of gear measurement uncertainty (capability) using the 5 mm module, 30º-helix angle artifact illustrated in Figure 12 to test the procedures in ISO 18653. The gear was measured over 10 times on each measuring machine. The master gear was measured using standard procedures: 4 teeth at 90º intervals were measured on both left and right flank, and pitch errors measured on all teeth, left and right flanks. Radial runout of the tooth space was calculated from the pitch results. Although 4 teeth were measured, only the first tooth was evaluated to minimize the risk of problems caused by instruments selecting different teeth to measure around the gear. Operators from each participating company performed the tests. Seven machines were tested, including manual gear testers, CNC GMMs and CMMs with gear software that were located in a shop floor environment or inspection rooms located on the shop floor.

The calculated measurement uncertainty results are summarized in Table 1 for profile error slope ($f_{H\alpha}$), total profile error (F_{α}), profile form error ($f_{f\alpha}$), helix slope error ($f_{H\beta}$), total helix error (F_{β}) helix form error ($f_{f\beta}$), tooth-to-tooth pitch error (f_p), cumulative pitch error (F_p) and radial runout (F_r) parameters, defined in accordance with ISO 1328, parts 1 and 2.

Table 1 shows most instruments operated in a shop floor environment are capable of 2–3 µm measurement uncertainty with a 95% confidence interval, which seems to be reasonable when compared to NMI capability of 0.7 to 1.5 µm (Refs. 6–7). The results for cumulative pitch (F_p) and radial runout (F_r) are generally higher due to the excessive runout of the centers on most of these machines. It appears that the importance of basic instrument alignment and runout of mounting centers is still not fully appreciated by users of measuring instruments. The ISO 18653 procedures quantify the importance of this, thus encouraging companies to invest in proper servicing and maintenance procedures.

The results show that, in general terms, the procedures for evaluating measurement uncertainty appear realistic. Examining individual measurement results revealed none in excess of the 95% confidence limits, and although it is

continued

Figure 11—Workpiece-like artifact: 350 mm-face helical gear for the wind turbine industry.

Figure 12—M5 master trial gear.

acknowledged that few tests were taken, it suggests that the procedure is somewhat in question.

Implementing ISO 18653 in the Workplace

Implementing the ISO 18653 standard in the workplace is relatively easy to accomplish in a 5-stage process:

1. Select two or three good-quality, representative, hardened workpieces with tooth numbers etched on them, and set them aside for measurement purposes. Once a week, measure these using standard measurement procedures and record the results in a table by hand or preferably in a spreadsheet (because it makes the sums easier, updating easier and the results can be plotted to identify trends). An example of this is in Figure 13. Experience at NGML is that once established, it takes only 30 minutes a week to complete, but this will depend on the manufacturing environment and artifact size.
2. For each parameter, estimate the mean and standard deviation with a minimum of 10 sets of results. This defines the reproducibility of the measurement process. Reproducibility is defined as the long-term repeatability of the measurement process.
3. Carefully record the measurement process, includng: geometry, axis correction method (if used), evaluation ranges, tooth numbers and flanks measured, probe size and how the axial position of the gear is defined. Send the gear to an accredited calibration laboratory and calibrate each parameter used for defining gear quality. The calibration interval will be less than for proper master gears, but because they represent typical workpieces, the value of the calibration data is enhanced.
4. Use the calibration data and the measured data on the subject gears to evaluate measurement uncertainty using Equation 2.
5. Tests on runout of centers and alignment with a mandrel should be made at between 1- to 4-week intervals, in accordance with the guidelines in ISO/TR 10064-5.

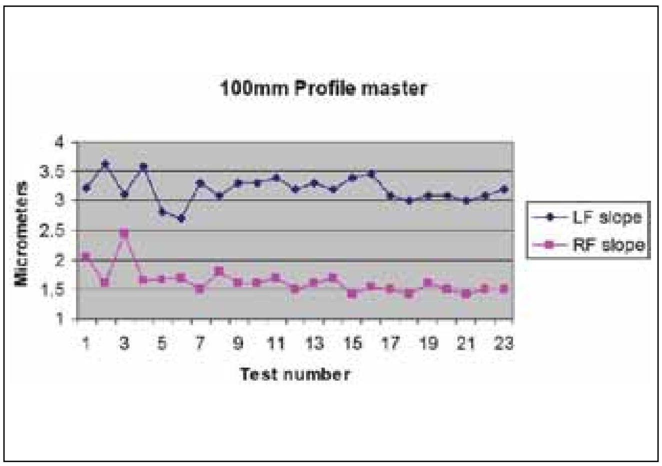


Figure 13—Example plot of reproducibility for profile measurement from weekly measurements.

These simple procedures will provide sufficient information to evaluate measurement uncertainty using the comparator procedure, to identify drift and trends with the measurement processes and to provide greater confidence in results obtained from the machine.

Problems arise if workpieces are larger than existing

Table 1—Summary of measurement uncertainty values calculated using the ISO 18653:2003 procedure.

Flank/ parameter	Measurement uncertainty (U_{95})							
	A	B	C	D	E	F	G	Mean U_{95}
1LF $f_{H\alpha}$	1.89	3.07	2.31	1.90	2.01	2.58	3.93	2.53
1LF F_{α}	4.01	2.22	2.29	2.23	2.47	3.08	3.47	2.82
1LF $f_{f\alpha}$	5.35	2.63	2.21	2.07	2.06	2.62	2.43	2.77
1RF $v_{H\alpha}$	2.88	4.39	1.73	2.55	2.05	3.26	2.66	2.79
1RF F_{α}	7.15	3.85	2.47	2.64	2.44	2.80	2.24	3.37
1RF $f_{f\alpha}$	5.06	2.03	3.11	2.15	2.03	2.31	3.09	2.82
1LF $f_{H\beta}$	2.10	3.00	3.77	2.46	2.51	2.10	1.98	2.56
1LF F_{β}	4.92	2.98	2.20	2.80	2.90	3.32	2.21	3.05
1LF $f_{f\beta}$	5.41	2.26	2.81	2.18	2.00	3.17	2.47	2.90
1RF $f_{H\beta}$	2.70	2.64	2.89	2.00	1.73	2.87	2.25	2.44
1RF F_{β}	5.75	2.47	2.81	2.47	2.05	4.06	2.17	3.11
1RF $f_{f\beta}$	5.08	2.40	2.99	2.27	2.06	3.53	2.28	2.95
LF f_p	1.60	2.48	1.63	1.96	1.64	2.90	1.91	2.02
RF f_p	2.06	3.17	2.17	1.68	1.97	2.50	1.89	2.21
LF F_p	2.48	14.41	4.15	5.17	3.37	4.79	2.28	5.24
RF F_p	2.38	14.99	4.79	5.77	2.67	3.44	3.11	5.31
F_r	3.01	9.59	3.75	4.31	3.63	3.60	2.96	4.41

Where: LF = left flank and RF = right flank facilities at NMIs. An alternative strategy is required, which addresses three key areas:

1. ***The effect of temperature is potentially far greater because thermal stabilization times are high.*** The only reliable solution to this is to leave gears to stabilize and complete a simple test to verify drift in measurement results against time to establish a suitable interval. Provided the stabilizing times are adhered to, this will not be a significant source of measurement uncertainty.
2. ***Measurement of elastic deflection of the measuring machine with workpiece load***. Large gears are heavy and they can cause significant deflections of the measuring machine. This can be addressed by measuring the deflection of the machine using precision electronic levels or laser interferometer methods to detect the movement of the machine when the gear is loaded. Not all deflections will have a first-order effect on measurement results, depending on instrument measurement strategy. This should be assessed on each specific machine, but guidance is provided in the BGA Code of Practice DUCOP 05/2 (Ref. 3).
3. ***The final additional source of uncertainty that should be assessed is u_g— the uncertainty from the difference between workpiece geometry and calibrated artifact geometry***. This is necessary because large gears use different parts of the instrument slides and are thus susceptible to different slide errors. Methods of measuring these errors are the subject of research by PTB and NPL (Ref. 8), although the results are not published. The solution has two elements: 1.) the measurement of geometry errors using laser systems or artifact-based systems such as ball/hole plates, and the use of a virtual CMM to simulate the effect that the errors have on measuring gears of a defined geometry using a Monte Carlo Simulation.

Until research is completed, NGML recommends (similar to the ISO procedure itself) the following strategy:

1. Select two or three good quality representative, hardened workpieces with tooth numbers etched on them and set

continued

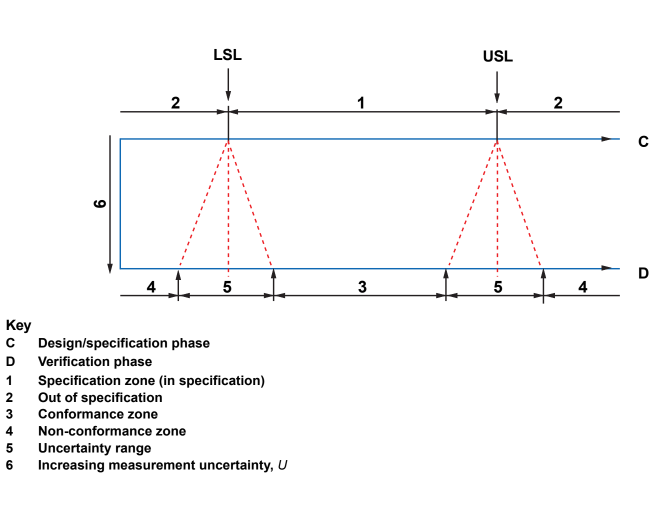


Figure 14—Extract from ISO/TS 14253-1:1995: the GPS method.

Table 2—Example of Measurement Uncertainty Budget.

Uncertainty Source	Units	Value	Dist	Divisor	Ci	n	Ui
Calibrated Artifact Uncertainties							
1 Artifact	mu	1.2	n	2	1.0	1	0.6
Repeatability of artifact measurement	mu	0.5	n	1	1.0	5	0.2
Uncorrected differences between data	mu	1	r	1.732	1.0	1	0.6
Drift of the reference artifact	mu	0.5	n	1.732	1.0	1	0.3
Difference in artifact temp. and 20°C	deg C	1	r	1.732	2.0	1	1.2
Uncertainty in artifact CTE	na	1.16E−06	r	1.732	173205.1	1	0.1
Workpiece Uncertainties							
2 Temperature affects	deg C	0.3	r	1.732	2.0	1	0.3
Reproducibility of workpiece measurement	mu	1.5	n	1	1.0	1	1.5
Instrument Geometry Uncertainties							
3 X-axis combined uncorrected slide errors		0.5		1	1.0	1	0.5
X-axis uncertainty		0		1	1.0	1	0.0
Y-axis combined uncorrected slide errors	mu/m	0.5	r	1.732	0.0	1	0.0
Y-axis uncertainty	mu/m	0	n	2	0.0	1	0.0
Z-axis combined uncorrected slide errors	mu	1.5	r	1.732	1.0	1	0.9
Z-axis uncertainty	mu	0.5	n	2	1.0	1	0.3

them aside for measurement purposes. Once a week measure them with the standard measurement procedures and record the results in a spreadsheet. It is important that if the standard measurement process involves transferring gears from the shop floor to the inspection room and stabilizing, this is reflected in the test practice.

2. From a minimum of 10 sets of results for each parameter, estimate the mean and standard deviation for each parameter to define the reproducibility of the measurement process.

3. Measure the elastic deflection of the machine with electronic differential levels in the appropriate planes that effect measurement results.

4. Use precision differential levels and laser-based systems to quantify systematic errors in guideways.

5. Construct an uncertainty budget similar to the simplified example in Table 2 (Ref. 9).

The uncertainty budget in Table 3 lists uncertainty sources, the units, the value of the uncertainty and defines the distribution as either normal- or rectangular-type (see ISO/TR 10064-5) and defines the sensitivity coefficient C_i, to calculate the effect the uncertainty source has on the measured result. In accordance with standard evaluation procedures, the overall standard uncertainty (1 standard deviation) is calculated by $\sqrt{\sum u_i^2}$ multiplied by a coverage factor of 2. For the example budget, this yields a measurement uncertainty of ± 4.7 µm for a 95% confidence interval.

It is acknowledged that this is a complex process, which requires specialist measurement skills, but giving due consideration to the value of large gears and costs incurred if mistakes are made, it is worth the effort.

Limitations with the Standard

The results from testing the procedures in ISO 18653 show no significant issues with using the standard method, but a small revision to the formula is proposed as follows:

$$U_{95} = k\sqrt{u_m^2 + u_n^2 + u_g^2 + u_w^2 + \left(\frac{E}{\sqrt{3}}\right)^2} \qquad (3)$$

The effect of this change is that bias is not added linearly—which, in the opinion of the authors—overestimates measurement uncertainty when the bias value is significant. The reason behind this proposal is that the bias E will vary from test to test, and is thus only a single example of the bias on the machine.

Conformance with Specification

Measurement uncertainty, once established, should be applied. ISO 18653, unlike the VDI/VDE guidelines (Ref. 2) and BGA codes of practice (Ref. 3), does not specify allowable limits for measurement uncertainty. This is addressed in ISO/TR 10064-5, where three methods are described:

1. ***GPS (ISO/TS 14253-1) tolerance reduction method***. This is the preferred method, unless there is prior agreement between supplier and customer. In this method the specified tolerance from the accuracy specification is reduced by the measurement uncertainty to define smaller limits. This is illustrated in Figure 14 and shows that if measurement uncertainty is small, the allowable manufacturing limits are large while, conversely, if measurement uncertainty is large, the manufacturing limits are small. This will reduce the chances that poor-quality gears are accepted and good-quality gears rejected.
2. ***Tolerance ratio method.*** This method defines that the measurement uncertainty should be a maximum of 30% of the specified tolerance. It has the benefit that it is simple to apply, but may result in a larger or smaller uncertainty than the application requires.
3. ***Instrument uncertainty guidelines***. These define maximum recommended uncertainties for a group of ISO 1328 accuracy grades. It is easy to apply, but gears of 10 mm diameter, say, require the same measurement uncertainty as gears of 2 m diameter, and thus is not very flexible. An extract is given in Table 3 for an ISO 1328 grade 8 gear.

The GPS method is the only method that realistically describes how we should consider measurement uncertainty when interpreting results. However, in the opinion of the authors, simply estimating measurement uncertainty using the procedures in ISO 18653 and stating it on the measurement report would be a far more simple way of applying the measurement uncertainty estimate.

Discussion/Conclusion

- Introducing ISO 18653 procedures into the work place is straightforward and requires minimum time and investment to implement, provided artifacts are suitable for existing calibration facilities. A simple procedure has been recommended.
- The benefits from using workpiece-like artifacts rather than the traditional artifact designs have been demonstrated.
- The ISO 18653 uncertainty values have been tested and found to be acceptable, but a small modification to the formula is recommended in future revisions.

Table 3—Example Maximum Process Measurement Uncertainty (ISO/TR10064--5).

ISO 1328 Grade	Maximum process measurement uncertainty (µm)				
	Single pitch	Cumulative pitch	Runout	Helix	Profile
8	±5	±6	± 6	± 5	± 5

- The requirements for calibration of large gears can still be achieved by applying the procedure in ISO18653, but the additional work requires suitable expertise and guidance from metrology institutions. The costs of this are small compared to potential benefit-and-risk reduction that results from this work.
- The strategies for applying measurement uncertainty when interpreting results were discussed. Until the revision to the ISO 1328 accuracy standard is completed, it is recommended that measurement uncertainty simply be accompanied by measurement results so informed decisions can be made.

References

1. VDI/VDE Guidelines 2613. *Pitch and Runout Testing of Gears*, Verein Deutscher Ingenieure, Dec., 2003.
2. VDI/VDE Guidelines 2612. *Profile and Helix Checking of Involute Cylindrical Gears*, Verein Deutscher Ingenieure, May, 2000.
3. *BGA Code of Practice for Gear Measurement*. "DUCOP.05.2: Verifying the Accuracy of Gear Measuring Machines–Part 2," Iss.1, BGA, July, 1994.
4. AGMA 99FTM3 Technical paper. "Measurement Uncertainty for Pitch and Runout Artifacts," B.L. Cox, Oct., 1993.
5. Mashaharu Komori, et al. "Evaluation Method of Lead Measurement Accuracy of Gears Using a Wedge Artifact," *Measurement Science and Technology*, 20, (2009), (025109), 13 pp., Jan., 2009.
6. Bicker, R., B. Cox, R.C. Frazer, H. Harary and F. Härtig. "An International Comparison of Involute Gear Profile and Helix Measurement," *J. Metrologia*, Vol. 41, pp. 12–16, 2003.
7. AGMA 01FTM05 Technical Paper. "Traceability of Gears—New Ideas, Recent Developments," Härtig, F. and F. Waldele, Oct., 2005.
8. Schweke, H., M. Franke, J. Hannaford and H. Kunzmann. "Error Mapping of CMMs and Machine Tools by a Single-Tracking Laser Interferometer," *CIRP Annals Manufacturing Technology*, Vol. 54, Iss.1, pp 475–478.
9. M3003: 2007, UK Accreditation Service (UKAS). *Expression on Uncertainty and Confidence in Measurement*.

Dr. Robert Frazer *completed an apprenticeship with GEC in Power Generation before studying for a degree in mechanical engineering at Newcastle University. He spent three years working in the gear manufacturing industry before returning to Newcastle, joining the Design Unit in 1988. He is head of the UK National Gear Metrology Laboratory, responsible for gear design and analysis within the Design Unit and is actively involved with delivering the British Gear Association (BGA) training seminar program. He is the UK representative on the ISO gear accuracy committee (ISO TC 60 WG2) and a member of the UK shadow committee supporting the work of ISO TC60 WG6 on gear performance.*

Steven Wilson *is an engineer working for the Design Unit at Newcastle University. He has 18 years' experience in industry following an apprenticeship at Crabtree of Gateshead Ltd (metal finishing press manufacturer). For the last 10 years he as worked at the Design Unit where he is deputy head of the UK's National Gear Metrology Laboratory and is responsible for gear manufacture. Wilson received a (Beng.Hons) bachelor's degree in mechanical engineering from Northumbria University in 2000.*

Software-Based Process Design in Gear Finish Hobbing

ANALYSIS AND OPTIMIZATION OF GREEN GEAR FINISH HOBBING BY PENETRATION CALCULATION COMBINED WITH CUTTING TRIALS

F. Klocke, C. Gorgels, A. Stuckenberg and R. Schalaster

Management Summary

In this paper, the potential for geometrical cutting simulations—via penetration calculation to analyze and predict tool wear as well as to prolong tool life—is shown by means of gear finish hobbing. Typical profile angle deviations that occur with increasing tool wear are discussed. Finally, an approach is presented here to attain improved profile accuracy over the whole tool life of the finishing hob.

Introduction

For efficient gear manufacturing, green finishing processes have to be applied, rather than a cost-intensive hard finishing operation, whenever they are capable to reach the necessary geometrical accuracy of the tooth system. Therefore the machining process and its technological influences must be well known. For green finishing of gears, machining with a geometrically defined cutting edge is common. This includes gear shaving and the growing market of gear finish hobbing.

Compared to gear shaving, finish hobbing offers ecological as well as economical advantages (Ref. 1). Hobbing is the only process that enables a dry gear finishing operation, which, in turn, allows a coolant-free process chain of gear manufacturing. Economical advantages refer to a shorter value creation chain. With finish gear hobbing, no separate finishing machine tool is needed. At the same time, setup and transportation time can be saved, as washing after wet machining is not needed.

In rough and finish machining of running gears by hobbing, a separate

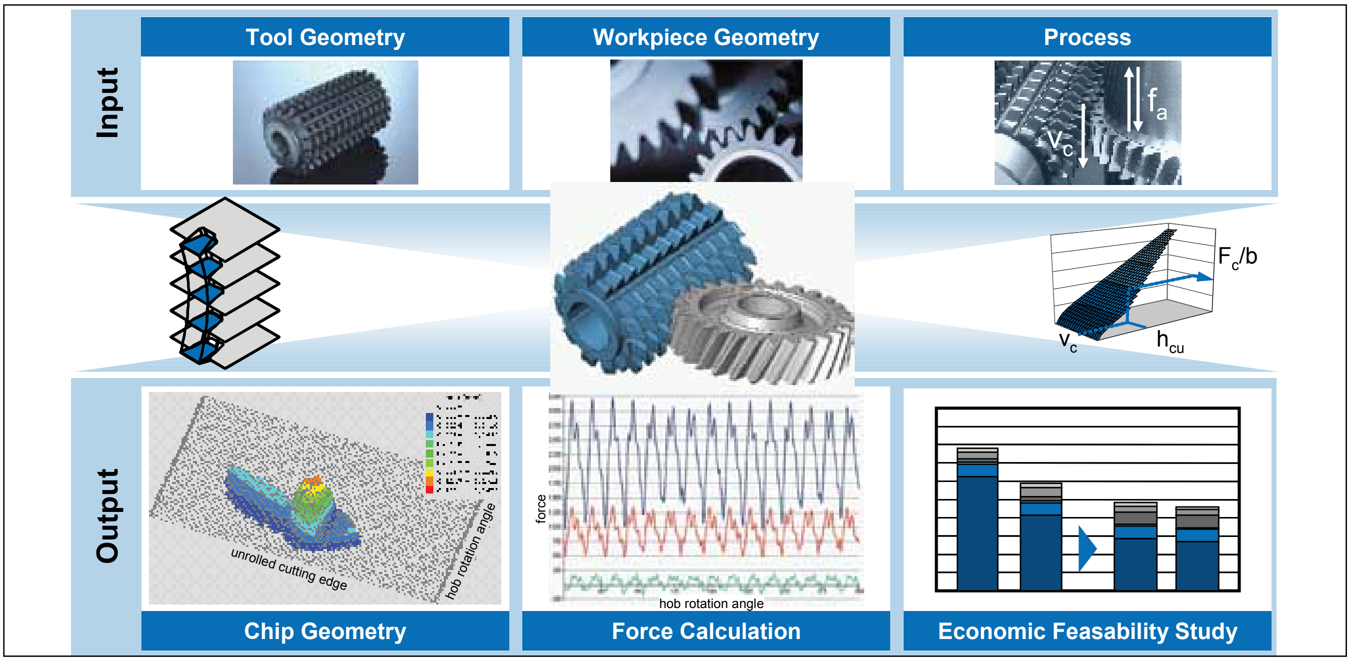


Figure 1—Functions of the software *SPARTApro*.

roughing-and-finishing pass is worthwhile (Ref. 2). During roughing, most of the material has to be removed, which leads to high forces and corresponding deviations. In this operation, only relatively low cutting speeds are applied. In finishing, restrictions exist regarding surface quality, feed marks and generated cut deviations due to the quality requirements of the part. Since only a small stock is machined, cutting speeds can be increased significantly (Refs. 3–5).

This paper addresses the question of how the roughing pass can be adapted to optimize gear finish hobbing regarding tool life and gear quality. For this purpose, theoretical analyses—as well as machining trials—are described.

Potentials of Software Support in Gear Hobbing

Hobbing is a very effective method for the green manufacture of external cylindrical gears. However, its productivity is influenced by numerous, mostly non-linear interacting factors. The tool costs per piece are likewise determined by the geometrical tool design. The parameters for a given machining operation have to be designed in order to meet the operational requirements of machining time and costs. Due to the complexity of the interrelations, this is a challenging task. Therefore the software tool *SPARTApro* has been developed at WZL to assist in designing and optimizing gear hobbing processes (Fig. 1).

The software can be used for three major applications:

1. ***Analysis of the chip geometries for a concrete process design***. *SPARTApro* provides all undeformed chip geometries that occur during the machining process by a process simulation based on penetration calculation. Characteristic process values like the maximum, undeformed chip thickness or the local chip volume for every point of the cutting edge are determined by this data. Based on this information, wear phenomena that occur in industrial applications can be analyzed. An experience-based estimation of the performance of a planned process design can be aided by the simulation results.

2. ***Estimation of cutting forces***. The progress of the cutting forces for the single generating positions (hob teeth) and of the resulting forces for the tool and the workpiece coordinate system can be determined based on empiric cutting force models, referring to Bouzakis (Ref. 6) and Gutmann, (Ref. 7). For the design of machine tools, cutting tools and workholding for high-performance cutting, knowledge of the static and dynamic process forces, as well as of the necessary spindle torque, are very important.

3. ***Economical or technological optimization of the tool geometry***. *SPARTApro* is able to consider a great number of possible tool variants with different design parameters—like the diameter and number of starts and gashes. For these tool variants, a process design is determined that meets defined requirements, such as maximum chip thickness and resulting feed marks. Based on analytic formulas regarding machining times, costs and further figures are calculated for all variants so that the operator can search for the tool geometry—e.g., with the lowest cycle time.

For the analysis of gear finish hobbing, the chip-forming software part has been used.

Sample Gear and Process Design

The investigations shown in this paper have been carried out by means of a gear that is representative for the automotive sector (Fig. 2). The material is a case-hardened steel 16MnCr5 with a tensile strength of about R_m = 565 N/mm². The finishing process will be analyzed by theoretical examinations as well as by cutting trials. For the cutting trials, a fly-cutting test is applied. This test is common for investigations in hob tool life since the fly-cutter creates nearly the same chip geometries as a real hob. Thus the load on the fly-cutter is the same as on a tooth in the middle of a shifted hob.

The hob that is simulated in the theoretical investigations, as well as by the fly-cutters, is designed with a separate roughing and finishing area (Fig. 2). This design allows roughing and finishing with the same tooth pro-

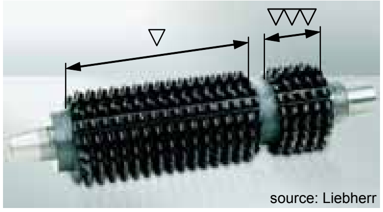
continued

Workpiece:
module m_n = 2.56 mm
number of teeth z_2 = 39
pressure angle α_{n2} = 17.5°
helix angle β_2 = 23 °
diameter d_{a2} = 116.2 mm
face width b = 30 mm
tooth height = 8.1 mm
no modifications

Material:
16MnCr5N
hardness = 168 HV
tensile strength R_m = 565 N/mm²

Flank Topography:
feed marks δ_x < 1.1 µm
gen. cut dev. δ_y < 0.8 µm

Simulated Hob:
carbide HW K10F
(Al,Cr)N-coating
separate roughing and finishing area
diameter d_{a0} = 80 mm
design n_i/z_0 = 16/2



Stock Geometry:

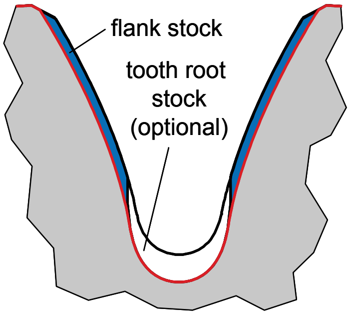


Figure 2—Workpiece, tool and stock geometry for finishing.

file, as well as roughing with a specially adopted profile and finishing only the flanks of the gear. Since the highest chip volume in finishing will be reached at the tip of the tool, avoiding the engagement of the tip during finishing may lead to an enhanced performance of the tool. The finishing part of the hob is designed with $n_i = 16$ gashes and $z_2 = 2$ starts, so that a surface with generated cut deviations of $\delta_y = 0.8$ µm can be achieved.

Theoretical Analysis

To analyze the load on the tool, a geometrical simulation of the chip geometries has been carried out with the software *SPARTApro*. Figure 3 shows some of the results for the finishing pass—with and without tooth root machining. A conventional cutting process is analyzed with a radial infeed in finishing of $h_2 = 0.2$ mm and an axial feed of $f_a = 1.0$ mm. The graphs display characteristic values for a tooth of a shifted hob. This means that the given graphs represent the chip geometries of all occurring generating positions. The values are plotted versus the unrolled cutting edge of the tooth, meaning that the middle of the graph represents the tip center of the tool. The horizontal axis represents the distance along the cutting edge from the tip center.

When the tooth root is machined, the maximum chip thickness appears for the tool tip with about $h_{cu,\ max} = 50$ µm, while the maximum chip thickness for the flanks is below $h_{cu,\ max} = 20$ µm. Due to the stock distribution left from the roughing process, the maximum cutting length along the cutting edge is nearly constant, with about $l_{cu,\ max} = 5.0$ mm. The number of cuts gives an idea of how often one single point of the tooth has to be engaged to finish one gear. For the transitions between the tip radius and the flanks, a maximum value of about $n_s = 10{,}000$ cuts can be found, which is about 30% more than the maximum value for the flanks. The graph of the specific chip volume shows peaks at the same positions of the tool. In general, the tooth tip has to cut a lot more material than the flanks. And so the highest mechanical and thermal load will be found at the tooth tip when it is engaged. When the tooth tip is not engaged, and only the tooth flanks are machined, this load maximum can be avoided.

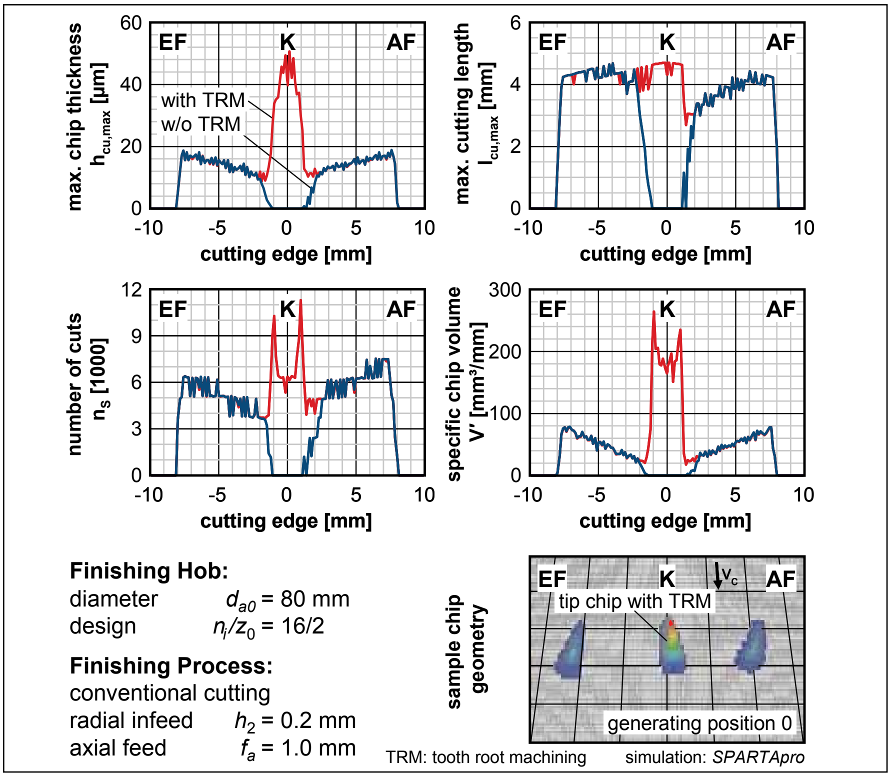


Figure 3—Characteristics of gear finish hobbing with and without tooth root machining.

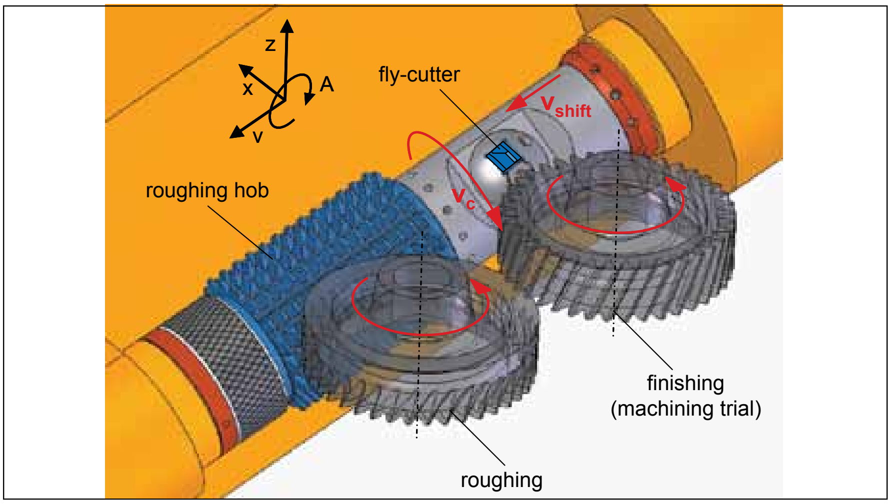


Figure 4—Experimental setup.

Cutting Trials

Cutting trials have been carried out with the parameters applied for the theoretical analysis. For the trials, the experimental setup shown in Figure 4 has been applied. A hob is used for roughing the gear while the finishing process is carried out with a fly-cutter mounted on the same shaft. This fly-cutter is shifted during the machining operation so that the created chips are similar to those created by a hob. The advantages of machining trials with a fly-cutter compared to a hob are fewer needed workpieces and the opportunity of wear analysis by an optical microscope or SEM, due to the good accessibility of the cutting edge.

Due to the low chip volume in the finishing process, the cutting trials have been carried out at a relatively high cutting speed of $v_c = 1{,}000$ m/min.

When the tooth root is machined, a tool life of about L = 27 m is reached before tool wear starts to increase progressively (Fig. 5). Since the tool life of a fly-cutter is in general about three times higher than the tool life per tooth of a real hob, this would mean about L_{hob} = 9 m per tooth. The SEM images of the tool (different scale in horizontal and vertical axis) show that the transition areas between the flanks and the tip radius show the greatest flank wear width. The rest of the cutting edge shows only initial wear and is in very good condition. This demonstrates that the tool life of the fly-cutter can be increased by more than 200% when the tooth root has already been finished in the roughing pass. The corresponding SEM images show a very smooth distribution of the flank wear for this trial, with a maximum flank wear width of about VB_{max} = 0.12 mm.

When the wear images are compared to the graphs in Figure 3, the correlation between the local wear—and especially the specific chip volume—stand out. This applies as well to the maximum wear at the transition zones of the first tool, as also seen in the increasing flank wear width from tip to root of the second tool with higher tool life.

Since gear finish hobbing is a green finishing process, the requirements for the resulting gear quality are higher than for a standard hobbing process. Figure 6 shows the profile and flank geometry of gears at the beginning and end of tool life for the tool with only flank machining. At the beginning of tool life, both profile and flanks are very straight, and good accuracy is reached. However, the accuracy highly depends on the tool and process design so that it can actually be improved by, for example, a higher number of gashes.

The profile of the gear's left flanks at the end of tool life shows a profile angle deviation, while the profile of the right flanks is straight. This can be traced back to two different factors. The first factor is a slight inclination of the fly-cutter due to its clamping. This causes a slight profile angle deviation, and consequently both flanks have to be parallel in the graph. The second factor is a change of the cutter profile, due to wear. The local wear causes an offset of the cutting edge, which is proportional to the flank wear width. The increasing wear from the tip to the root (Fig. 5) leads to an increased thickness of the workpiece tooth—from the root to its tip.

To sum up, there is a fundamental tendency of increasing profile angle deviations with increasing tool life that has been pointed out to be dependent on the local chip forming characteristics shown in Figure 3. This leads to exploring whether the deviations can be avoided by adjusting defined chip forming characteristics.

Improved Stock Distribution to Avoid Profile Angle Deviations

As shown above, the wear of the tooth flanks and the specific chip volume correlate very well. Therefore the first approach to avoiding profile angle deviations is adjusting the specific chip volume on the tooth flanks to a constant value. To do this, modifications in the stock distribution along the gear profile are necessary. These modifications must be reached by a specially adopted profile of the roughing hob.

Geometrical simulations have been carried out with *SPARTApro* in order to find this profile. The result is a tool profile with an adjustment of the pressure angle, as well as a slight crowning. The stock geometry generated by this tool leads to the characteristics shown in Figure 7 when compared to the original figures. Indeed, the distribution of the specific chip volume is much more even along the engaged cutting edge. Therefore the goal of theoretical process optimization to improve profile accuracy in gear finish hobbing has been met.

The outstanding question is if the wear behavior of the tools will change, as assumed.

Conclusion

This paper has shown that there is a wide field of applications for software support in gear hobbing, particularly regarding cost-effective hob design, cutting force determination and the analysis of tool wear causation. The software *SPARTApro* has been used to

continued

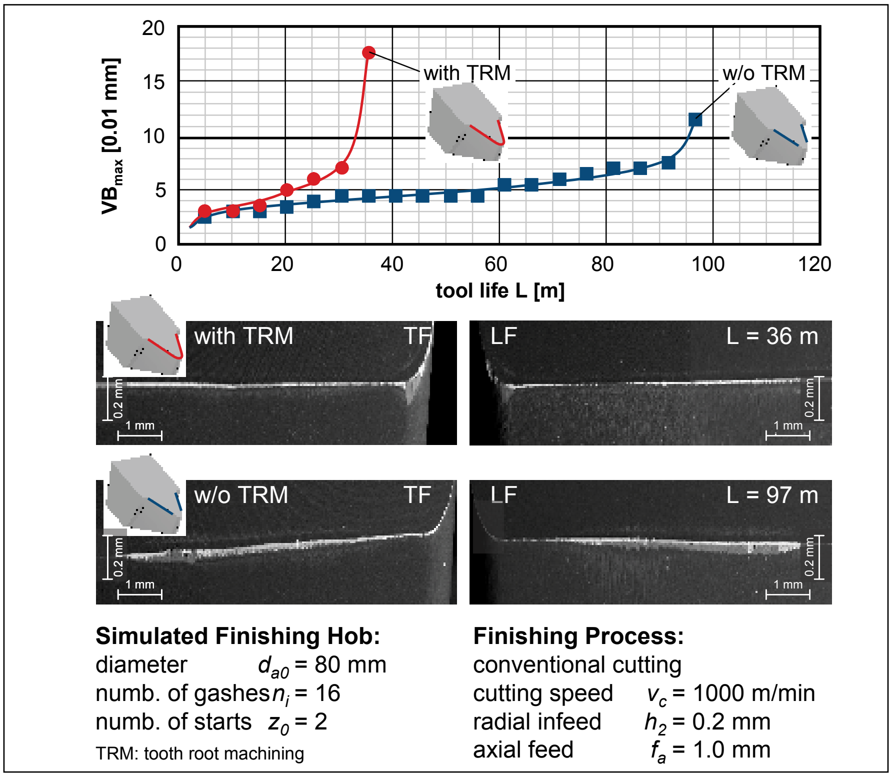


Figure 5—Gear finish hobbing with and without tooth root machining: performance.

simulate the undeformed chip geometries of a gear finish hobbing process, and to identify critical areas of the cutting edge. In combination with cutting trials, the geometrical simulation has shown that the greatest local load on the tool can be avoided when the tooth root is not machined in the finishing pass. This can be used either to increase tool life by about 200% or to boost productivity by increasing cutting speed.

However, typical profile angle deviations arise with the progression of tool life. They can be traced back to the distribution of tool wear along the flanks due to other local cutting conditions. To avoid these profile deviations, the influence of the roughing tool profile on local cutting conditions has been analyzed theoretically. Profile modifications have been found that promise a very smooth distribution of the specific chip volume.

Further cutting trials are needed to prove whether this modified roughing tool profile leads to improved wear behavior of the finishing tool and, in the end, to enhanced profile accuracy.

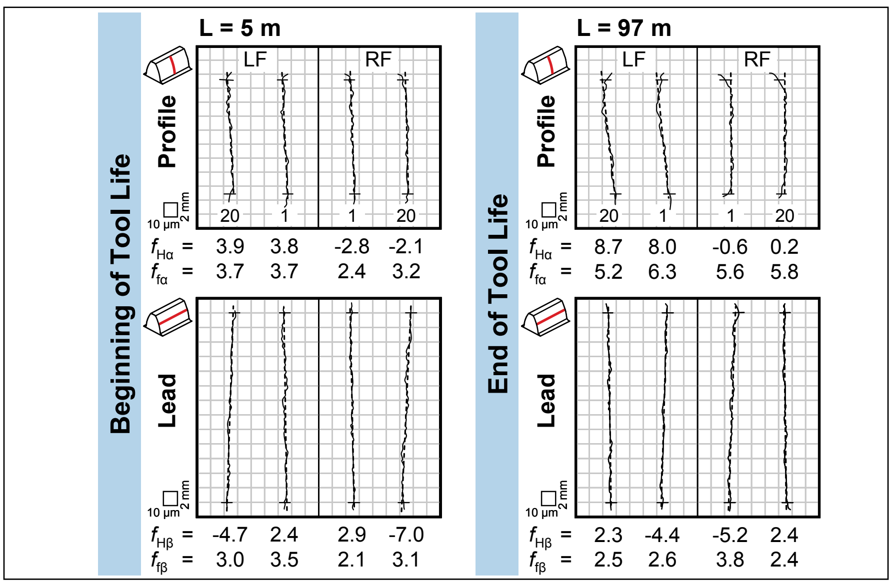


Figure 6—Gear finish hobbing without tooth root machining: workpiece accuracy.

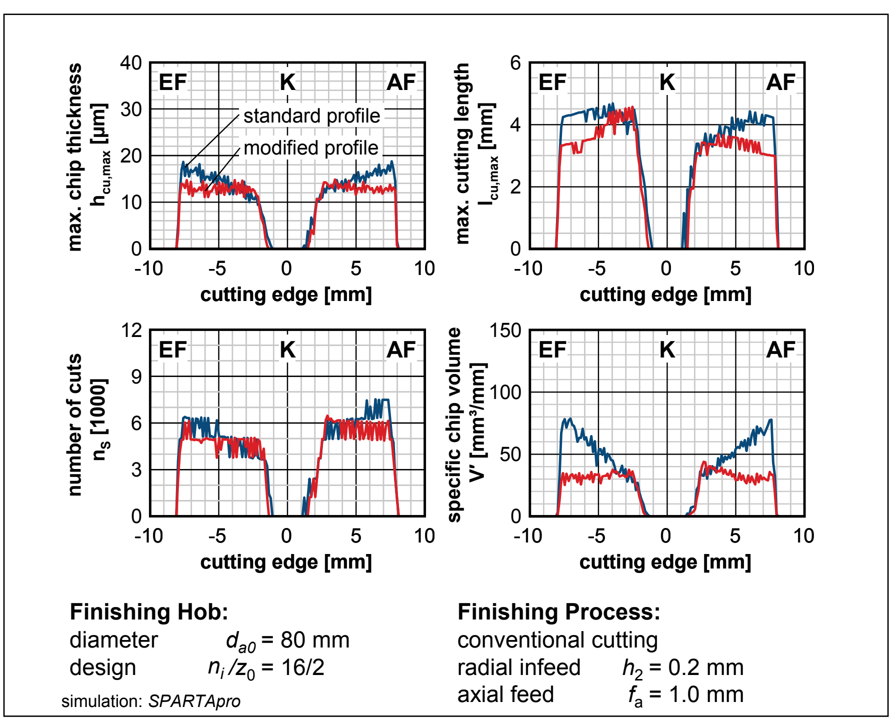


Figure 7—Characteristics of gear finish hobbing with modified stock geometry.

References

1. Kleinjans, M. "Einfluss der Randzoneneigenschaften auf den Verschleiß von Beschichteten Hartmetallwälzfräsern," Dissertation, RWTH Aachen, 2003.

2. Winkel, O. "Finish Hobbing–Present and Future," Seminar—Gear Finishing Technology, Aachen, 2007.

3. Peiffer, K. "Finish Hobbing—An Alternate Solution to Shaving?" Seminar—Gear Finishing Technology, Aachen, 2005.

4. Vucetic, D. "Finish Gear Hobbing at High Cutting Speeds," Seminar—Trends in Soft Gear Manufacturing," Aachen, 2006.

5. Klocke, F., C. Gorgels and R. Schalaster. "Technologische Potenziale des Fertigwälzfräsens von Verzahnungen," *Proceedings of the 49th Conference on Gear and Transmission Research*, WZL, RWTH, Aachen University, 2008.

6. Bouzakis, K.-D. "Konzept und Technologische Grundlagen zur Automatisierten Erstellung Optimaler Bearbeitungsdaten beim Wälzfräsen," Habilitationsschrift, RWTH, Aachen, 1981.

7. Gutmann, P. "Zerspankraft-berechnung beim Wälzfräsen," Dissertation, RWTH, Aachen, 1988.

Dipl.-Ing. Christof Gorgels *has a degree in mechanical engineering. Since 2003 he has worked for the Gear Research Center at the Laboratory of Machine Tools at RWTH Aachen University. He worked in the area of gear grinding with a focus on causation and effects of grinding burn. Since 2008 he is chief engineer of the Gear Research Center.*

Prof. Dr.-Ing. Dr.-Ing. E.h. Dr. h.c. Fritz Klocke *is head of the chair of manufacturing technology at the Laboratory for Machine Tools and Production Engineering (WZL), a part of RWTH Aachen University in Germany. Also, he is director of the Fraunhofer Institute for Production Technology in Aachen, Germany.*

Dipl.-Ing. Rolf Schalaster *is a research associate and doctoral candidate under Prof. Klocke in production engineering at the Gear Research Center at RWTH Aachen University. His principal field of work is gear hobbing and especially process optimization of gear finish hobbing processes.*

Dipl.-Ing. Arne Stuckenberg *is a research associate and doctoral candidate under Prof. Klocke in production engineering at the Gear Research Center at RWTH Aachen University. His principal research activities are in gear hobbing. He works on tool reconditioning of hobs and process forces in gear hobbing.*

Allowable Contact Stresses in Jacking Gear Units Used in the Offshore Industry

A. N. Montestruc

Management Summary

An offshore jack-up drilling rig is a barge upon which a drilling platform is placed. The barge has legs that can be lowered to the sea floor to support the rig. Then the barge can be "jacked up" out of the water, providing a stable work platform from which to drill for oil and gas. Jack-up drilling rigs were first introduced in the late 1950s. Rack-and- pinion-type jack-up units were introduced soon after that and have dominated the industry ever since. The rack-and-pinion systems used to raise and lower the rig are enormous in terms of gear pitch, or module, by gear industry standards. Quarter-pitch (101.6 module) pinions are common, with both larger and smaller teeth used. The lifetime number of cycles for these units is—by gear industry standards—tiny in that rack teeth typically have 25-year lifetime cycles measured in the low hundreds. That is off the charts for AGMA (and ISO or DIN) design rules, which draw a straight line to zero cycles for contact stress cycles less than 10,000. Use of any standards was abandoned from the start in the offshore industry for jacking applications. The author presents methods via experience in that industry and suggested allowable contact stresses in such applications.

Introduction

The new and inexperienced designer of rack-and-pinion jacking systems with no experienced mentor will often initially turn to AGMA, ISO or DIN rules for the design of gears. Once he gets started and has had a chance to look at commercial systems on the market, he will wonder how on earth his competition can have gears so much smaller, cheaper and lighter than those he creates using those standard design methods. This paper is intended to address that issue and to aid the designer as to how this is done, and to show what allowable contact stresses have been used and seem to work in this industry for these applications. The designer is cautioned against using these values for other applications—especially at relatively high mesh speeds, or larger numbers of cycles than discussed in this paper—without careful consideration and experienced engineering judgment. Note also that in consideration of other applications, the mesh speeds of jacking systems are quite low: 500 mm per minute for jacking pinions engaged with racks is now the industry standard.

Historical Overview

The offshore oil and natural gas industry began in the period following World War II with the introduction of what are now commonly called lay barges or swamp barges. They were in fact converted cargo barges with a land-type drilling rig placed on it that were moved to a spot in the swamp or in other waters shallow enough that the top deck of the barge would be above the water when the barge was sunk. And that is exactly what was done; the barge was sunk in a controlled manner such that it grounded on the mud and provided a secure, stable platform from which to drill for oil or natural gas.

Prior to that time, it was held by many geologists that little or no oil or gas was offshore. But the success of these ventures, and the fact that "slant" drilling from such rigs showed that oil and gas indeed existed in deeper waters,

continued

eventually resulted in the first jack-up-type rigs being introduced by the Bethlehem Steel Company in the mid-1950s. The jack-up-type drilling rig is a barge much as the previous lay barges, but with the introduction of structural legs that could be lowered to the sea floor. With that, the rig could then be jacked up onto these legs to provide a fixed, stable platform from which to drill. (A stable platform with respect to the earth is critical to drilling operations.) These legs allowed jack-up rigs to be used in waters many miles from shore, and so opened up enormous areas of the sea to oil and gas exploration.

Figure 1—Used 8-tooth, 2/3-pitch pinion, rejected for further service, yet having been pulled in this condition from a working jacking system (courtesy ESI, Inc.).

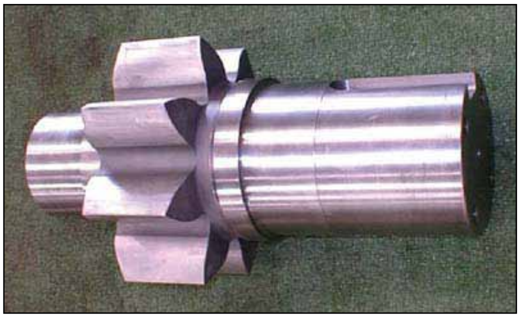


Figure 2—New 8-tooth, 2/3-pitch pinion (courtesy ESI, Inc.).

Figure 3—Used 54-tooth, 1.5-pitch gear rejected for further service, yet also having been pulled in this condition from a working jacking system (courtesy ESI, Inc.).

The Bethlehem rigs were not of the rack-and-pinion type, but rather had a hydraulic cylinder pin-and-yoke system. While this system worked well enough, and was reasonably safe, it was slow and labor intensive to operate. The success of these first rigs caused a boom in offshore oil rig construction, and in the late 1950s, LeTourneau introduced the first true rack-and-pinion-type jacking system rig.

Since that time, in waters up to about 400 feet deep, rack-and-pinion-type jack-up drilling rigs have been the dominant type of offshore oil and natural gas drilling rig. Jack-up rigs were also used for maintenance and to meet many other needs in the oil and gas industry. And just recently, jack-up-type rigs have started to be employed in the offshore wind energy business as installation and maintenance vessels.

The author was introduced to this industry and to jacking systems through work as an engineer for a firm that—rather than designing jack-up rigs or jacking systems—was primarily concerned with making spare parts for jacking systems of offshore oil rigs, including orphaned rigs whose original manufacturers had gone out of business, especially during the oil bust of the 1980s.

Thus, the author was presented with machinery that obviously worked, and had been working, in many cases over 30 years at the time the author started in this business. But the machinery did not at all conform to AGMA or other standardized contact or even bending stresses. In fact, it grossly exceeded them, despite the absence of original design data.

As regulatory bodies required that non-OEM spare parts be properly certified, this required the author to generate appropriate design drawings, calculations and engineering studies to prove that these non-OEM spare parts would work and be safe—even when mixed and matched with OEM parts. Starting from this position, the author was required to reverse engineer the bending and contact stresses of the gears of known geometry, material specification (which was difficult but not impossible to obtain by appropriate hardness and chemical analysis) and known jacking loads.

As can be seen in Figure 1, at times the wear and Brinell flow of gears can become significant. All of the below photographic figures are of gears new or used for a 1968- vintage National Oil well 400-type jacking system commonly used on older Friede & Goldman, Ltd. L-780 class rigs.

Figures 1 and 2 are photographs of both a used and new 8-tooth, 2/3-pitch 25-degree pressure angle pinion that in service is designed to drive a 40-tooth bull gear, which, in turn, drives a 7-tooth, 10.00" circular rack pitch pinion that lifts the rig.

Figures 3–5 are of a used and new 54-tooth, 25-degree pressure angle 1.5-pitch gear that is mounted on the shaft of the abovementioned 8-tooth pinion. As you can see, significant deformations of the used gears are seen. Similar damage has at times been seen on all high-torque, low-speed gears in the jacking gear train.

This is not how the gears look in normal wear, however. It is indicative of the kind of loading they are seeing, and the way jacking gears are designed.

Jacking gear units are and should be generally designed to have higher ductility and through hardness, rather than case hardening, as a fracture failure is not acceptable. A fracture failure can lead to more serious failures. The damage seen in the accompanying photos will allow the system to continue working, if perhaps at much higher friction. Even when the jacking system is jammed by such deformation, this is a more desirable outcome than a fracture failure that can domino into a failure that can risk lives and/or sink the rig.

For the rig operator, having to replace deformed gears that have prevented the rig from falling in an occasional storm is an acceptable cost of doing business. A much more costly carburized part that will not fail until it gets to much higher load but does not absorb much energy in purely elastic deformation—and when it fails fractures and may cause much more expensive damage to the rig—is less acceptable.

It is possible to make the jacking unit strong enough that it is safe using carburized gears, and in fact this has been done by some manufacturers. However, these are also very expensive and nearly all energy absorption under storm loading is done by racks, which are harder to repair than replaceable, ductile components of a jacking system.

Fundamental Formulations

How high is "high" in terms of stress? Looking at a jacking pinion against a leg rack, consider the old F&G standard L-780 rig that had what is still the common leg rack material (ASTM A514 D) and has a Brinell hardness of a 227. If you calculate an allowable per AGMA 2001-C95—and ignore all negative factors such as facewidth, alignment and the like, and consider only positive factors like setting the reliability at 50% and the number of cycles at the minimum that ANSI/AGMA 2001-C95 considers—you get an allowable of 1,647 MPa.

The lowest normal contact stress the rack is subjected to under normal rotational operations, and again ignoring minor details like alignment and so on, is 2,202 MPa, or 33.8% over the 50% failure value.

The theoretical contact stress on the pitch line will go as high as 3,320 MPa under maximum, non-rotational load conditions, but it falls short as the rack will deform in a Brinell process when that happens. This sort of deformation of the rack surface is in fact seen—essentially a shallow indentation of the rack surface corresponding roughly to the pinion curvature.

If you look at the equations for a Brinell tester relating the load on the test ball and the diameter of the indentation on the test piece, you can derive an exact relationship between the Brinell hardness number, and from that a pressure normal to the surface hardness measured (Fig. 6).

Then what I shall call the Brinell stress (σ_{Br}) defined as follows:

$$\sigma_{BR} = \frac{F}{\frac{\pi}{4} D_i^2} \quad (1)$$

Note that D_i is characteristic of a specific Brinell hardness, and is listed in standard Brinell testing tables. Linear interpolation between data points listed in the tables is generally accepted. For the 227 HBN rack, that stress is 2,325 MPa, which is determined by the D_i characteristic of 227 HBN. This "Brinell stress" is representative of the stress at which Brinell flow of steel starts. This is a specialized case that has the following limitations:

continued

Figure 4—New 54-tooth, 1.5-pitch gear (courtesy ESI, Inc.).

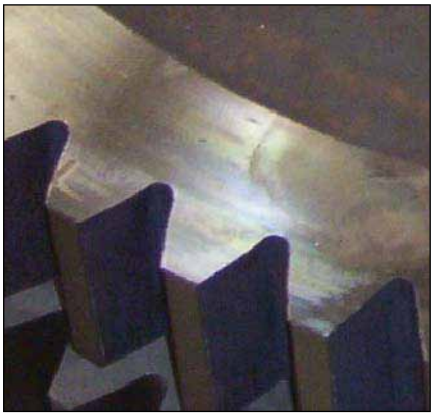
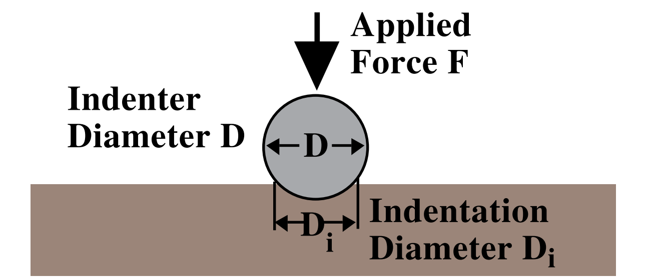


Figure 5—New 54 tooth, 1.5-pitch gear with close-up of teeth (courtesy ESI, Inc.).



$$BHN = \frac{F}{\frac{\pi}{2} D \left(D - \sqrt{D^2 - D_i^2}\right)}$$

Figure 6—The relationship between Brinell hardness and test ball diameter.

1. The radius of curvature of the gear tooth surface considered must be large with respect to the characteristic dimension D_i, or the equivalent width of line contact between gear and pinion.
2. The thickness of material under the surface considered (typically a gear tooth) must be large with respect to the characteristic dimension D_i, or the equivalent width of line contact between gear and pinion.
3. We are only considering through hardened materials in this paper; case hardened materials will have significant issues regarding case crushing and a characteristic case depth. This is not so with a through hardened material, as the hardness of the through hardened material varies much less with depth under the surface. The sort of failure that can be expected under this kind of extreme loading (high enough to Brinell the layer of material under the case) in case hardened gears is cracking of the gear tooth.
4. This Brinell stress is caused by direct, compressive stress in one load event where the material gives way at a stress characteristic of a given material hardness, and no motion between parts other than one part deforming in a direction normal to the surface being compressed.

Brinelling is plastic deformation of the metal in which no mass is lost from the part with Brinell damage. This phenomenon is discussed at length by Tabor (Ref. 2) in which he comes to the conclusion that the projected area method used here to calculate the Brinell stress is a "more satisfactory and fundamental concept in the measurement of hardness."

A phenomenon sometimes mistaken for Brinelling—commonly called "false Brinelling"—is caused by abrasion and material loss from the part. That phenomenon is also commonly seen at much lower stresses, and is characterized by motion of one surface with respect to the other along the plane of the surface. Sometimes this is caused by frettage, sometimes by other sorts of repetitive motion that causes wear.

As an example from the above photographs, please reexamine Figure 1. Note the radial striations in the gear tooth that get deeper as you get close to the tooth tip, and fade to nothing as you approach the pitch circle of the gear, while all along the surface where the opposing gear engages, you can see Brinell flow with flashing on the outer rim where the opposing gear tooth engages.

The striations are an example of abrasion that might also be called false Brinelling. This abrasion was caused by motion of the opposing gear tooth in a direction generally radial to the surface of the depicted gear tooth. However, this motion is approximately zero near the pitch line, where we only see rolling motion without sliding of one gear tooth across the other. At that location these radial striations are not seen in Figure 1, but the indentation and flashing around the edges are. That last is true Brinelling and is not seen at all at contact stresses below the Brinell stress.

Note that case hardened gears will generally never see true Brinell failure of the surface, as you will see cracks in case hardened gears before that happens under extreme loading.

With jacking gears, in the author's experience, both wear and Brinell/plastic flow are commonly seen, especially in extreme loading conditions. As to the number of cycles, a jack-up drilling rig is designed on the assumption of the rig moving (and so having to jack down, move, then jack up again) four or five times a year for 20 to 25 years. In fact,

Table 1—Results of the ratio of contact stresses of the pinion in normal jacking to its Brinell stress, and ratio of contact to theoretical AGMA failure stress.

Mesh #	Pressure angle, degrees	Module	Pinion, Z_1	Gear, Z_2	Tan load, kN	Face-width, m	Calculated design contact--P, MPa	HBN pinion	HBN gear	Pinion Brinell stress, MPa	Gear Brinell stress, MPa	Pinion AGMA 50% allowable, MPa	Gear AGMA 50% allowable, MPa
1	25	80.85	7	infinite	1957	0.127	2203	263	227	2677	2325	1829	1647
2	25	38.10	8	40	727	0.130	2030	365	349	3677	3520	2345	2264
3	25	16.93	12	54	242	0.114	1542	280	312	2844	3157	1915	2077
4	25	8.47	17	76	77	0.076	1262	260	250	2648	2550	1814	1763

Table 2—Ratio of calculated, actual pressure during normal jacking to Brinell stresses, and AGMA reliability stresses for pinions, gears and estimated 40-year lifetime cycles.

Mesh #	Pinion ratio actual/Brinell stress	Gear ratio actual/Brinell stress	Pinion ratio actual/all stress	Gear ratio actual/all stress	Pinion lifetime jacking cycles	Gear lifetime jacking cycles
1	0.823	0.948	1.205	1.338	4114	400
2	0.552	0.577	0.865	0.896	20,571	4114
3	0.542	0.488	0.805	0.742	92,571	20,571
4	0.476	0.495	0.696	0.716	413,849	92,571.43

40-year-old F&G rigs are not uncommon. So a reasonable number of cycles that rack teeth are subjected to at this loading are not more than about 400 cycles. That would be once up, once down, five times a year—for 40 years.

The jacking system discussed had, as mentioned, a contact stress between rack and pinion under normal jacking of 2,202 MPa, while having a Brinell stress of 2,325 MPa. That gives a ratio of actual to Brinell stress of 94.75%. On the other hand, a few jack rigs have been built that use higher contact stresses with ratios as high as 104% of Brinell stress. These higher-contact stress jacking systems do work, but with significantly more wear seen on both rack and pinion, to the point that it has become something of an issue.

On the other hand, the pinion on that jacking system will see about 4,000 jacking revolutions in that forty year life span, and is considerably harder. The ratio of contact stress of the pinion in normal jacking to it's Brinell stress is only 82.3%, while its ratio of contact to theoretical AGMA 50% failure stress at 10,000 cycles is 120.4%. The results of this are shown in Table 1.

The calculated design contact pressure was calculated ignoring adjustments for misalignment, tooth width, overload factors, dynamic factors, size factors and surface condition factors. Likewise, the AGMA 50% reliability allowable was calculated without such considerations and with the number of cycles set at 10,000 (the minimum considered). Brinell stresses were calculated as shown above.

Table 2 shows the ratio of calculated actual pressure during normal jacking to Brinell stresses and to AGMA 50% reliability stresses for both pinions and gears, as well as for estimated 40-year lifetime cycles.

Proposed Allowable Stress for Like Applications

Knowing as we do that in this application normal jacking contact stresses quite closely to, and at times over, the Brinell stress of the rack material provide satisfactory results at ~ 400 lifetime cycles, the author proposed the following as an allowable contact stress for similar, low-speed, low-cycle gear design applications when using through hardened steel gears of significant ductility.

$$\sigma_A = 1.40\ (\sigma_{Br})\ (N^{-0.056}) \tag{2}$$

where:

σ_A is the allowable contact stress in normal jacking or normal operations;

σ_{Br} is the Brinell stress defined above;

N is the number of cycles a typical gear tooth will see. That value should be in the range 400 to 100,000 at most.

For larger numbers of cycles, the allowable contact stresses are well established by others. The exponent is taken from Figure 17 of AGMA 2001-C95, which shows the formula for "Z_N"—the pitting resistance stress cycle factor. The factor of 1.40 falls out such that σ_A will equal σ_{Br} at $N = 400$. This is used due to the lack of any well-documented experimental data.

The user is cautioned that employing this relation in steels with low ductility (less than ~ 14% elongation) is not advised, as significant plastic deformation of the gear tooth surface takes place that will result in work hardening of the surface. This is acceptable in this application if the material was ductile enough at the outset. If not, very rapid wear is likely.

Conclusions

• In the design of gears for very slow-speed applications, where the number of cycles is also far below what is considered normal for gear system design, it is possible to build gear systems that will work satisfactorily at contact stresses far above those published by AGMA when using relatively soft, through- hardened steel for gears for hundreds to tens of thousands of cycles.

• The Brinell/plastic deformation stress, and the proposed allowable stress discussed in this paper, is a useful guide to indicate which contact stresses to stay below in rolling load cases for jacking systems and like applications.

• Experimental work is needed for development of a better, more reliable guide to the limits of contact stresses—especially regarding through-hardened steels.

Acknowledgement

This paper would not have been possible without the cooperation and active assistance of the management and employees of Energy Services International, Inc., of 1644 Coteau Road, Houma, LA, 70364.

References:

1. ANSI/AGMA 2001-C95, "Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth."

2. Tabor, D. *The Hardness of Metals,* 1951, Oxford University Press Inc., New York.

Alfred N. Montestruc III, P.E., *currently works as an engineer and jacking systems project manager for Friede & Goldman Ltd., a marine engineering and naval architecture firm. He has worked in the offshore industry since 1994 upon leaving graduate school and has become known as an authority on rack-and-pinion jacking system design. He co-owned an independent naval architecture and marine engineering firm—Liebkemann & Montestruc Engineering Company—from 1996–1999. Two jack-up rigs designed by that firm are now in operation in the Persian Gulf. He also worked as chief engineer for ESI Incorporated, which supplies and repairs jacking systems, and for some five years, worked at ABS (a non-profit offshore regulatory body) as design review engineer, mostly of jacking systems. He now sits on the steering committee for ABS's Rules Committee regarding MODU (Mobil Offshore Drilling Unit) rules. He holds a Bachelor of Science Mechanical Engineering and a Master of Science Mechanical Engineering, respectively, from the University of New Orleans and Louisiana State University.*

Underwriters Laboratories (UL) is a leader in the fight against industrial counterfeit products. This unique hologram design label is easy to identify and difficult to replicate (courtesy of UL).

The Counterfeit Culture

FAKE PRODUCTS AND PARTS PRESENT GLOBAL MARKET CHALLENGES

Matthew Jaster, Associate Editor

It's happened to most manufacturers at one point or another. A defective product comes back from a customer in need of repair. Perhaps a bearing or a gear drive has failed, and the customer simply needs a replacement. Upon further examination, the company realizes it was never one of its products in the first place, but a fabricated copy that snuck into the market. The manufacturing community has been dealing with counterfeit products for decades, but used machinery dealers and Internet shoppers seem to continuously get hit by scam artists.

In the 1990s Arrow Gear came across a right angle gear drive out of South Korea that looked awfully familiar. "The company had duplicated our casting and ground off the Johnson Gear Drive logo, but everything else looked the same," says Joe Arvin, president at Arrow Gear.

Today, strict quality and documentation requirements for the aerospace industry have prevented other duplicates on the market. "There's a paper trail big enough in aerospace to keep track of the gearboxes, making it very difficult for fabricators to copy them today," Arvin says.

It's a safe bet someone is probably trying. Counterfeit industrial products cost an estimated $600 billion a year, according to the International Anti-Counterfeiting Coalition (IACC). Approximately five to seven percent of world trade is in counterfeit goods. Everyone from the Federal Aviation Administration (FAA) to the Motor and Equipment Manufacturers Association (MEMA) has had problems with counterfeit industrial parts. As manufacturers continue to pursue global business, it's important to be aware of the counterfeit culture and understand the holes found throughout the industrial distribution line.

"Counterfeiting and piracy continue to rob legitimate manufacturers of much needed revenue, slowing the creation of jobs that is vital to economic recovery, and discouraging the type of innovation and capital investment that is essential to long-term growth," Robert Barchiesi, president of the IACC, recently stated in a press release. "Intellectual property theft, in the form of trademark counterfeiting and piracy, remains a major concern for U.S. business, and is estimated to cost the U.S. economy up to $250 billion each year and 750,000 jobs."

The IACC recently focused on ten countries of concern, most notably China, Russia and Canada, with a priority watch list on Brazil, Mexico, The Philippines, South Africa, Spain, Turkey and Paraguay. China appears to be the largest culprit of industrial fabrication, the main reason many manufacturers prefer daily working relationships with distributors and suppliers here in the United States.

"Counterfeit products are a whack-a-mole kind of problem," says Clark Silcox, general counsel at the National Electrical Manufacturers Association (NEMA). "It's persistent and nagging, and just when you think you've taken care of one issue, another one comes up."

Thanks to custom seizure data and a distribution channel that is much more aware of the problem, Silcox says NEMA hasn't seen the volume of counterfeit products lately that the organization has seen in the past. "It hasn't disappeared in certain electrical products, but I'd say the problem was much worse ten years ago. China is still the focal point. It has the low-cost skill-set and volume to pull off some of these fabricated parts."

In the gear industry, companies will occasionally find something on the market pretending to be something it's not.

"We are finding counterfeit reducers in our markets," says David Ballard, corporate manager at SEW Eurodrive, Inc. "We have had customers send us failed gear reducers thinking they were SEW products. The counterfeit product failed soon after the installation. The customer expected quality and a long operating life. You can imagine the shock when he found out the drives were not SEW, but imitations. Fortunately, since they were imitation units, SEW was able to supply drop in replacements that could perform as expected."

Eyes on the Internet

The Internet is, by far, the largest contributor to the counterfeit problem. One can simply visit eBay to find gears, bearings, motors, circuit breakers and full system gearboxes at discount prices. "The Internet is the great facilitator," Silcox says. "Rockwell Automation had a problem with its software on eBay a few years ago, and we've had problems in the past as well. Although eBay is responding better to counterfeiting today, there's still work left to do."

Additionally, Silcox has come across several English-only websites created in China. "They'll give you an address on one side of the country and a contact number on the other. Nothing matches, and you end up playing detective trying to figure out if the company exists and where it's actually located."

Gary Rusnak, marketing/projects at Torque Transmission, has found familiar images while surfing the Internet for industrial products. "We've seen Chinese manufacturers using our JPEG images to sell thrust bearings. I've also seen some knockoff worm gear reducers from the Motovario line out of Italy coming out of China. It's a tough business."

The lack of traceability and accountability on the Internet should scare companies looking for cheap industrial parts online. Problem is, with growing financial concerns in other areas, an easy fix is to shop online.

The distribution network is being much more careful of online counterfeit products as the penalties increase.

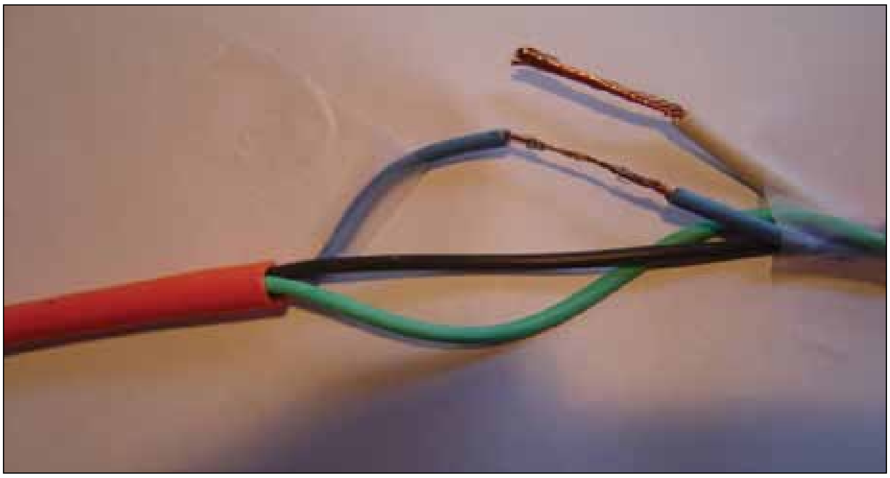
"If they're carrying the faulty products, the products will be seized, and then you start getting into product liability suits and other economic issues. It's best just to have a network of individuals across the supply chain that you can trust," Silcox says.

Safety First

The bigger issue with low-quality knockoffs is the safety and health concerns. "Chinese manufacturers can compete with the exterior of many of the products that are manufactured in the United States," Silcox says. "The interior is where the real problem is. These components will only last eight years when companies expect them to last 40. These are dangerous parts that either don't work at all or work on a limited basis. In regards to electrical parts, we've seen counterfeits that may have been responsible for burning buildings down."

Silcox adds, "Product defects are becoming a bigger problem in the courtroom. If a judge doesn't find anybody to back the product up,

continued

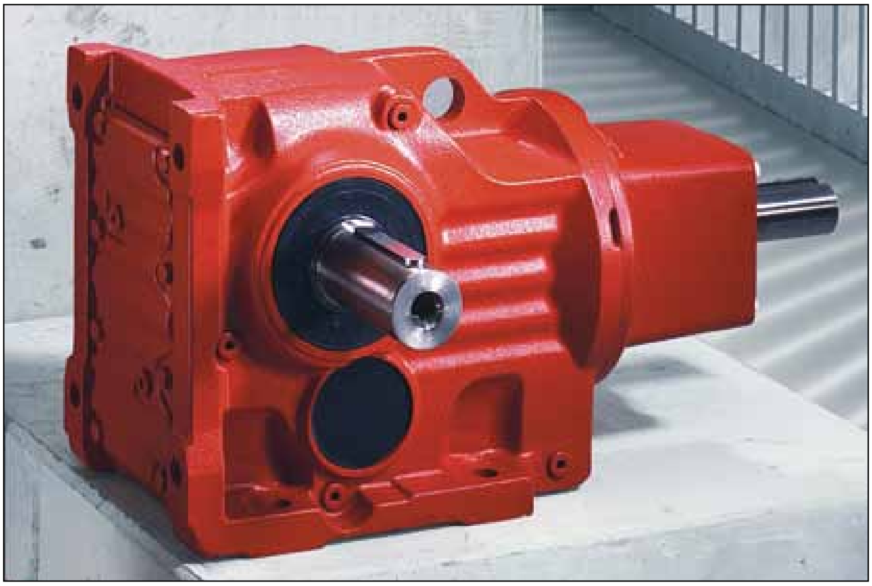


Faulty counterfeit wires have been responsible for several industrial safety hazards (courtesy of NEMA).

many times it's the distributor that's left holding the bag. They may have thought it was from a legitimate company and had no reason to believe otherwise. The legal ramifications are significant."

At the end of the day, manufacturers want to know the products they are purchasing are exactly what they claim to be. As it becomes more a safety and reliability issue, many feel that harsher laws and more government involvement needs to be implemented.

"Counterfeit components are a problem that is not going to go away anytime soon," Arvin at Arrow Gear says. "The government needs to do everything they can to make sure the distributors and suppliers are aware that bogus bolts, nuts, shims and bearings are still making their way into the market."


This SEW Eurodrive right angle gear reducer has been duplicated on the market (courtesy of SEW).

Thankfully, the U.S. government has been more focused on counterfeiting in the last ten years. "Both the Bush and Obama administrations have been great partners in the fight against counterfeit products," Silcox says. "The government has contributed several resources to help solve these issues. If it starts to hit the smaller companies like it has hit some of the larger ones, you'll see even more activity on the federal level."

According to the IACC, Attorney General Eric Holder announced in February the formation of a new Department of Justice Task Force on Intellectual Property as part of a department-wide initiative to confront the growing number of domestic and international intellectual property (IP) crimes.

"The rise in intellectual property crime in the United States and abroad threatens not only our public safety but also our economic well being. The Department of Justice must confront this threat with a strong and coordinated response," Holder says in a press release. "This task force will allow us to identify and implement a multi-faceted strategy with our federal, state and international partners to effectively combat this type of crime."

The task force, to be chaired by the deputy attorney general, will focus on strengthening efforts to combat intellectual property crimes through close coordination with state and local law enforcement partners, as well as international counterparts. It will also monitor and coordinate overall intellectual property enforcement efforts at the department, with an increased focus on the international aspects of IP enforcement, including the links between IP crime and international organized crime. The task force will also serve as an engine of policy development to address the evolving technological and legal landscape of this area of law enforcement.

As with any process, the fight against counterfeit products comes down to dollars and cents. There are covert identification and tracking technologies available to manufacturers to track a product's history, many that are being adopted now for the automotive industry. But many technologies and innovations carry a heavy price tag.

"There are hand tools that can read for authenticity, and cell phones are adapting similar technology as well," Silcox says. "For the most part, the industrial market is slow to take up these advancements. I think Underwriters Laboratories (UL) is one of the few leaders in covert identification marks at this point in time. Most of these technologies can be an expensive proposition."

The best line of defense might simply be dealing only with suppliers and distributors you are comfortable with.

"In general, it is important to know the supply chain used by your customers and to ensure it is not being compromised with counterfeit products," Ballard says. "This is one of the critical steps to maintaining the customer relationship. Make sure they are purchasing the product from either a reputable and/or authorized supplier of the manufacturer or directly from the manufacturer."

Know the Enemy

In the case of the SEW counterfeit reducers, these items were practically identical in dimension. Upon closer examination, however, those involved realized that they were not SEW parts. Silcox at NEMA has found circuit breakers and ground rods online that mirrored original products.

So how does one identify counterfeit products? There can be minor visual imperfections inside and out that give counterfeits away. Bar codes could be in the wrong place, labels can be ground off or misspelled, and components could look slightly different upon close examination.

Price may be the ultimate weapon against counterfeit products. "If you find something online and the price is too good to be true, it probably is," Silcox says. "Word of mouth has always been helpful in the past as suppliers and distributors have shared information regarding counterfeit sources."

This brings us back to the Internet where online resources can actually help fight against counterfeiting. In the electrical sector, companies like General Electric, Siemens, Schneider Electric and Eaton sponsor an anti-counterfeit products initiative at *www.counterfeitscankill.com*.

The website offers news and resources for counterfeit products to bring these issues to the forefront and examine key proposals to fight back. The industrial market as a whole, including the gear industry, should consider similar initiatives to keep faulty products out of their customers' hands.

"I don't think the problem will go away, but educating market sectors on the issues will make OEMs and users aware of counterfeit products in the industry and what they can do to be part of preventing their use," Ballard says. "I believe many countries have intellectual property laws that protect the rights of the initial developer. The ones that do not probably don't have an effective means to monitor the offenders. We at SEW are addressing the issues as we become aware of them."

Silcox at NEMA adds, "For the computer software and music industry, counterfeits account for billions and billions of lost revenue. Thankfully, the manufacturing sector is nowhere near these numbers presently."

For more information:

Arrow Gear
2301 Curtiss Street
Downers Grove, IL 60515
Phone: (630) 353-9260
Fax: (630) 969-7699
www.arrowgear.com

International Anti-Counterfeiting Coalition
1730 M Street NW, Suite 1020
Washington DC 20036
Phone: (202) 223-6667
Fax: (202) 223-6668
www.iacc.org

NEMA
1300 North 17th Street, Suite 1752
Rosslyn, VA 22209
Phone: (703) 841-3200
Fax: (703) 841-5900
www.nema.org

SEW Eurodrive, Inc.
2001 West Main Street
Troy, OH 45373
Phone: (937) 335-0036
Fax: (937) 332-0038
www.seweurodrive.com

Torque Transmission
1246 High Street
Fairport Harbor, OH 44077
Phone: (440) 352-8995
Fax: (440) 352-7682
www.torquetrans.com

EVENTS

Hybrid, Alternative Drivetrains

TAKE CENTER STAGE AT CTI SYMPOSIUM

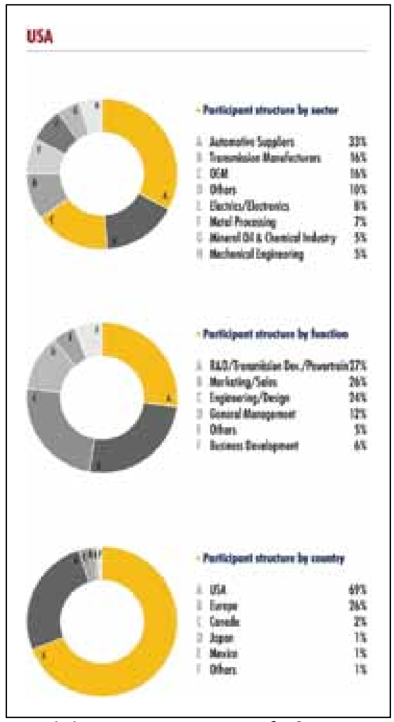
As the automotive industry continues to reinvent itself, new transmission technologies are at the forefront of this effort, and there is a whirlwind of new developments being detailed at the German Car Training Institute's Automotive Transmissions and Drive Trains Symposium North America.

The symposium consists of over 30 presentations, including both plenary and parallel sessions on a wide range of subjects. "The presentations are a mixture of transmissions [that] are newly developed and in a concept status, close to production or new into production," says Nadja Thomas, a spokesperson for the Car Training Institute (CTI).

Some of the major new technology topics being presented include dual clutch transmissions—like Fiat Powertrain's dry dual clutch—automatic transmissions, transmissions for alternative drivetrains—like ZF's new eight-speed hybrid—and engine downsizing. Alternative drive concepts will be discussed in respect to future development requirements, opportunities for market success, certification and patent situations. Reports on technology in ongoing development will be presented, including Toyota's plug-in hybrid vehicles and Mitsubishi's fleet testing of battery quick charging and other experiences with its zero emissions Mitsubishi Innovative Electric Vehicle (iMiEV).

The two-day program was developed based on dialogue with CTI's target audience and the CTI advisory board, and it has evolved since the annual event was first held in 2007. This North American event builds on experiences of the mother event held in Berlin each year. The launch of a North American counterpart seemed like a natural progression. "CTI decided to support the international exchange of experiences in this special field of automotive engineering by adding another opportunity beside the European Symposium, which already exists since nine years," Thomas says.

The program has changed from previous years in respect to trends the industry reflects. Transmissions for alternative drivetrains weren't discussed last year at all, and the most significant example of the program's evolution is the addition of drivetrains to the event's title. "Due to the fact that the development focus in automotive manufacturing is currently more on the optimization of the overall system of engine and transmission as well as the strong interest in alternative drivetrain technologies and their requirements for transmission development, the concept of a two-day transmission symposium with a special hybrid day as add-on was given up," Thomas says. "The topics around alternative drives are now an integral part of the symposium. The consideration of alternative drives is no longer limited to HEVs (hybrid electric vehicles). The new event title accommodates this change."



Participant structure of the 2009 Car Training Institute's North American Transmission Symposium and Exhibit.

(Photos courtesy Euroforum)

One highlight of the program is a panel discussion, at the end of the second day, discussing competing strategies for fuel-efficient vehicles and who makes the race. Participating on the panel is a range of executives and technical leaders from Toyota, BorgWarner, Ford Research, GM and FEV Engine Technology Inc. The panel was formally added to the program after an unplanned version was a hit in 2009. "After the spontaneously set up panel discussion last year, we have decided to make it a part of the program," Thomas says. "Panelists are representatives of OEMs and suppliers discussing the challenges and requirements they see for the market success of fuel-efficient technologies and customer satisfaction."

Major manufacturers from Europe, Asia and the United States attend the symposium, including ZF, Getrag, BMW, Daimler, Fiat Powertrain, Ford, GM and Toyota. Over 150 participants attended the event in 2009. Participants come from a range of backgrounds, from transmission manufacturers and OEMs to mineral and chemical industry representatives. Automotive suppliers are the most dominant presence when categorized by industry sector, comprising 33 percent of all participants.

In addition to the conference program, a small trade exposition takes place featuring a dozen or so manufacturers, including Ernst Grob AG.

"The exhibition opens for visits by the participant in the morning prior to the first presentations," Thomas says. "All breaks are taking place in the exhibition area. As well, the poster presentations during the lunch breaks are given in the exhibition area."

The fourth International CTI Symposium and Exhibition, "Automotive Transmissions and Drive Trains North America," takes place June 8–9, at the Four Points by Sheraton Ann Arbor Hotel, Ann Arbor, MI. For more information, visit *www.transmission-symposium.com*.

AGMA

PRESENTS 50-YEAR AGMA MEMBERSHIP AWARDS

From left to right: Dave Ballard, AGMA board chairman, John Cervinka, Arrow Gear international business development manager, and Joe Arvin, Arrow Gear president.

Bison Gear and Engineering and Arrow Gear Company both received AGMA's 50-year membership award, presented during the recent AGMA/ABMA Annual Meeting in Tucson, AZ.

Bison Gear's George Thomas, executive vice president, and Sylvia Wetzel, chief learning officer, were on hand to receive the award for the company. Bison Gear was founded in 1960, joining AGMA in its first year. It was acquired by Norman and Ronald Bullock in 1987.

Dave Ballard, left, George Thomas, right, Bison Gear executive vice president.

As Bison's current chairman, Ron Bullock has opened the company to the global market, expanded the overall product line and established a research and development center. He is a former AGMA board member and a major advocate for manufacturers and education. He served on the National Association of Manufacturers' board of directors and chaired its small business committee. He more recently served as chair of the Illinois Manufacturers Association.

In a manufacturing education capacity, Bison has worked with local manufacturers, industry, government, educators and communities to create the Manufacturing Skills Standards Council, which provides a path for young adults, adults and displaced workers to acquire the core skills needed by manufacturing companies.

On hand to receive the award for Arrow Gear was Joe Arvin, president, and John Cervinka, business development manager. Arrow Gear was founded by James J. Cervinka and Frank E. Pielsticker in 1947 as a small operation in Worth, IL. In 1961, the company moved to its current location in Downers Grove, IL, which has been expanded seven times to accommodate new technologies and machinery.

Arrow Gear has been an active participant in many AGMA committees and councils as well as the board of directors over its 50-year tenure as a member. Arrow Gear's chairman, James Cervinka, received the AGMA Chairman's Award of Excellence in 2002.

Broadwind Energy

ANNOUNCES BRAD FOOTE PRESIDENT

Daniel E. Schueller

Daniel E. Schueller was appointed president of Brad Foote Gear Works, Inc., the gearing systems business of Broadwind Energy, Inc. Schueller reports to Broadwind Energy CEO J. Cameron Drecoll.

"We are delighted to have Dan join our leadership team and expect that he will lead the gearing systems team with a robust combination of deep manufacturing experience, leadership skills and customer focus," Drecoll says. "As the anticipated upswing of the U.S. wind energy market creates new opportunities for Broadwind's precision gearing system business, Dan's proven success as an executive leader in manufacturing will be an asset to our customers and stockholders."

Before joining Broadwind Energy, Schueller served as vice president and general manager of Federal Signal Corporation's Vactor Manufacturing Inc. subsidiary, a leading manufacturer of municipal combination catch basin/sewer cleaning vacuum trucks. Prior to that, Schueller served in positions of increasing responsibility in operations with Tecumseh Products Company, a global manufacturer of compressors and related products.

Schueller has a bachelor's degree in mechanical engineering technology from the Milwaukee School of Engineering and a master's degree in business administration from St. Ambrose University in Davenport, IA.

Schueller comments, "I look forward to working with the Broadwind team as we capitalize on a rich heritage of more than 85 years of gearing leadership at Brad Foote."

Hansen Transmissions

APPOINTS CEO

Upon the retirement of Ivan Brems from active executive duties as chief executive officer of Hansen Transmissions International NV, Alex De Ryck has been promoted from chief financial officer to CEO, effective March 31.

Alex De Ryck

The Hansen Board is in the process of appointing a new CFO. Meanwhile, Brems will serve as a consultant to the

continued

N E W S

board and executive committee. Tulsi Tanti, chairman of the board, commented: "Ivan Brems has been instrumental, over many years, to the successful growth of Hansen into a world-leading supplier of high quality gearboxes for the wind industry. The Board wants to thank Ivan for his valuable work at Hansen and is happy that he will continue to support Hansen on a consultancy basis in the next stage of the company's development."

Brems first joined Hansen in 1974, and he became CEO in 2006. Previously he served as vice president of corporate marketing and business development. "It is with great confidence that I hand over to Alex De Ryck, who has known Hansen for more than 20 years and has been with the group for six years as CFO," Brems says. "I have worked with Alex for almost six years and am delighted to be handing over to him. He was the unanimous choice of the board, and I am convinced that he is the right successor and will lead Hansen to continued future success."

De Ryck became CFO of Hansen in 2004. Prior to joining the group, he held a number of high profile positions, including CEO of Esselte Belgium and Eldon Belgium, CFO of the Dymo Group and the Eldon Enclosures Group and finance manager at Honeywell Europe.

Ivan Brems

"I am extremely honored to be offered the opportunity to lead Hansen at this important time in the Company's development," De Ryck says. "Ivan has been critical to the success of the group over many years, and we wish him well in the future. Although these are clearly challenging times for the wind industry, we are well prepared and have an outstanding team in place. Trading for the current financial year remains in line with previous guidance, and as anticipated in January, we have recently created additional financial flexibility for the Group by re-negotiating our bank covenants. I am convinced that Hansen is well placed to exploit the opportunities that lie ahead and look forward to leading the company to future successes."

Spicer India

BREAKS GROUND ON GEAR PLANT

The gear facility in Chakan, India will produce 240,000 of these AdvanTEK gear sets a year, which comprise specially designed and manufactured hypoid gears with high power density.

Spicer India Ltd. announced groundbreaking on a hypoid gear manufacturing facility and testing center in Chakan, Pune, India. The joint venture company of Dana Holding Corporation, USA, and Anand Automotive Systems plans to expand services to the Indian automobile industry.

"Indian-based OEMs are demanding improved efficiency, power density, fuel economy, torque-carrying capacity and weight reduction," says James E. Sweetnam, president and CEO of Dana Holding Corporation. "In response, Dana has developed the AdvanTEK series of axles to meet these growing customer requirements, and we are pleased to announce that—with these new and expanded facilities—we will be positioned to manufacture these axles in India."

AdvanTEK axles comprise specially designed and manufactured hypoid gears with high power density. The 50,000-square-foot "greenfield" facility in Chakan, near Pune, is planned to produce 240,000 of these gear sets a year. At full capacity, the plant will employ around 130 people. Over the next few years, $35 million to $40 million will be invested in the facility, which is expected to open in late 2011.

"In the last few years, Indian OEMs have aimed at achieving world-class quality of vehicles manufactured here and meant for domestic and international markets," says Deepak Chopra, CEO of Anand Automotive Systems. "With this new gear plant, Spicer India will have contributed in its own way to help achieve this motive. This investment represents our ongoing commitment to the Indian automotive market."

continued

NEWS

B.D. Singh, Chief Operations Officer of Spicer India, says, "The setting up of this new facility represents another important milestone in Spicer India's roadmap to growth. As leading OEM suppliers in the country, we are pleased to be in a position to keep pace with our customer requirements and in meeting market demands."

PTG

PLANS TO SELL SUBSIDIARIES

The board of U.K.-based Precision Technologies Group announced the proposed sale of a number of its subsidiary businesses to Chongqing Machinery and Electric (CQME), a large Chinese industrial group, pending approval by the Chinese government. The businesses proposed for transfer to CQME include Holroyd Precision Ltd., Precision Components Ltd., PTG Heavy Industries Ltd. (Binns and Berry and Crawford Swift), PTG Advanced Developments Ltd. and PTG Deutschland GmbH. Jones and Shipman Precision Ltd. is not affected by this announcement and continues to trade under its current ownership.

CQME's aims to establish a strong foothold in international markets and sees this acquisition as a significant statement of intent, according to a PTG press release. The combined group will continue to invest, develop technology and intellectual property of the U.K. businesses to create products for the market. Existing manufacturing facilities, services and supply chains in the U.K. will be maintained, and all staff of the above companies will be transferred to the new group.

PTG specializes in machine tool design, build and supply of surface, cylindrical, creepfeed, rotor, thread and gear grinding machines, as well as super abrasive machining systems, rotor milling machines and lathes.

SAMP

CONSOLIDATES INTO NEW PLANT

All Samputensili and Sampingranaggi activities are being integrated into the SAMP Group's new plant in

Bentivoglio, Italy, near Bologna. This is part of a larger corporate reorganization campaign announced earlier this year aimed to improve various aspects of production.

The layout of the Sampingranaggi division has been updated by replacing some obsolete machines with new generation ones. The production system in place is more verticalized, and operations like turning and OD grinding are concentrated in the new plant.

New generation machines have been installed as part of the Samputensili production system, cutting down to one third the machining time before heat treatment and other reductions in transfer time. Weekly, the Bentivoglio plant will be capable of manufacturing 250 hobs, 60 shaper cutters, 80 shaving cutters, 60 chamfering/deburring tools and other cutting tools, like masters and large-module hobs.

These technological improvements along with new web-based software platforms will allow quotes for new tools to be available in three days. While SAMP is restructuring its Tools Production Organization in Europe, it is also strengthening production sites in China, Korea, Brazil and the United States.

"Everybody at SAMP is working to bring into the site of Bentivoglio the most advanced technologies in gear production," says Artemio Affaticati, CEO of SAMP Group in an open letter to customers. "Bentivoglio extends on an area of about 60,000 square meters. It has been built using the environmental, low-impact, advanced technologies and its 18,000 square meters of solar panels are able to generate up to 735 kilowatt-peaks (kWp).

"SAMP is investing in gear technology as we deeply believe we are able to give a significant contribution to the development of this sector, as shown by recent business agreements made with companies operating in the robotics, automotive and aerospace sectors."

ADVERTISERS INDEX

Use this index to contact advertisers

ADVERTISER	PAGE	PHONE	E-MAIL	INTERNET
American Gear Tools	65	(734) 961-0300	leon@americanbroach.com	www.americangeartools.com
Arrow Gear Co.	17	(630) 969-7640		www.arrowgear.com
B&R Machine & Gear Corp.	IBC	(731) 456-2636, (800) 238-0651	inquiry@brgear.com	www.brgear.com
Beavermatic	31	(815) 963-0005	sales@beavermatic.com	www.beavermatic.com
Bourn & Koch Machine Tool Co.	66	(847) 649-1450	sales@star-su.com	www.star-su.com
The Broach Masters/Universal Gear Co.	19	(530) 885-1939	info@broachmasters.com	www.broachmasters.com
Broadway Gear	71	(972) 351-8737	info@broadwaygear.com	www.broadwaygear.com
Capital Tool Industries	67	(254) 742-1979	capitaltool@usa.net	www.capital-tool.com
Clifford-Jacobs Forging Co.	22	(217) 352-5172	sales@clifford-jacobs.com	www.clifford-jacobs.com
DTR Corp.	21	+(82) 32-814-1540, (847) 375-8892	dragon96@kotis.net, alex@dragon.co.kr	www.dragon.co.kr
Engineered Tools Corp.	8	(248) 619-1616	rdeneau@engineeredtools.com	www.engineeredtools.com
Fässler Corp.	32	(414) 769-0072	sales@faessler-ag.ch	www.faessler-ag.ch
Forest City Gear	3	(815) 623-2168	fyoung@forestcitygear.com	www.forestcitygear.com
Frenco	6	(262) 781-6777	info@eurotechcorp.com	www.eurotechcorp.com
Gear Manufacturing Inc.	71		info@gearmfg.com	www.gearmanufacturing.com
Gear Motions Inc.	71	(315) 488-0100	sales@nixongear.com	www.gearmotions.com
The Gear Works—Seattle, Inc.	71	(206) 762-3333	sales@thegearworks.com	www.thegearworks.com
Gleason Corp.	36–37, 71	(585) 473-1000	dmelton@gleason.com	www.gleason.com
Hans-Jürgen Geiger Maschinen-Vertrieb	34	+(49) 7123-18040	geiger@geiger-germany.com	www.geiger-germany.com
Hexagon Metrology	24	(401) 886-2422	peter.edge@hexagonmetrology.com	www.hexagonmetrology.us
Höfler	OBC	(734) 416-9300	inquiries@greatlakesgeartech.com	www.greatlakesgeartech.com
IMTS	61	(800) 524-0475	AMT@amtonline.org	www.IMTS.com
IPTEX 2010	63	+(91) 80-25567028	info@virgo-comm.com	www.virgo-comm.com
JRM International	71	(815) 282-9330		www.jrminternational.com
Kapp Technologies	7	(303) 447-1130	info@kapp-usa.com	www.kapp-usa.com
KISSsoft	65	(815) 363-8823	info@kisssoft.com	www.kisssoft.com
Koepfer America	28	(847) 931-4121	sales@koepferamerica.com	www.koepferamerica.com
McInnes Rolled Rings	20	(800) 569-1420	sales@mcrings.com	www.mcinnesrolledrings.com
MGT – Magnetic Gearing & Turbine Corp.	25	+(61) 402-383-352	sales@mgt.com.au	www.mgt.com.au
Midwest Gear & Tool Inc.	69	(586) 779-1300	midwestgear@sbcglobal.net	
Mitutoyo	27	(888) 648-8869		www.mitutoyo.com
Niagara Gear	66	(800) 447-2392	info@niagaragear.com	www.niagaragear.com
Overton Chicago Gear	11	(630) 543-9570		www.overtongear.com
Precipart	15	(631) 694-3100	sales@precipart.com	www.precipart.com
Presrite Corp.	35	(216) 441-5990		www.presrite.com
Process Equipment	13	(800) 998-4191	msdsales@processeq.com	www.gearinspection.com
Proto Manufacturing	33	(519) 737-6330		www.protoxrd.com
Quality Transmission Components	68	(516) 437-6700		www.qtcgears.com
Reishauer Corp.	71	(847) 888-3828	reishauer-us@reishauer.com	www.reishauer.com
Riverside Spline & Gear	26	(810) 765-8302	valerief@splineandgear.com	www.splineandgear.com
Sandvik Coromant	29	(800) 726-3845		www.coromant.sandvik.com/us
Schafer Gear Works Inc.	23	(574) 234-4116		www.schafergear.com
Schnyder S.A.	68	(630) 595-7333	hanikcorp@aol.com	www.hanikcorp.com
The Shot Peener magazine	69	(800) 832-5653, (574) 256-5001		www.shotpeener.com
Sigma Pool	5	(734) 429-7225	info.lgt@liebherr.com	www.sigma-pool.com
Star SU LLC	IFC–1, 66, 71	(847) 649-1450	sales@star-su.com	www.star-su.com
Stock Drive Products/Sterling Instrument	67	(516) 328-3300		www.sdp-si.com/e-store

CLASSIFIED SECTION

SERVICE

GEAR MANUFACTURING

GEAR MANUFACTURING

Alternative Gear Manufacturing

Also Topics

Plastics, Powder Metal, Forging, etc.

Next

Gear Technology June 2010

Sherlock Holmes and the Gear-Filled Weapons of Mass Destruction

Robert Downey Jr. as Sherlock Holmes and Jude Law as Dr. John Watson star alongside many gears in Warner Bros. Pictures' and Village Roadshow Pictures' action-adventure mystery "Sherlock Holmes," distributed by Warner Bros. Pictures (Photos courtesy Warner Bros. Pictures).

What's that sound? The churning of gear teeth meshing with the creak of film reels. A bit of "Holmesian deduction" leads us to the conclusion that it's time for the next installment of the Addendum's Gears in Film Series!

And what better setting for a big-screen gear cameo than the industrial steam engine-filled era of late 19th century London; home to famed consulting detective Sherlock Holmes and his partner, Dr. Watson. Director Guy Ritchie's 2009 adaptation of the celebrity sleuth's adventures gives us gear-heads plenty to scheme about.

Gears make their first major entrance at a shipyard as Holmes and Watson fend off a Goliath-like adversary. Holmes runs and ducks under heavy chains and poles reinforcing a ship as his enemy hacks them systematically with an axe. As the ship begins to roll, the giant strikes a blow to the winch brake. The gears are released and spin at whirlwind speed, sparks fly, the ship roars to life and is whipped out of the yard. Holmes narrowly averts disaster thanks to the lightning fast reflexes of Watson, and they watch the ship sink.

The next major gear appearance comes in an industrial slaughterhouse where Holmes and Watson are led by their investigation. "They cleared something away from here, not minutes ago," Holmes says.

"Like what," says Watson.

"Not sure; something mechanical."

He then notices a dead rat, the obvious subject of a lab experiment, and he cuts its tail to preserve as evidence.

Next, the villain Blackwood sets a fiery trap for the duo, complete with a hostage as bait and a slaughter machine. As Holmes sets about to disengage the assembly line, he is able to jam an open gear assembly in the floor that is facilitating the machine. The gears grind against the jam and prove strong enough to keep engaging; although, they delay the machine enough for the heroes to narrowly avert yet another disaster.

The most significant gear role of the movie comes as an integral part of Blackwood's dark magic: the previously missing machine that evidently serves as a chemical weapon. "The first of its kind….It will revolutionize warfare," Holmes deducts from the rattail specimen, which displayed blue discoloration and other "tell-tale traces of cyanide."

The intricate contraption features numerous gears of varying sizes operating in every which direction. It uses electromagnetic waves to convert the cyanide chemical into gas to be released into the ventilation system of British Parliament. As a fight scene erupts surrounding the machine, gears churning in the backdrop, Holmes and his cohorts struggle to deactivate the machine. "It's specifically designed to prevent us from disarming it," Holmes says after they try lodging a coin between the gears only for it to be violently repelled.

The gear teeth click as they mesh, and the clock is ticking as time runs short for them. A contained explosion is produced using Holmes' famous clay pipe, and they are able to remove the cyanide-filled cylinders before the gas is released. The gears slow to a stop, and Blackwood's plan to take over the world is, for now, delayed.

Back at home on Baker Street, Holmes is quite literally tying up the loose ends of the case. When word comes of another linked murder and evidence supporting a stolen piece of the machine, the case is reopened. The stage is set for a sequel featuring the true supervillain: Professor Moriarty—to be continued…

…Until the next edition of Addendum's Gears in Film Series.

HÖFLER "heavy duty" production of Internal Gears!

The latest innovations for internal gears:

HÖFLER *HF I* INTERNAL GEAR GASHER

Around the world, gear manufacturers have long been confident in the exceptional performance of their **HÖFLER** gear grinders and **HÖFLER** gashers/hobbers for external gear production.

Combining unique design principals, manufacturing precision and advanced process practices the ***RAPID I*** series gear grinders are market leaders, having set the highest standards in both external and internal gear grinding.

Today, using that same commitment to innovation with torque motor table drives and heavy duty construction - the new ***HF I*** series of dedicated "internal gear gashers" provide all the well known advantages and unsurpassed performance of **HÖFLER** ***HF*** external gashers/hobbers with this new line of dedicated ***HF I*** intenal gashers!

HÖFLER once again – for the performance, accuracy, productivity and flexibility that your company expects and deserves!

HÖFLER gear grinders – from 10 to 8000 mm (0,4" to 315")
HÖFLER gashers/hobbers – from 10 to 8000 mm (0.4" to 315")

HÖFLER Maschinenbau GmbH
Industriestraße 19 — p. +49 / 7243 599 - 0
D-76275 Ettlingen, Germany — f. +49 / 7243 599 - 165
www.hofler.com — e. info@hofler.com

HÖFLER America Corp.
26 Sky Manor Road — p. +1 / 908 442 4361
Pittstown, NJ 08867, USA — f. +1 / 908 996 6977
e. usa.sales@hofler.com

HÖFLER USA Agent: Great Lakes Gear Technologies
9421 Haggerty Road — p. +1 / 734 416 9300
Plymouth, MI 48170, USA — f. +1 / 734 416 7088
www.greatlakesgeartech.com