GEAR SOLUTIONS MAGAZINE

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AGMA/ANSI/ISO Standards on Bevel and Hypoid Gears

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Pre–Gear Expo

COMPANY PROFILE:
Felsomat-USA

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PRE-SHOW ISSUE

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FEATURES

Felsomat-USA

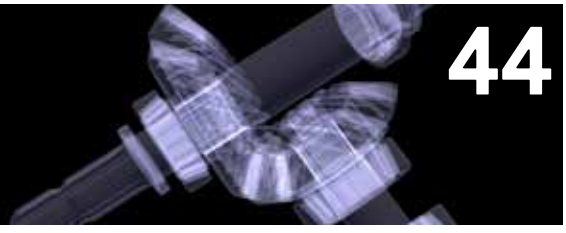
By Kenneth Carter

With a history of engineering ingenuity and manufacturing innovation, Felsomat has become a world leader in automated gear manufacturing.

Harnessing Drive Data for Smart Process Design

By Dipl.-Ing. Karl-Martin Ribbeck

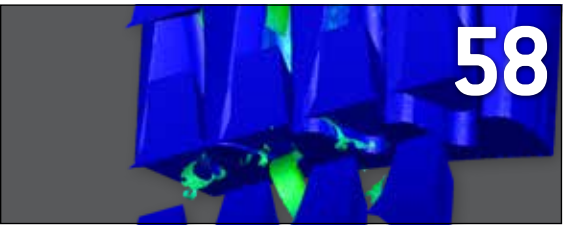
Graphical support for process optimization in bevel gear cutting leads to increased machine performance and longer cutting tool life.



AGMA/ANSI/ISO Standards on Bevel and Hypoid Gears

By Stephen P. Radzevich, Ph.D., Dr. (Eng.) Sci.

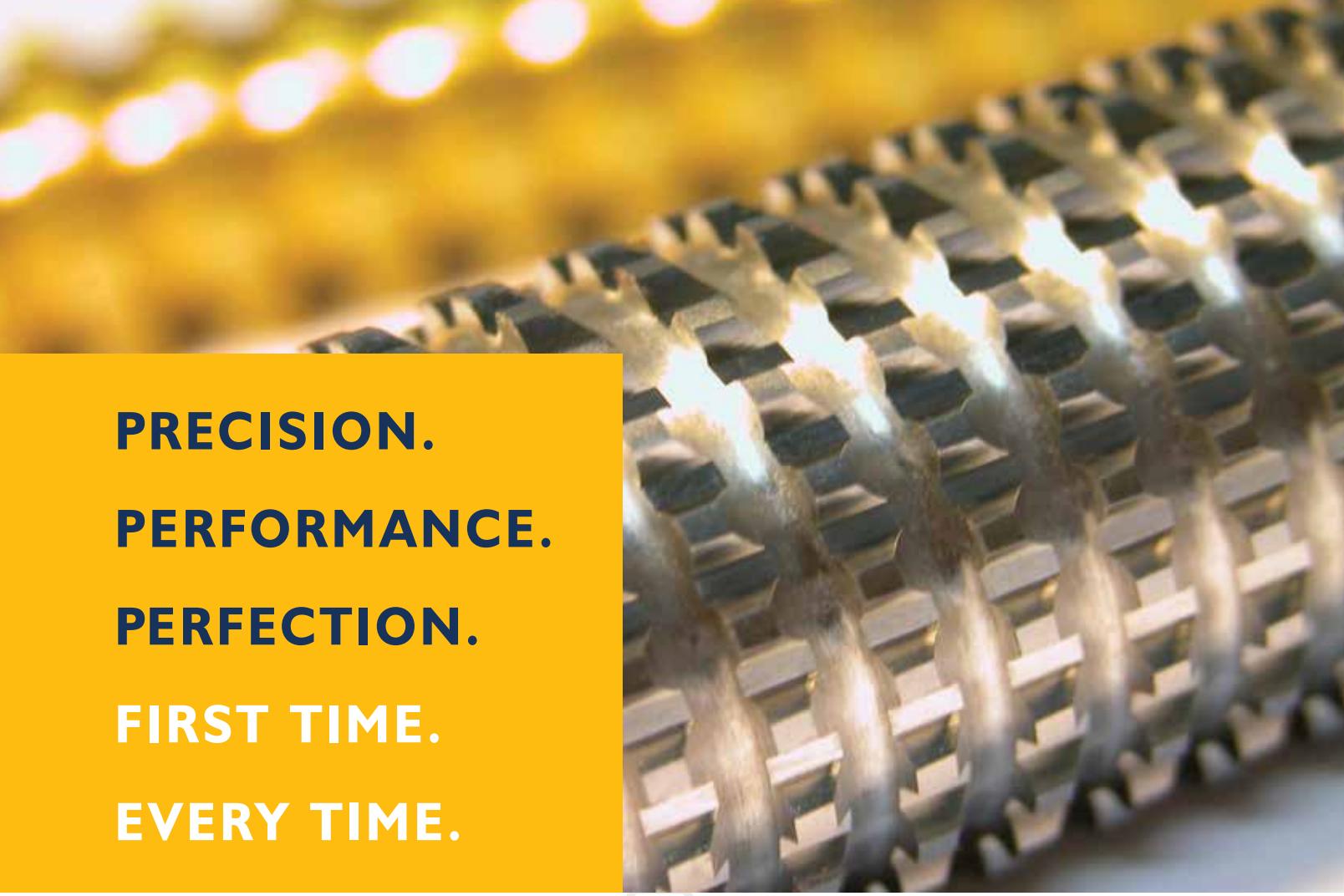
An examination of how standards for bevel and hypoid gearing benefit from the latest achievements in gearing theory.



A New Wave in Virtual Machining

By Cory Arthur

Finite element gear cutting simulation helps identify process solutions more quickly than conventional trial-and-error testing.



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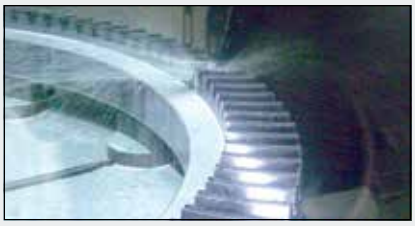
DEPARTMENTS

Renk roller-bearing test systems delivered



Mazak adaptive gear machining solutions to take center stage at Expo

08 INDUSTRY NEWS

Reports, data, and developments to keep you aware of what's happening with your colleagues in the gear-manufacturing industry around the country and world.

In this section, the premier supporter of gear manufacturing in the United States and beyond shares news of the organization's activities, upcoming educational and training opportunities, technical meetings and seminars, standards development, and the actions of AGMA councils and committees.

25 American Gear Manufacturers Association

30 MATERIALS MATTER

Patrick I. Anderson

MATERIALS MODELING FOR BETTER GEAR DESIGN AND PERFORMANCE

Modeling techniques can quickly determine the best design and required steel cleanness level based on a gear's application and performance requirements.

32 TOOTH TIPS

Brian Dengel

UNDER PRESSURE

Understand the choice of pressure angle in the design of spur or helical gearing.

34 HOT SEAT

D. Scott MacKenzie, Ph.D., FASM

HOW PARTS CLEANING MAXIMIZES HEAT TREATMENT

The impact of proper cleaning and rinsing on part quality prior to heat-treating is critical to the surface finish and overall quality of the finished gear.

62 PRODUCT SHOWCASE

76 Q&A

Vince Marlowe

DIRECTOR OF SALES AND MARKETING

Mijno-USA

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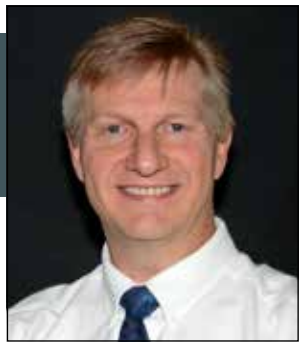
BPA WORLDWIDE℠ BUSINESS

EDITOR'S LETTER



Did someone say Gear Expo 2017?

Gear Expo 2017, the biggest drive technology show in the industry, is just around the corner in Columbus, Ohio, October 24-26, and we here at *Gear Solutions* couldn't be more excited.

It will be my first gear conference, and I am looking forward to meeting industry experts, officials, and movers and shakers in order to put a face on names and voices, as well as make new friends who are looking for a forum to share their gear knowledge with the industry. That's what *Gear Solutions* is for, and I will be at the show to find just the right spot for your subject, whether that's a submitted article, company profile, or Q&A.

That being said, consider this issue of *Gear Solutions* a bit of a primer for Gear Expo with a range of industry news and articles to help get you in the mood for Columbus.

Stephen P. Radzevich looks at AGMA/ANSI/ISO standards on bevel and hypoid gears, while an article from Klingelnberg discusses how to harness drive data for smart process design.

Cory Arthur with Third Wave Systems shares his thoughts on using computer simulations to help identify process solutions quicker than conventional trial-and-error testing.

And our company profile spotlights Felsomat and how its emphasis on innovation has made it a world leader in automation and manufacturing machine tools.

In our AGMA section, you'll get the scoop about how to serve on an AGMA technical committee and what it can mean to both the industry and employees. You'll also find an overview of Gear Expo networking events.

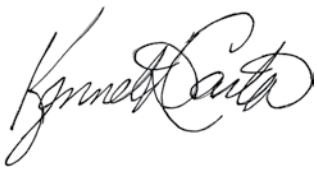
I'd also like to introduce to you our newest columnist. Brian Dengel with KHK Gears is taking over the reins of Tooth Tips, and he hits the ground running right out of the gate as he discusses how to understand the choice of pressure angle in the design of spur or helical gearing.

Dengel steps in for Rick Miller, who has been our Tooth Tips columnist for a while. Thank you, Mr. Miller, for letting *Gear Solutions* share your expertise.

If you're headed to Columbus, we've included a bonus in this issue: a look at restaurants, attractions, and more for you to enjoy when you're not in gear mode.

So enjoy this Gear Expo preview, and stop by booth #543 and introduce yourself. I'd love to shake your hand and talk about how *Gear Solutions* can help you share your message.

Thanks for reading!



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INDUSTRY NEWS

NEW TRENDS, SERVICES, AND DEVELOPMENTS

Assembly of the DDTR load unit. (Courtesy: Renk)

Renk roller-bearing test systems delivered

Augsburg-based Renk Test System GmbH, a subsidiary of Renk AG, has delivered two unique test rigs to serve as the critical components in the world's most powerful test center for large bearings. Commissioned by SKF in Schweinfurt several weeks ago, the test rigs will help to optimize the performance of future generations of large bearings. The objective is the development of even more compact, robust, lower-friction, and longer-lasting large bearings. The bigger of the two test rigs is the world's first for testing not only the main bearing of a wind turbine up to 6 meters in diameter, but also the entire bearing assembly. The control software Renk Dynamic Data Systems (RDDS) enables the rig to test every conceivable load case occurring in wind-energy plants, e.g. in extreme storms or with a tumbling rotor.

The two test systems, the Main Shaft Test Rig (MSTR) and the Dynamic Development Test Rig (DDTR), are a thousand times bigger than a "normal" Renk test rig rated in kilonewtons. In contrast, the systems installed in Schweinfurt operate on a meganewton scale. With combined load input, the MSTR can act on the tested bearing with a bending moment of 40 MN and a dynamic force of 8 MN both in axial and radial directions. The smaller DDTR, engineered to thoroughly test large bearings in the shipbuilding, mining, paper, cement, and steel industries, can deliver a commendable performance, too. It achieves speeds of up to 250 rpm while applying loads of up to 7 MN to the bearings. Such testing of new components, geometries or materials here, too, accelerates the torture suffered by the bearings.

The sheer dimensions and weight of the two test systems are gigantic. Featuring an energy recovery system, the MSTR is approximately 9 meters wide, 11 meters tall, and 8 meters deep. It weighs about 700 metric tons. The load disk alone has a weight of 125 metric tons and a diameter of about 7 meters. The deadweight of the


Assembly of the MSTR load unit. (Courtesy: Renk)

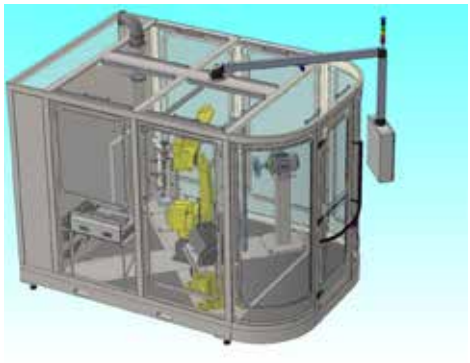
Companies wishing to submit materials for inclusion in Industry News should contact the editor, Kenneth Carter, at editor@gearsolutions.com. Releases accompanied by color images will be given first consideration.

DDTR, which also features energy recovery, is in the region of 300 metric tons. Both of the rigs are mounted on reinforced-concrete foundations weighing hundreds of tons, to ensure safe operation. Since the designs will facilitate extremely efficient testing and also contribute toward a resource-friendly production of future generations of large bearings, they have been sponsored to a total value of about 3.5 million euros by the Bavarian State Ministry for Economic Affairs and Media, Energy and Technology, and the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

These test rigs also serve as tools in basic development work. Even the most modern simulation programs are unable to faithfully reproduce all the dynamic processes to which large bearings are submitted under actual operating conditions. This is why, until now, such bearings have been engineered with "built-in safety reserves" which cannot completely exclude premature damage. Hence, experts assume that, under practical conditions, certain phenomena still occur that have not been adequately allowed for in today's simulation models. Test rigs are intended to help analyze such situations. Among the functions is to investigate the reciprocal effects of varying lubrication conditions and bearing designs as well as materials under highly dynamic loads.

FOR MORE INFORMATION: www.renk.biz

Matrix Design, LLC to demo robotic deburring applications system at Gear Expo



Caption: Matrix Design, LLC will feature the Deburr Demo cell at Gear Expo in Columbus, Ohio. (Courtesy: Matrix Design)

Matrix Design, LLC will be exhibiting at Gear Expo 2017 from October 24-26 in Columbus, Ohio. Thousands of gear industry professionals are expected to attend the event to discover cost-effective solutions and new technologies.

Gear Expo, owned by the American Gear Manufacturers Association, offers learning opportunities and educational options designed to give technology professionals and those that serve the industry tools to succeed in the future.

Matrix will exhibit in booth #422, and will feature its brand-new Deburr Demo cell. Here, attendees will have the opportunity to see live advanced robotic deburring technologies. This modular-designed automation system includes four interchangeable stations arranged in a quadrant formation around a single M-20iA35M FANUC robot, each featuring various deburring solutions which address the unique challenges associated with deburring.

"We are very excited to unveil our new robotic deburring applications system," said

Jeff Bennett, vice president of sales and marketing. "This new system will allow us to demonstrate our automated deburring technologies to manufacturers, as well as qualify new potential deburring applications." Matrix's staff will be on hand to present, answer questions, and to help end users understand how manufacturers' operations can benefit from increased productivity, improved safety and work environment, decreased costs, and consolidation of processes.

FOR MORE INFORMATION: www.matrixdesignllc.com

Mazak adaptive gear machining solutions to take center stage at Expo

At Gear Expo 2017, Mazak will demonstrate recent advancements in manufacturing systems and processes that make the business of producing high-quality gears an easier, faster, and highly profitable endeavor for job shops across all industry segments. Visitors to booth 123 will discover how Mazak's multi-tasking machines, when equipped with the latest MAZATROL Smooth CNC and Mazak Smooth Gear Cutting Solutions, can serve as adaptive machining solutions for precision gears of all shapes and sizes.

More than 90 model configurations of Mazak multi-tasking machines can be paired with the right software and CAD/CAM system to perform a wide variety of operations that include hobbing, forming, surfacing, and skiving in a single setup. Shops with occasional gear work, for example, can use a Mazak multi-tasking machine to turn a part's I.D. and O.D., process its mating features, then power skive its gear tooth pattern. Such capability on one machine improves overall accuracy because every part feature runs true to the gear teeth. Plus, when the machine is not busy with gear work, it can be used to process a broad range of complex, non-gear components.

At the Expo, Mazak will highlight its new closed-loop gear machining strategy, developed in conjunction with software developer Dontyne Systems, which simplifies the measurement and validation of the accuracy of virtually any gear tooth profile. Through

A Mazak INTEGREX e-1550V/10 multi-tasking 5-axis machining center cuts a 6-foot diameter ring gear. (Courtesy: Mazak)

this groundbreaking process, shops with full, 5-axis multi-tasking capabilities can productively and profitably produce tight-tolerance gears in small and medium volumes. The process also makes it possible to generate more complex and specialty forms for better overall gear performance.

Attendees of Gear Expo will also experience how Mazak's MAZATROL SmoothX CNC operates four times faster than the company's previous-generation controls. Gear makers, especially, will benefit from faster rotary axis speeds, which allow the machine tool to quickly perform gear hobbing and skiving operations.

FOR MORE INFORMATION: www.mazakusa.com

HBM Holdings completes platform acquisition of Schafer Industries

HBM Holdings (HBM) announced that it has acquired Schafer Industries (Schafer) of South Bend, Indiana. Schafer is a leading producer of high-precision, custom-engineered gears and machined parts for a wide range of applications, as well as transaxles, brake assemblies, and other components for off-road vehicles. The acquisition of Schafer is a continuation of HBM's long-term strategy to acquire and build market -leading manufacturers of industrial products.

"We are thrilled to bring Schafer into our portfolio," said Mike DeCola, HBM's CEO. "Schafer's leadership team has done a remarkable job of growing the company by helping customers solve complex problems. Building on this success, we look forward to further expansion of the business. Schafer is a perfect fit for our model, as the current ownership group is ready to transition the business to reach a new level of capability and success," continued DeCola.

Founded in 1934, Schafer is a privately held company operating through two vertically integrated divisions: Schafer Gear Works and Schafer Driveline. Schafer Gear Works manufactures gears that power products across a diverse set of markets and custom applications, including aerospace, industrial warehouse equipment, and general transportation applications found in the automotive, agricultural, and construction sectors. Schafer Driveline is a leading manufacturer of custom engineered and assembled transaxles and brake components, bringing integrated power delivery solutions to the recreational and off-highway vehicle industries. In total, Schafer operates four facilities in the Midwestern United States, with over 300,000 square feet of manufacturing space.

Bipin Doshi, CEO and president of Schafer, said, "As we engaged in the process of selling Schafer, our priorities were our employees and our customers. Throughout the process, HBM Holdings stood out not just in value for us as shareholders, but in terms of cultural fit. They understand our markets, technology, and resource constraints and have a talent development strategy that will help our people continue to grow and succeed. Their focus on growth will benefit both our employees and our customers."

Mr. Doshi, along with his wife, Linda, and Stan Blenke, executive vice president and CFO, acquired the business from South Bend Lathe approximately 30 years ago. As a result of their leadership, the company has experienced tremendous expansion organically and through acquisitions. Both Doshi and Blenke will stay involved during a transition period.

Eric Van Rens will become the company's CEO effective immediately. Since 2004, Eric has served as the vice president, sales and marketing for Mississippi Lime, an HBM portfolio company. He also held earlier roles in operations, marketing and general management with Astaris and FMC Corporation. Eric holds a Bachelor of Science in mechanical engineering from the University of Wisconsin and a Masters of Business Administration from Rutgers University.

Terms of the transaction were not disclosed.

FOR MORE INFORMATION: www.hbmholdings.com

Hexagon engineer earns recognition for CNC systems optimization work

Hexagon Manufacturing Intelligence announced one of their young achievers has earned recognition in the Fifth Annual "30 under 30" issue of *Manufacturing Engineering*, a publication of the Society of Manufacturing Engineers (SME) and Advanced Manufacturing Media.

Tim Pheland, a manufacturing engineer at Hexagon, has been selected as an honoree among a field of 30 young men and women (all age 30 or younger at the time of nomination) who are professionals and students. His profile appears in the July issue of *Manufacturing Engineering*, which celebrates this group of talented individuals for their demonstrated achievements, leadership, and high-tech work in manufacturing. This SME recognition program emphasizes that the industry is evolving and advancing, and young people are enjoying careers in manufacturing that are important, challenging, and rewarding.

Pheland received his Bachelors of Science degree in Industrial and Systems Engineering from the University of Rhode Island. He began his engineering career working for a manufacturer of precision fasteners for the aerospace industry. Pheland accepted a position as a manufacturing engineer with Hexagon and continued to enhance his career with a Master's degree in the same concentration. Three years ago, Pheland joined the parts manufacturing department located at Hexagon's Quonset Point headquarters in Rhode Island. In his new engineering capacity, he focused on optimizing the company's CNC systems in the areas of programming and tooling. In just six months, his efforts resulted in a significant reduction in cycle time, as well as doubling throughput, enabling the department to improve quality, and cut their 'cost per part' in half.

Tim Pheland, a manufacturing engineer at Hexagon, has been selected as an honoree among a field of 30 young men and women who are professionals and students.

"We are very pleased that one of Hexagon's rising stars has been recognized by the Society of Manufacturing Engineers (SME) Fifth Annual '30 Under 30' list," said Steve Ilmrud, vice president of operations, Hexagon Manufacturing Intelligence North America. "Tim Pheland, a manufacturing engineer at our Rhode Island headquarters, is a shining example of the up-and-coming talent needed to push advanced manufacturing forward in the United States. Tim's dynamic leadership and focus on excellence in the parts manufacturing area has helped our team to significantly improve production processes and systems. And his optimization work continues today."

FOR MORE INFORMATION: www.hexagonmi.com

Kapp Niles presents Rocky Mountain Profile Grinding School

The Rocky Mountain Gear School is celebrating its 10th year and is all about profile grinding. The school takes place October 11-13, 2017, in Boulder, Colorado. Officials have worked methodically through this decade to fine-tune the program, so experienced experts can meet attendees' needs. The multi-layered program is specifically designed to optimize learning and strengthen understanding of profile grinding.

The program includes a well-balanced mixture of profile grinding technology in a classroom setting, and hands-on demonstrations to turn participants into profile grinding experts. Every participant will have the chance to put the learned skills into practice immediately with on-site machines. Additional workshops provide further opportunities to explore, and network with others in the field.

The school's concept is that machine demonstrations reinforce the theoretical training and help people retain more of the information taught in the classroom. Workshops offer further opportunity for review, as well as a platform to explore students' own applications with experts, as well as others in the group.

Additionally, this year offers one of the following options:

- Bring-Your-Own-Gear Session.
- Tour of Aerocom Industries.

FOR MORE INFORMATION: www.kapp-usa.com

Seco partners with local university for engineering internship program

Seco Tools, LLC has partnered with Ferris State University (FSU) in Big Rapids, Michigan, to offer local area engineering students an opportunity to participate in a multi-year internship program at Seco. The program invites the top three engineering applicants to participate for an initial first-year internship. Then, based on their interest and performance, the students are potentially asked back for a second year. Once a student graduates from the program, Seco often offers employment at one of the company's several U.S. locations.

Under the guidance of seasoned mentors, Seco interns experience a combination of classroom training and real-world business experience while earning their degree at FSU. The first-year interns take part in technical training and the development of custom tooling. They will also learn to operate machines and accompany Seco applications specialists on outside customer calls. These facets of the program ensure students receive a comprehensive overview of all their potential areas of interest. During their second year, interns are often sent out-of-state to shadow an experienced sales rep and make professional sales calls for on-the-job experience. Students participating in the sales portion of the internship program are paid competitive wages during the internship and receive assistance with housing placement and living expenses. Seco also provides a company car to all second-year students.

"We are very proud of our values at Seco," said Andrew Nalian, human resource generalist and head of Seco's internship program. "One of our values is family spirit, and we want to make sure our students are

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Engineering students interested in an internship with Seco should plan to visit the Seco booth at Ferris State University's career fair to be held in October.

taken care of and have all the tools they need to succeed. Because Seco takes care of everything, the students' parents don't worry about their son or daughter moving to a new city and having to locate and pay for housing. If the intern is participating in the second-year sales program, the parents don't need to worry about a car either, as a company car is provided."

Seco's internship program has been in place for several years, and feedback has been extremely positive. The majority of students who complete the program end up working for Seco.

"We have placed second-year students all over the country, from South Carolina, to Texas and California," said Nalian. "Most of these students will have a job offer with us before they even graduate. In today's marketplace, that's a huge advantage."

Engineering students interested in an internship with Seco should plan to visit the Seco booth at FSU's career fair to be held in October. Inquiries may also be directed to Nalian via email at: andrew.nalian@secotools.com.

FOR MORE INFORMATION:
www.secotools.com

Senvol president to join SME's additive manufacturing community advisers

SME recently announced that it has selected Senvol President Zach Simkin to join as an adviser to SME's Additive Manufacturing Technical Community. Selections for the advisory board are based on a combination of active industry contributions, reputation, and personal commitment to expand the use of additive manufacturing.

"Society of Manufacturing Engineers (SME) is delighted to have Zach join their tenured Additive Manufacturing Advisory Committee," said Jeff DeGrange, chairman of the advisory board and chief commercial officer of Impossible Objects. "He brings a wealth of additive manufacturing expertise to the industry and we look forward to his positive contributions."

Simkin's role as an SME AM adviser will be for a three-year term.

SME, previously known as the Society of Manufacturing Engineers, promotes advanced manufacturing technology and develops a skilled workforce. It was founded in 1932. The board helps to advise SME on its additive manufacturing initiatives and strategy.

FOR MORE INFORMATION: www.senvol.com

POWDERMET2018 issues call for papers

An official call for papers and posters has been announced for POWDERMET2018: International Conference on Powder Metallurgy and Particulate Materials, June 17–20, 2018. This leading North American powder metallurgy (PM) conference will be at the Grand Hyatt San Antonio, Texas, and is seeking a wide variety of topics.

Submission categories include the following:

- Design and modeling of PM materials, components and processes
- Particulate production
- General compaction and forming processes
- Powder injection molding (metals and ceramics)
- Pre-sintering and sintering
- Secondary operations
- Materials
- Refractory metals, carbides and ceramics
- Advanced particulate materials and processes
- Material properties
- Test and evaluation
- Applications
- Management issues

"The POWDERMET conference provides a perfect opportunity for everyone involved in the PM industry — from the visionaries and the theorists to the current and the practical," said Ken Schatz, sales manager, Metco Industries, and longtime conference attendee. "For me, the main benefit is in the showcasing of available current products and the ability to learn about the latest technology in current production applications. It also provides a good forum to network with vendors, suppliers, other part producers, and end users. "

Submissions will be accepted through November 3, 2017.

FOR MORE INFORMATION: www.powdermet2018.org

AMPM2018 conference issues call for presentations

An official call for presentations has been announced for AMPM2018: Additive Manufacturing with Powder Metallurgy, June 17–20, 2018. This leading North American metal additive manufacturing (AM) conference will take place at the Grand Hyatt San Antonio, Texas, and will feature top industry experts in this fast-growing field.

Submission categories include the following:

- Materials
- Applications
- Technical barriers
- Process economics
- New developments

"Metal AM is still expanding exponentially," said Jim Adams, executive director/CEO, Metal Powder Industries Federation (MPIF). "Due to increased conference participation over the last several years, we've decided to extend the technical sessions at AMPM2018 to three days. Speakers will have more time to explain their research, and attendees will have even more opportunities to learn and grow."

Submissions will be accepted through November 3, 2017.

The conference is sponsored by the Metal Powder Industries Federation, the North American trade association representing the powder metallurgy industry, and its affiliate APMI International.

FOR MORE INFORMATION: www.ampm2018.org

Huron touts growth, innovation as keys to success

Seeing Huron's brand-new assembly line in Eschau, France, in person is the best way to see industrial progress up close. (Courtesy: Redex)

While Huron is proud of its 130-year history of technical and industrial culture and of being a member of the exclusive club of the three leading French manufacturers of machine tools, it is not about to become complacent.

Huron's MU Series universal-head milling machines, revered by several generations of engineers and technicians, have long since passed into history and been replaced by the ultimate in high-precision 5-axis machines.

The decisive advantages in the handle explain why it has been a favorite in recent decades. Known since Day 1 for the extreme rigidity of its frames and the resulting natural rigidity, Huron is quick to assert the strong conservativeness of its engineering and design departments in this field.

"Our frames, which have long been optimized by structural calculations, have amply proven their outstanding quality in field conditions," said Jean-François Killian, head of Huron's R&D and engineering and design departments.

These field conditions are particularly demanding when considering that Huron supplies machines to high-tech industries such as aeronautics, space, defense, and precision molding.

Above all, the tools used and the forces they are subjected to during machining are factored into overall design of each machine.

"Companies in these sectors really appreciate the surface finishes and machining precision possible with our machines, particularly when they are used for working hard metals," Killian said. He cited the manufacture of Inconel or titanium parts, two benchmarks.

Scale is no factor; Huron's 5-axis machines handle small precision instruments and medical prostheses as well as large molds and aircraft structural components.

When it came to expanding Huron's offerings by adding new drive solutions to replace, or provide alternatives to, the usual technologies, the meeting with Redex seemed natural.

"We already knew that Redex is a French manufacturer known around the world for making high-tech products with outstanding precision," Killian said. "But when you take a closer look at their machines, you see that they are beautifully designed."

The first discussions between Huron and Redex confirmed Redex's ability to provide ready-to-use modular solutions perfectly suited to the most demanding machine tool applications.

"Quite simply, our experience with Redex is that the company reduces risk down to its simplest form," Killian said.

Once the first project was initiated, Philippe Le Floc'h, Redex's key account expert for France and Benelux, established close working relationships with his contacts at Huron's engineering and design departments. As usual with applications of this type, the initial goal was to clearly identify the strategic parameters.

"We were quickly able to fully settle all the details of the specifications together," Floc'h said. "After that, it was the responsibility of Redex to come in and to recommend sizes, options, placement, and adjustment methods."

A Redex technician was even posted to Huron to actively participate in the initial set-up and testing.

"The level of technical discussions we have with Redex is exactly the same as that which we have long had with our suppliers of motors, drives, and linear measuring systems," Killian said. "Like with Redex, we always choose companies that are world leaders in their fields. In any case, we have direct access to their top business specialists."

For the sake of technical safety, the company chose to fit the first machines with mechanical preload drive systems. Doing so facilitated mechanical integration easily and, more importantly, avoided having to change the number of axes managed by the numerical control. Other criteria included substantial savings on the cost of the drive.

One of the advantages of this modular solution was that it could subsequently be fitted with an electrical preload system if necessary. This electrical preload solution was quickly used when required by other machines configuration. The results were better than expected, and Redex's solution was immediately implemented on any subsequent machines.

FOR MORE INFORMATION: www.redex-group.com or huron.fr

API Services announces accreditations

Automated Precision-Services Division (API Services), a company specializing in three-dimensional measurements and high-value metrology solutions, announces that it has been awarded A2LA Accreditation to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 Awarded by the American Association for Laboratory Accreditation (A2LA). It has expanded its current accredited tracker calibration capabilities to include our Omnitrac 2 laser tracker and machine tool calibration equipment/processes.

"By us being accredited, customers have the assurance that the equipment used and data provided is accurate and reliable," said Kati Allison, quality manager.

ISO 17025 certification is a global compliance system for calibration and testing laboratories requiring strict adherence in order to guarantee the reliability of the measurements provided. Accreditation proves the technical capability of a laboratory to execute certain types of measurement and raises the bar for the company.

"Our recent assessment by A2LA on the compliance to ISO 17025 is huge for us," said Vice President of Services, Ron Hicks. "First of all, our continued successful compliance to calibrate our API Laser Trackers at our Newport News office confirms our personnel training, enhanced processes and our communication with our Rockville headquarters means our program is working. Our customers should rest assured that that we have the technical knowledge and expertise to calibrate and repair their expensive assets."

"In addition, the scope we have added for CNC Machine Tool Calibration, both standard and volumetric, also assures the customer our program is working. The ISO 17025 accreditation for machine tool calibration is a testament that our API equipment is up to the test and our personnel are trained to use on the customers CNC's."

This ISO certification shows API Service's commitment to deliver reliable, high-quality calibrations and to continually improve development processes. The scope of the ISO certificate includes the calibration, repair, and service of test and measurement equipment and software. A2LA Accreditation imposes stricter requirements than ISO 17025 and ANSI/NCSL Z540 certification alone, particularly focusing on technical competence, traceability of measurements and proficiency of the calibration lab. A2LA is a nonprofit, nongovernmental, public service membership society whose mission is to meet the needs of both laboratories and their users for competent testing and calibration; improve the quality of laboratories and the data they produce; and increase acceptance of accredited laboratory data to facilitate trade, based on internationally accepted criteria for competence (ISO/IEC 17025:2005).

A2LA-accredited laboratories are recognized and accepted in 46 countries and in more than 30 federal, state, and local government agencies, companies, and associations. API is also recognized by the ILAC, the International Laboratory Accreditation Cooperation, giving more credibility overseas.

FOR MORE INFORMATION: www.apisensor.com

Schunk USA begins headquarters expansion

Schunk USA announced the start of construction of an expansion at its US headquarters that will more than double the size of existing facilities. Schunk's US headquarters is already the largest facility outside of

Breaking ground at 211 Kitty Hawk Drive, from left, Jan Kuehne (Schunk), Ed Yerha (Cary mayor pro tem), Herb Bass (Schunk), Bernd Schellenbauer (Schunk Germany), Milton Guerry (Schunk US President), and Jim Bell (Bobbitt). (Courtesy: Schunk)

Germany. This expansion will provide space for a state-of-the-art tech center and training facility, additional manufacturing capabilities, and increased office space to allow Schunk to better serve customer needs.

The company will be investing $30 million in infrastructure, equipment, and personnel by 2022. More than 80 new jobs will be created over the course of four years. In addition to the jobs created and the stimulus to the local economy, the manufacturing community will benefit greatly from this resource. The additional manpower will enable Schunk to provide even greater customer care and continue to meet the demands of a rapidly growing and continually evolving manufacturing industry.

"This expansion is important for us to continue meeting the needs of our customers. As manufacturing processes grow and change, Schunk will continue to be a leader in the industry, with cutting-edge technology and a focus that continually places the customer first," said Milton Guerry, president of Schunk USA.

Two separate expansions will be built in phases. Initially, a 19,000-square-foot addition to the east side of the building will expand the size of the manufacturing area by 150 percent. This will allow for greater efficiency and increased production capabilities to better respond to customer requests and specialty orders. This addition will also double the space dedicated to the successful NCTAP apprenticeship program, allowing Schunk to continue to train future generations of workers.

A separate 22,000-square-foot three-story addition to the north side of the building will encompass a state of the art Tec-Center, training facility, and more office space. With these facilities, Schunk will be

Rendering of the 22,000-square-foot three-story addition to the north side of the building, which will encompass a state of the art Tec-Center, training facility, and more office space. (Courtesy: Schunk)

Rendering of the 19,000-square-foot addition to the east side of the building, which will expand the size of the manufacturing area by 150 percent. (Courtesy: Schunk)

able to host enhanced training programs for distributors and customers, allowing them to understand products better and improve their own applications. The Tec-Center will showcase the latest innovative technology for customers to view products in a real-life application and through interactive demonstrations.

Schunk celebrated this milestone with a groundbreaking ceremony on August 15, which included remarks by Milton Guerry, Schunk US President, and Bernd Schellenbauer, CFO Schunk Germany. Ed Yerha, mayor pro tem of Cary, spoke about the importance of manufacturing in the United States. Other guests included North Carolina State Rep. Joe John, several members of the Cary Chamber of Commerce, and representatives of prominent area manufacturing companies.

Construction of the expansion at 211 Kitty Hawk Drive in Morrisville, is expected to be completed in the fall of 2018.

FOR MORE INFORMATION:
www.us.schunk.com

Breakthrough in digital transformation: thyssenkrupp connects machinery

Thyssenkrupp connects the machinery of the materials division via a new digital platform. "Toii" is an in-house development that connects machines of different makes and generations. Thanks to toii, all machines can communicate with each other. Due to predictive maintenance, the platform is also supposed to forecast the necessity of machine services in the future. The name chosen by the business area is a double play on words – it spells IIoT backwards, the abbreviation for "Industrial Internet of Things" – and it is pronounced like the word "toy," an indication of how the new platform makes linking heterogeneous machines to existing IT structures "child's play." Toii was developed completely in-house by company software engineering experts and tailored to the specific requirements of materials services.

ONE PLATFORM FOR EVERYTHING

The machinery belonging to the business area, which focuses on global materials distribution and processing services, is highly diverse: The machines perform a wide range

of tasks, were made by various manufacturers, and differ in age. Now, toii makes it possible to connect bandsaws and bending machines, mobile objects such as cranes and forklifts, and even complex production facilities such as slitting and cut-to-length lines and sophisticated processing solutions through milling machines and laser systems digitally in line with the Industrial Internet of Things.

The digital platform allows the machines to share data and communicate with one another and with the IT systems. Processes can be planned and coordinated optimally and flexibly across locations worldwide. As a further major benefit, the platform simplifies data analysis: Which product has been produced when and in what quantities? Which machine needs maintenance? What could be developing into a problem? What additional materials need to be delivered? The system answers all of these questions and many more by gathering and analyzing data. The results are just a mouse click away – clearly structured, and easy to understand.

"We've created an end-to-end solution that is tailored specifically to our needs. It will enable us to accelerate the automation of our production operations and make our processes much more efficient," said Hans-Josef Hoß from the board of thyssenkrupp Materials Services.

"We are now taking the digital transformation to the core areas of our business: our production shops, our machinery and equipment, and our materials. Our customers will feel the benefit – and so will we."

CLOSE TEAMWORK OF MAN AND MACHINE

Toii has already successfully proven its worth in several pilot projects. For example, at Materials Processing Europe in Mannheim, a new, highly complex cut-to-length line that cuts sheet from coil was fully connected with the platform. The result: toii transfers work orders directly and in real time from the SAP system to the machine and controls its settings from sizes and weights to volumes. The platform also automatically retrieves the machine information required by SAP. As a result, the status of production and the finished products can be viewed at any time. Other machines have also already been digitally connected and automated using toii, for example, measuring the thickness of metal strips for effective quality control and automatic blanking. In the latter case, the platform even made it possible to fully integrate the blanking operation into a production line. In other areas, from high-bay storage to mobile construction machinery, toii is improving efficiency as well.

The platform is an in-house development, highly scalable, and can integrate up to several hundred machines a year. An international materials services team of IT professionals from Germany, India, and the United States worked together to develop toii. Alongside various projects in Germany, there are already plans to deploy the system in the UK and the USA. All data are currently hosted on a central server in Germany. But to be able to comply with all data protection law requirements, local servers will also be created in the UK and USA as part of the further roll-out.

FOR MORE INFORMATION:
www.thyssenkrupp.com

Set adjustable bore gages quickly, accurately with new Mahr tool

A new bore gage setting tool from Mahr Inc. makes setting up adjustable indicating instru-

ments, such as Mahr's 844 N Adjustable Bore Gage and 844 T Universal ID/OD gage, quick and accurate. The Multimar 844 S Bore Gage Setting Tool uses gage block combinations and a simple hand clamping mechanism to set instruments in either the horizontal or vertical position.

It provides accurate nominal value setting for internal and external dimensions using gage block combinations, and the simple hand-clamping mechanism assures quick accurate setting

"Typically, adjustable bore gages are set using micrometers or master rings," said George Schuetz, Mahr director of precision gages. "But micrometers have inherent errors that can be passed along to the gage, and master rings can be expensive, especially if one is required for each of many sizes on the shop floor. Using a bore setting gage with a gage block stack assembly in a clamp with jaws at both ends provides a highly accurate reference master."

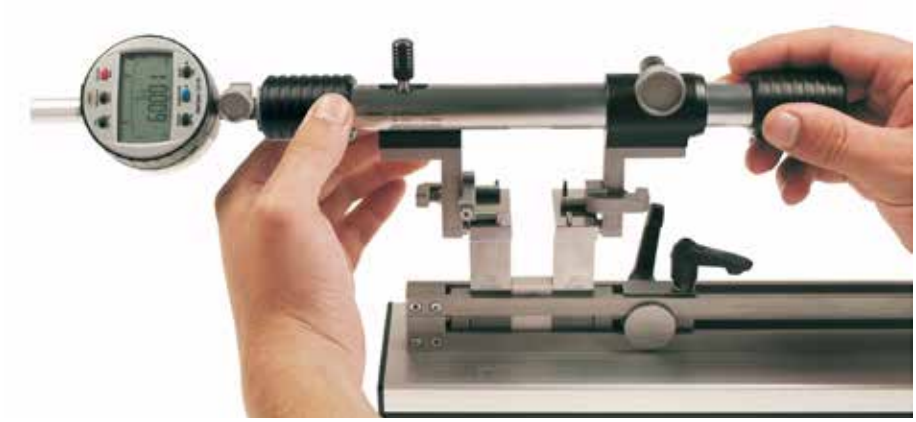
The rigid base of the Multimar 844 S bore gage setting tool is made of anodized aluminum for mobile or stationary use, either in the lab or on the production floor. Three sizes are available: 15.5", 45", and 85.8", along with a wide range of accessories for various gage types.

Mahr Inc. is a member of the Mahr Group, which has over 150 years of experience providing dimensional measurement solutions to fit customer application needs. The company manufactures and markets a wide variety of dimensional metrology equipment, from simple and easy-to-use handheld gages to technically advanced measurement systems for form, contour, surface finish, and length.

FOR MORE INFORMATION:
www.mahrexactly.com

ABM Drives doubling China plant for new self-powered hub wheel drive

Offered as a .6 kW version, this powered hub wheel drive package includes the wheel with tire, AC motor, gearbox and brake. Typical applications include moving 1,000 -5,000 pounds at speeds from 1.5 to 2.5 mph. The max wheel diameter is 230 mm. This is one of the most frequently sold products of ABM Drives Suzhou Co. Ltd.; revenue of the hub wheel drive is in the five-digit range.



A new bore gage setting tool from Mahr Inc. makes setting up adjustable indicating instruments, such as Mahr's 844 N Adjustable Bore Gage and 844 T Universal ID/OD gage, quick and accurate. The Multimar 844 S Bore Gage Setting Tool uses gage block combinations and a simple hand clamping mechanism to set instruments in either the horizontal or vertical position. (Courtesy: Mahr)

This is a new product from ABM that emphasizes the versatility and compactness of their product design. The motor, drive, and brake are nearly inside the caster wheel itself. The company is excited about this brand-new product and a plant expansion to make it. It is perfect for small robotic applications.

In June 2007, ABM Greiffenberger Antriebstechnik GmbH founded its subsidiary ABM Drives Suzhou Co. Ltd. in the Chinese city of Suzhou, near Shanghai. ABM Greiffenberger went to China to better serve customers worldwide, to improve response and delivery times, to ensure quick service, and to strengthen its position in the global market. Today, there are 27 employees working in sales, purchasing, and production in Suzhou. In 2017, sales are at 13 million euros.

By the end of August 2017, a move into a new, and larger, building of 3,200 square meters is planned. "The old building is bursting at the seams. The move opens best prospects for the future," said Robert Lackermeier, CEO of ABM Greiffenberger Antriebstechnik. In these premises, further products will be built for the Chinese market, and new production processes will be added. "This will strengthen our position even more," Lackermeier said.

ABM Drives is doubling its China plant for its new self-powered hub wheel drive.

"We have established ourselves very well in the Chinese market," said Bernd Hauenstein, general manager of ABM Drives (Suzhou) Co, Ltd. "We are offering comprehensive service with short response times because our employees are quickly on site. The production in Suzhou ensures short delivery times. We are producing a very high quality which meets German and international standards."

The Weihua – Group, a prominent Chinese crane builder, has honored ABM as an "outstanding supplier." For the assessment, the selected criteria were quality, innovation, ability, and delivery reliability. ABM Greiffenberger supplies Weihua with hoist and travel drives for hoist technology.

At several national and international production sites, an average of approximately 300,000 drive units are produced annually. It is the future goal for ABM to penetrate the focused markets of hoist technology, conveyor technology, storage logistics, material handling, e-mobility, and renewable energies even more intensively. Also, the company aims at further areas, like construction and textile machinery to increase world market shares.

FOR MORE INFORMATION:
www.abm-drives.com

American Gear Manufacturers Association

Justin Skorski
AGMA Staff Engineer

Serving on an AGMA technical committee can benefit the industry and employees

Many already know that AGMA is an association of companies, consultants, and academicians with a direct interest in all things gears, couplings, and power transmission components. Some are equally aware that AGMA hosts an exceptional Gear Expo every two years, holds an annual Fall Technical Meeting showcasing work of some of the industry's best gear experts, and is growing the AGMA Foundation every year to provide more student scholarships and encourage young engineers to pursue their dreams. What you might not already know is that AGMA has 23 active technical committees that are always looking for new individuals with a broad range of experience and expertise to contribute to the development of AGMA Standards.

The future of the gear industry is only as strong as the members that get involved to grow and improve it. From aerospace to cutting tools and mill gearing to wind turbines, there is a technical committee for everyone in the gear business. By volunteering to be part of a technical committee, your company taps into a vast network of knowledge. Committee membership connects you to more than 200 other active AGMA member companies that are developing standards for the industry.

"The non-technical benefits to the committees are the relationships you build. You have a chance to get involved with experts who are available and happy to talk with you," said Allen Willison, president of A&J Engineering and chairman of the AGMA Computer Programming Committee. "Sometimes, you have competitors in the group, but, when coming up with a program or understanding a standard, it is all about the effort versus anything happening in the marketplace. Building those relationships and learning from each other is one of the best benefits that I see from being on the AGMA committees."

Joining a technical committee is a unique way to develop a network of peers to achieve better insights into the work you perform and the markets you serve every day. In addition, anyone who joins has the opportunity to learn from the experts and will be able to study various technical subjects that relate to gear design, manufacture, and operation, which are important to career development and your company's future. The best part? No experience is needed. All types of gear-related employees are welcome to join. No one should feel intimidated, because all new committee members start off as an observer; over time, they will gain the confidence to participate more freely and bring some unique ideas to the table, and then in turn, back to your company. Due to the vast locations of members, most meetings are held via web conferencing, which makes the time commitment more efficient for busy schedules.

"Companies that support AGMA technical committees will receive an employee that has been exposed to very specific technical information for both well proven concepts as well as information on the cutting edge of gear and gear unit design, manufacture, and failure," said Todd Praneis, director of Product Development at Cotta Transmission Co. and chairman of the AGMA Technical Division Executive Committee. "Their employee will gain industry contacts that may help find the right resource to help solve a problem or improve a product or process. Young engineers may believe that the information in a standard is 'handed down from On High,' but by being involved in a committee, one will learn the origin and gain a deeper knowledge of the subject material."

You could make an impact both in the United States and around the world. Many of our technical committees also act as a technical advisory group (TAG) to their ISO counterpart working groups (WG) for the development of ISO standards. This type of international relationship building is very beneficial for each company that wants to grow with the industry.

"We highly encourage all of our members to be a part of the technical committees, not only for the benefit of their own company and employees, but also for the benefit of the industry itself," said Amir Aboutaleb, Technical Division vice president of AGMA. "We know there is a need for younger engineers to take over the responsibilities and direction of the standards through these committees, and what better way to get started now when our experienced members can pass on their knowledge?"

To find out more about AGMA technical committees, visit the technical committees page under the Standards tab on agma.org, or email tech@agma.org.

GEAR EXPO NETWORKING EVENTS

GEAR EXPO 2017

Gear Expo and ASM Heat Treating Society Networking Reception

Tuesday, October 24 | 5 – 6 p.m.

The first day of Gear Expo is always exciting and busy. AGMA and ASM Heat Treating Society want to welcome all those who have worked so hard to exhibit and attend Gear Expo 2017. All are encouraged to meet in the exhibit hall for a beverage and a chance to mingle. This will be a great way to connect with new peers and discuss the upcoming events for the following days. This event is free for all Gear Expo and education program attendees.

Taste of Columbus Reception

Wednesday, October 25 | 7 – 9:30 p.m.

Columbus' North Market
(short walk from Convention Center)

Sign up for the event when you register for Gear Expo.

$75 for members
$95 for non-members

AGMA and ASM will co-host an exciting new joint networking event at Ohio's North Market. The evening has been set up for Gear Expo exhibitors and attendees to bring guests and potential business leads to enjoy the food and entertainment Columbus has to offer while continuing the industry conversations outside of the EXPO.

There will be more than a dozen vendors lined up to serve people as they stroll through the 100-year-old historic market. Some participating food artisans include: The Fish Guys, Little Eater, Jeni's Splendid Ice Cream, and A Taste of Belgium. In addition to the magnificent food, Watershed Distillery and Middle West Spirits will have bourbon tastings and fresh-rolled cigars at the cigar-rolling station. The food and spirits will be topped off with entertainment provided by Lieutenant Dan's New Legs, a popular band from Columbus that will be sure to have the crowd on their feet.

GEAR EXPO 2017
THE DRIVE TECHNOLOGY SHOW

October 24–26, 2017
Columbus, OH
Greater Columbus Convention Center
www.gearexpo.com

WHAT DRIVES YOU

Industry Tour

When you register for Gear Expo 2017, you can sign up for a free guided tour around the show floor that will give you a personal introduction to 10 of the exhibiting companies. You will have one-on-one conversations that will provide information on the latest technologies from some of the top companies in the industry.

The tours are one hour on Tuesday and Wednesday. This new service is the best way to meet the experts from AGMA's Gear Expo 2017 and ASM's Heat Treat 2017 and enhance your show experience.

For more information about Gear Expo's networking events, please visit:
www.gearexpo.com/networking-opportunities

American Gear Manufacturers Association

GEAR EXPO SOLUTIONS CENTER – KEYNOTE SPEAKERS

Free education sessions will be available in the Solutions Center on the show floor. Come listen to the latest innovations coming out of the drive technology industry. These sessions can help you solve your manufacturing predicaments and can provide you with an ROI that will more than pay for your trip. The complete list of presenters is available on the Gear Expo website (www.gearexpo.com) or download the free Gear Expo app through the Apple or Android stores.
Each day there will be a special keynote presentation from 1 - 2 p.m

Paul Boris, COO of Vuzix

Boris is an expert in the Industrial Internet of Things (IIoT) and how manufacturers now have the ability, even with minor investment, to have IIoT projects in their factories that can provide actionable results. He will discuss IIoT in his presentation: The Industrial IoT is Here — and Manufacturers at ALL Levels Can Implement and Find ROI Quickly. Boris first spoke to the AGMA audience during an Industrial Internet of Things (IIoT) panel at this year's Annual Meeting. Due to the popularity of his presentation, AGMA recognized the companies at Gear Expo would appreciate the innovative energy Boris has and would benefit from the direct impact of his knowledge.

Mark Johnson, Director of the Advanced Manufacturing Office at the Office of Energy Efficiency and Renewable Energy

Dr. Johnson, director of the Advanced Manufacturing Office (AMO) in the Office of Energy Efficiency and Renewable Energy (EERE), is focused on creating a fertile innovation environment for advanced manufacturing and enabling vigorous development in the United States of new energy-efficient manufacturing processes and materials technologies. Johnson will address the needs for the industry of the future and discuss key enabling technologies that will help achieve these goals. He will highlight ways in which the Department of Energy and the AMO are helping support innovation in the field of advanced manufacturing while continuing stewardship for energy efficient manufacturing processes and materials technologies.

Jay Rogers, CEO and Co-Founder of Local Motors

John "Jay" Rogers is the CEO and co-founder of Local Motors, a technology company that uses a co-creating community to design, develop, and build Olli, the world's first self-driving cognitive vehicle. Local Motors is redefining the development of connected hardware by pairing micro-manufacturing with the open-source technology community. It is the first company to use direct digital manufacturing (DDM), debuting the world's first 3D-printed car, the Strati, in September 2014. This type of innovation works well with Gear Expo's drive technology focus and AGMA's strategy of bringing emerging technology to the gear industry. In addition, the Gear Expo attendees represent a variety of industries including industrial applications and automotive. They come from around the United States, international manufacturing hubs, and emerging markets to conduct profitable business transactions and learn about the innovations to streamline their operations. Rogers will be able to appeal to many of the attendees on different levels.

For more information about the Gear Expo Keynote Speakers, please visit:
www.gearexpo.com/keynote-speakers

Fall Technical Meeting

October 22-24

AGMA's Fall Technical Meeting is a three-day conference that covers the gear industry's latest research and technical developments. Presentation topics include design, analysis, manufacturing and application of gears, gear drives, and related products, as well as associated processes and procedures.
Papers will be presented in these sessions:

- **Session I —** Efficiency, Lubrication, Noise and Vibration
- **Session II —** Manufacturing, Inspection and Quality Control
- **Session III —** Application, Design and Rating
- **Session IV —** Materials and Heat Treat
- **Session V —** Gear Wear and Failure

For complete information, visit:
www.agma.org/events/2017-fall-technical-meeting

Gear Expo Education Classes

October 24–26

Registration now open for the following classes:

- **Basics of Gearing**
  October 24, 8 a.m. – 5 p.m.
- **Why Bearings are Damaged**
  October 24, 1 – 4 p.m.
- **Taming Tooth Deflections: The Case for Profile Modifications**
  October 24, 8 a.m. – noon.
- **Reverse Gear System Engineering**
  October 25, 1 – 5 p.m.
- **High Profile Contact Ratio Gearing**
  October 25, 8 a.m. – noon.
- **Gearbox Field Inspection**
  October 25, 8 a.m. – noon.
- **How to Read and Interpret a Gear Inspection Report**
  October 26, 8 a.m. – noon.
- **Materials Selection & Heat Treatment of Gears**
  October 26, 8 a.m. – 5 p.m.

For complete information, visit:
www.gearexpo.com/education

AGMA has over 1,000 Twitter followers! Join the conversation @agma

CALENDAR OF EVENTS

Whether you're looking for technical education, networking opportunities, or a way for your voice to be heard in the standards process, AGMA has something to offer you. If you would like more information on any of the following events, visit www.agma.org or send an email to events@agma.org.

Events are open to AGMA members only. Not a member? Send an email to membership@agma.org.

SEPTEMBER

September 19 — Materials and Metallurgy Committee Meeting WebEx
September 21 — Gear Accuracy Committee Meeting WebEx
September 26 — Cutting Tools Committee Meeting WebEx
September 27 — Sound & Vibration Committee Meeting WebEx
September 28 — Helical Gear Rating Committee – subcommittee 925 WebEx

OCTOBER

October 3 — Nomenclature Committee Meeting WebEx
October 4-5 — Fall Marketing & Forecasting Conference Chicago, Illinois
October 4-6 — Steels for Gear Application Alexandria, Virginia
October 10 — Plastics Gearing Committee Meeting WebEx
October 17 — Lubrication Committee Meeting WebEx
October 19 — Wind Turbine Gear Committee WebEx
October 19-20 — Aerospace Gearing Committee Meeting Columbus, Ohio
October 22-24 — Fall Technical Meeting Columbus, Ohio
October 24-26 — Gear Expo Columbus, Ohio
October 31 — Fine-Pitch Gearing Committee Meeting WebEx

NOVEMBER

November 2 — Flexible Couplings Committee Meeting WebEx
November 7 — Metallurgy and Materials Committee Meeting WebEx
November 9 — Gear Accuracy Committee Meeting WebEx
November 14 — Helical Gear Rating Committee Meeting WebEx
November 14-16 — Detailed Gear Design Dallas, Texas
November 16 — Nomenclature Committee Meeting WebEx
November 29 — Technical Division Executive Committee WebEx

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General requests: webmaster@agma.org | **Membership questions:** membership@agma.org | **Gear Expo information:** gearexpo@agma.org
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KAPP NILES

GEAR EXPO 2017
THE DRIVE TECHNOLOGY SHOW

visit us at
Booth #1006

KNe 3G
Generating Gear Grinding

efficient
effective
ergonomic
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PGM 400

KNM 7C

High precision metrology featured by
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MATERIALS MATTER

PATRICK I. ANDERSON
MANAGER ADVANCED MODELING GROUP
TIMKENSTEEL CORPORATION

MATERIALS MODELING FOR BETTER GEAR DESIGN AND PERFORMANCE

Modeling techniques can quickly determine the best design and required steel cleanness level based on a gear's application and performance requirements.

PRIOR ARTICLES IN THIS SERIES HAVE highlighted the importance of clean steels as they relate to gear design and preventing premature component failures. Discussions on the increased occurrence of sub-surface-originated fatigue failures at material imperfections, inadequacy of current industrial standards for steel cleanness measurement, choosing the right material from the start in order to prevent failures, and increased demand to develop power dense mechanical systems all highlight the need for industrially relevant tools that can quantify the effect of steel cleanness on component life performance with minimal physical testing and design iterations. As my colleague put it in the May 2017 Materials Matter column: "From the design perspective of the bearing and gear engineer, the challenge is deciding how much cleanness the application requires…"

Fortunately, advances in materials modeling software and computer hardware have brought materials modeling to the forefront of innovating the next generation of materials — even gear steels. These tools, now commonly referenced in the connected framework of integrated computational materials engineering (ICME), can be used to decrease the time and money spent designing and implementing new steel solutions. Intensive efforts and collaborations are underway between national laboratories, universities, and industry to create and apply computational tools that can connect the nano- and micro-scale characteristics of materials to the typical bulk materials specifications relating to strength, toughness, and fatigue performance. [1, 2]

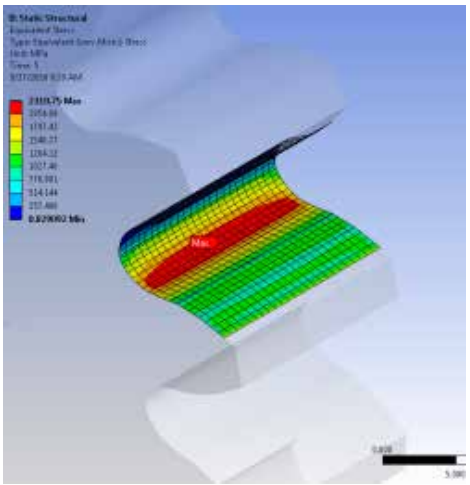

Figure 1: Traditional finite element analysis showing the surface stress on a gear tooth during bending.

In the case of designing steels for successful application to power density and light-weighting initiatives, material models become even more powerful when used in conjunction with refined measurement methods such as automated scanning electron microscopy or ultrasonic inspection for inclusion analysis. For example, a laboratory measurement tool, such as an SEM, is used to feed realistic inclusion population characteristics into a computational materials model that calculates the effect of various inclusions on fatigue performance. The results provide a quantitative measure of the impact of a particular steel cleanness on fatigue performance, thus providing critical information to gear designers on the allowable inclusion population for a given gear application.

More traditional modeling efforts focused on finite element analysis (FEA), which is a mature methodology that can provide 2D or 3D stress and strain distributions in a component, such as those shown in Figure 1 for the surface stress created when bending a gear tooth. If any material imperfections were incorporated in these calculations in the past, they were typically only simplified inclusion or void shapes due to computational limitations.

Thanks to advances in custom materials modeling software, we are now able to easily incorporate the combined effects of component geometry (shape, surface finish), material strength (alloying, grain size), inclusion characteristics (type, size, location, shape, stringer interaction) and stress state (component loading conditions, residual stress from heat treat or machining). Now, even complex inclusions or microstructural

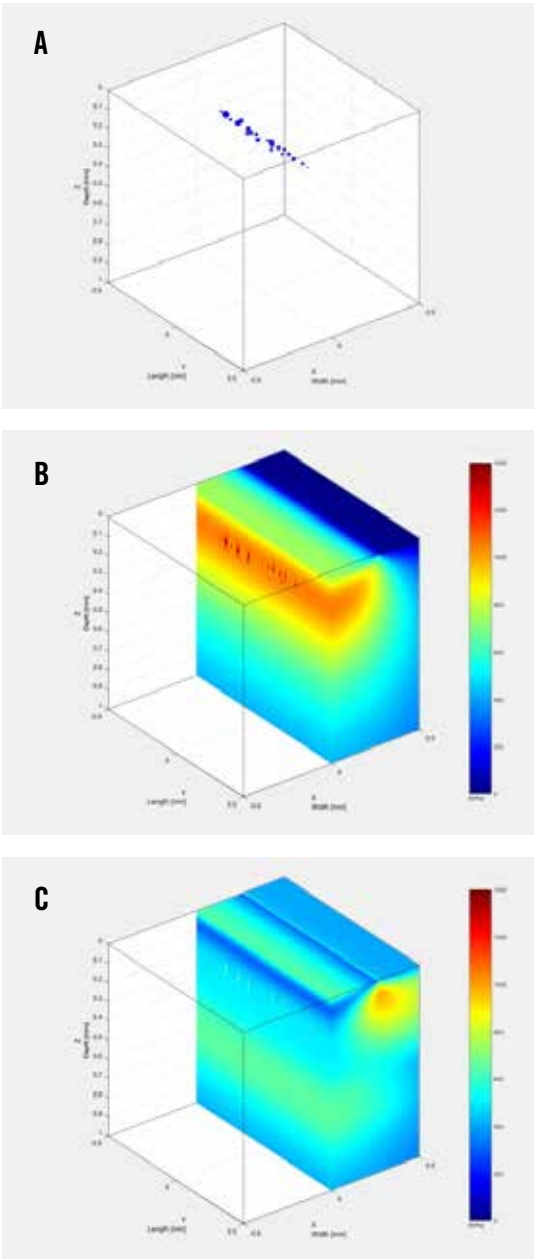

Figure 2: Simulated images showing: (a) a complex stringer inclusion and the local stress state when considering; (b) just contact loading stress, and (c) contact loading stress plus residual stress from heat treatment.

heterogeneities can be captured and accounted for in finite element models using tools that can mesh 2D or 3D materials data directly or by creating synthetic microstructure features based on representative measured data. [3, 4]

The latter method was used to generate the stringer oxide inclusion shown in Figure 2a. Inclusion characteristics were distilled from laboratory measurements in order to adequately describe a random stringer geometry configuration. The advantage for any further calculations is that this subsurface stringer inclusion shown in Figure 2a is not self-aware. The inclusion doesn't know if it is in a gear or a bearing, or whether its home component has been carburized or through-hardened. It simply interacts with the applied stress field according to the rules of the simulation environment. The stress field shown in Figure 2b takes into account the stress induced from contact loading, while Figure 2c additionally includes a pre-existing residual stress field. The resultant, cumulative, localized stress concentration effect for single or repetitive loading cycles can then be quantified using one of many calculations or indicator parameters. [5, 6]

While the example shown is interesting, and Figure 2 is visually appealing, the true power of this method in particular comes from quickly running this calculation in a highly repetitive fashion within a structured statistical framework. This allows us to truly connect the variability in the inputs to the potential variability in the output result — fatigue performance. By taking the results from a larger scale computational design of experiments, you can now produce the previously discussed relationships between steel cleanness, torque and gear mass on fatigue performance (July 2017 Materials Matter).

The increased need for gear materials design support can be met by advanced materials models used in conjunction with appropriate measurement methods. This confluence of past (laboratory) and present (computational) approaches can answer the critical question at hand: What level of steel cleanness is needed for my gear? The potential benefit from materials modeling increases the earlier it is used in the design process, but the approach can be applied at any stage—whether a new, smaller gear that requires an equivalent load to its predecessor or an existing gear that is being asked to carry an increased load.

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BRIAN DENGEL
GENERAL MANAGER
KHK USA INC

UNDER PRESSURE

Understand the choice of pressure angle in the design of spur or helical gearing.

THE PRESSURE ANGLE OF A GEAR IS DEFINED AS THE ANGLE formed by the radial line and the line tangent to the profile at the pitch point. As noted in the image in Figure 1, the pressure angle is the jump off angle of the characters.

In most cases, the pressure angle being referenced is the normal pressure angle, although the transverse pressure angle and the axial pressure angle are also considered when working with helical gearing.

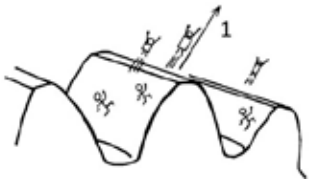

Figure 1

Looking at Figure 2, the line labeled "1" is normal to the tooth profile; the line labeled "2" is the tangent to the reference circle; the line labeled "3" is tangent to the profile, and the line labeled "4" is the radial line. In this image, the normal pressure angle is labeled α. Here $\alpha = \alpha'$. Therefore, α' is also the pressure angle.

A common value of 14 degrees, 30 minutes was historically used in diametral pitch gearing. The basis for this selection was that this pressure angle allows for reduced noise in the gear mesh and exhibits a lower rate of wear. Mechanisms that did not need to transmit heavy power transmission were ideal for this pressure angle. However, it was recognized by AGMA that a 20-degree pressure angle was more suited for most applications and included this value as its preferred value for normal pressure angle beginning in the early 1980s.

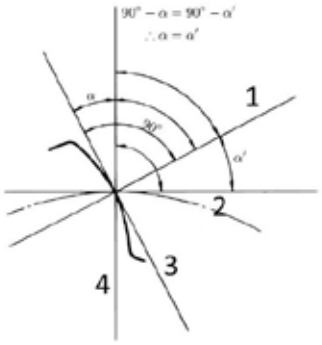

Figure 2

The benefits of selecting a 20-degree pressure angle include additional power transmission capacity, better lubrication in the gear mesh, and reduced numbers of teeth for the pinion without undercutting. The 20-degree pressure angle gear tooth has a wider base that allows for additional load capacity, but it incurs additional wear on the tooth flank during interchange of teeth in and out of mesh. For some specialty applications where noise is not an issue but strength is, pressure angles of 22 degrees, 30 minutes; 25 degrees; or 30 degrees have been used.

When designing a pinion, one consideration that must be reviewed is the relationship between the number of teeth, the gear pitch, and the pressure angle. As each of these values decreases, the minimum number of teeth to prevent undercutting increases. For example, a module 1 spur gear with a 14-degree-30 minute pressure angle will begin to exhibit undercutting if it has less than 26 teeth. However, a module 1 spur gear with a 20-degree pressure angle would not exhibit undercutting until it has less than 15 teeth. This is significant when designing systems where a relatively large reduction ratio is required. For example, if one desired to use spur gears to reduce the speed from 1,200 rpm to 200 rpm and chose to design with 14-degree-30 minute pressure angle gears, the minimum number of teeth for the input would be 26, and the number of teeth for the output would be 156. These gears would have a very large footprint compared to a 20-degree pressure angle pair that could accomplish the same task with a combination of 16 teeth on the input and 96 teeth on the output. If designed with the same pitch, the 20-degree pressure angle output gear would be 38 percent smaller in diameter than the 14-degree-30-minute pressure angle gear. This would reduce both the space requirements for the gearing as well as reduce the weight of the gearing.

Gear racks are defined as a spur gear having a pitch radius of infinite size. For a 14-degree-30-minute pressure angle rack and for a 20-degree pressure angle rack, the racks both have the same straight-sided tooth form, but the sides of the teeth are at different angles. As such, the angle of the tooth profile and the pressure angle for the gear rack are the same.

For helical gearing, it is important to understand the action of the transverse pressure angle, and the axial pressure angle. The transverse pressure angle is defined as:

$$\alpha_t = \tan^{-1}\left(\frac{\tan \alpha_n}{\cos \beta}\right) \qquad \textbf{EQUATION 1}$$

where α_n is the normal pressure angle and β is the helix angle.

For example, if you design a helical gear with a 10-degree helix angle, a 14-degree-30-minute pressure angle, and 30 teeth, the resulting radial pressure angle will be 14 degrees, 42 minutes, 50 seconds. For a 10-degree helix angle but a 20-degree normal pressure angle, the resulting radial pressure angle will be 20 degrees, 17 minutes. This increase in pressure angle in the radial direction is due to the increase in the base circle. It permits an increase in power transmission proportional to the increase in the tooth width at the root.

One requirement for all gearing is that the pressure angle must be the same for both gears in mesh. A 20-degree pressure angle will not mesh properly with a 14-degree-30-minute gear, even if all of the other gear geometry is the same. For simplicity, metric spur gears as produced to JIS standards are always 20-degree pressure angle gears.

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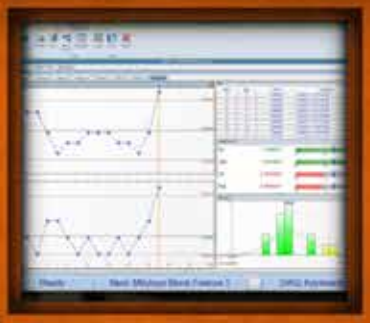

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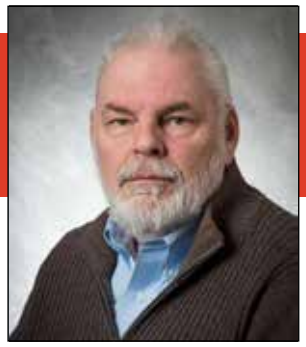

HOW PARTS CLEANING MAXIMIZES HEAT TREATMENT

The impact of proper cleaning and rinsing on part quality prior to heat-treating is critical to the surface finish and overall quality of the finished gear.

THE DEMANDS OF HEAT-TREATED GOODS are increasing. Not only do they have to meet property and straightness requirements, but they also have to meet increasingly stringent appearance specifications. It is not only important that parts perform as expected, but they must look good doing so. The perception is that clean parts are quality parts. In my experience, staining of parts and cleanliness issues is the No. 1 problem experienced by heat treaters, followed by distortion. Property issues are far down the list of potential problems.

Cleanliness is a relative term. The total process will dictate the degree of cleanliness. For example, a part is being cleaned during various states of manufacture to remove chips or machinery fluids. The cleaner will leave behind a residual rust protective film. Although there is residual film on the part, it is considered clean. In the case of electroplating, blackening, or enameling, the part must be chemically clean. This is often referred to by the term "water break free." After cleaning, if a part is rinsed in clear water, the water should run down the part in a continuous unbroken film. This indicates a water break free part. If the film is interrupted, this indicates some soil is remaining on the surface. Cleanliness should be determined by the customer. During a cleaner trial, it is good policy to allow the customer to make the initial comments concerning cleanliness. A part that may appear to be dirty to an operator could be quite acceptable to the final customer. Typical soils for heat-treating processes are shown in Figure 1.

BASIC FACTORS TO CONSIDER

With few exceptions, there are certain principles that apply to all types of cleaning. These include:

- Increased temperature usually improves cleaning.
- Agitation to move the soil (rather than the cleaner) improves cleaning. Agitation to move the cleaner is important when the layer of cleaner next to the surface has become heavily contaminated with soil or has cooled off.
- A minimum concentration of cleaner is needed for cleaning; above this level cleaning improves with increased concentration, but each increment of cleaner has a lesser effect than the previous. A point of diminished returns is eventually encountered.
- Adequate time must be provided for detergency or reaction of cleaner with soil. Otherwise, agitation or mechanical removal effects become more important.
- Rinsing away of soil and cleaner is necessary and must take into consideration factors such as: The amount that can be left behind without harm; how much cleaner residue can be tolerated; and pressure rinse water or an agitated rinse is far more effective than a "still" rinse.
- Soil must be kept from redepositing on the work. This might take the form of cleaner components to suspend the soil or design of the vessel holding the cleaner to provide room for soil to settle to the bottom (away from the cleaning area) or an overflow for oil to float away from the surface of the rinse.

The general effect of process variables on cleaning is shown in Figure 2.

There are three different scenarios for cleaning prior to heat treatment:

- Prior to carburizing or neutral hardening.
- Prior to vacuum processing.
- Prior to induction hardening.

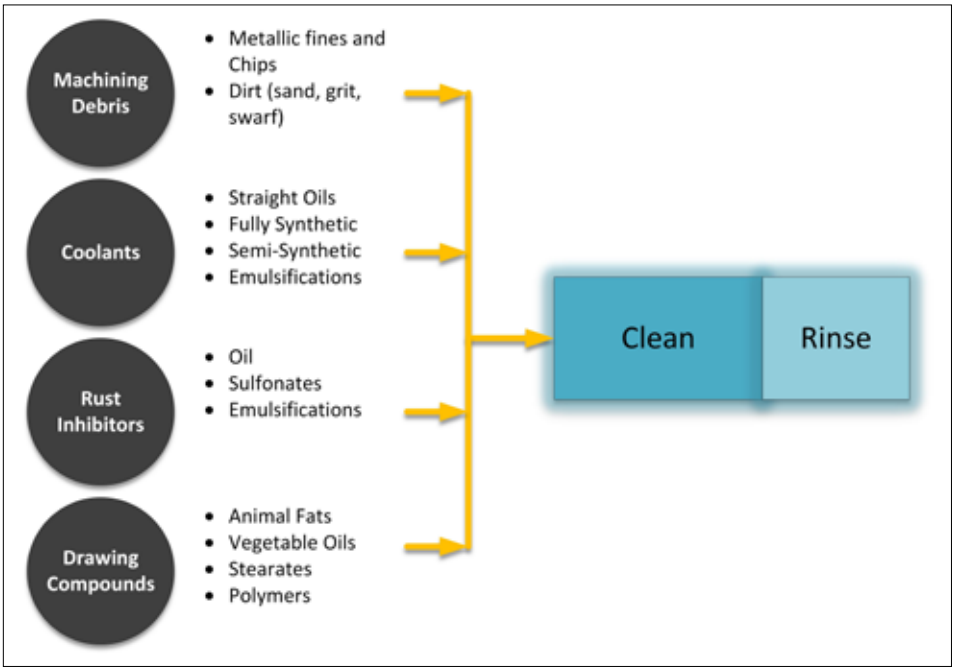

Figure 1: Typical soils found on parts prior to heat treatment.

CARBURIZING AND NEUTRAL HARDENING

The presence of various soils, such as coolants, if improperly removed, can have a drastic effect on the carburized case. If the coolant contains significant quantities of sodium borate or sodium tetraborate, residues of coolant can form a low temperature glass on the surface of the part, which effectively blocks carburizing. Highly chlorinated oil-based coolants can result in carbonaceous deposits forming on parts with chlorine attacking the surface of the part.

Highly sulfurized parts can attack not only parts, but the fumes from the breakdown of the coolant can attack alloy within the furnace and form low-melting temperature NiS compounds at the grain boundaries of alloy. This shortens the life of burner tubes and supporting alloy racks and fixtures. The formation of nickel sulfide at grain boundaries can also lead to catastrophic failure of burner tubes.

It is important to properly clean parts prior to heat treatment. As a general rule, the organic components will burn off (but possibly leave a carbonaceous film). Inorganic constituents will burn onto the part, creating sites for subsequent rusting or blocking the diffusion of carbon.

VACUUM PROCESSING

There are several factors that should be considered preparing work pieces for vacuum heat treating or brazing. Cleanliness of the work piece is extremely important to prevent staining of parts or damage to parts.

These parts should be free of oil, dirt, and other contaminants prior to austenitizing. Compounds that contain sulfur can cause discoloration of the part and also result in poor braze alloy flow.

These contaminants can be either water-based or oil-based. Different cleaners are required for the different contaminants. Aqueous cleaners are required for water-based contaminants, and solvent cleaners should be used for oil-based contaminants. Generally, solvent-based cleaners are the first choice for vacuum-processed parts. However, solvent-based cleaners do not properly clean water-based contaminants. In this case, the use of alkaline cleaners and at least one rinse is recommended. Often, multiple rinse cycles are required. The rinse tank should be dumped on a regular basis to prevent re-contaminating the part.

Parts should be inspected for contaminants in deep recesses or holes for entrapped lubricants or coolants, as well as metal chips. Tags and wire used to attach the tags should be verified to make sure they are not of a low melting point alloy such as aluminum.

Some materials require special cleaning practice. Titanium and zirconium alloys should never be cleaned in chlorinated solvents such as trichloroethylene or methyl chloride. Chlorine residues can result in stress-corrosion-cracking (SCC) when heated to above 280°C. These alloys should be cleaned in non-chlorinated solvents such as acetone or alcohol. Alkaline water-based cleaners can also be used. Care must be taken to properly rinse the parts. Many drawing lubricants contain sulfur and possibly lead. Both of these elements can attack nickel alloy surfaces and form a low melting temperature eutectic that will embrittle nickel alloys. Nickel-based parts must be thoroughly cleaned and rinsed to ensure the removal of drawing or stamping compounds. After cleaning, the parts must be dried to prevent degradation of vacuum during the process cycle.

Influence of Process Variables

Time	Temperature	Agitation	Concentration	Part Orientation
• Increasing time increases cleaning • Allows time to remove difficult deposits	• Increasing temperature increases cleaning • Dependent on cleaner • Excessive temperature may cause rusting	• Increasing agitation increases cleaning • Lifts deposits	• Increasing concentration improves cleaning • Diminishing return • Increases likelihood of residual cleaner residue	• Must be adequate to allow cleaner to reach all parts • Adequate part spacing (1T)

Figure 2: Influence of process variables on proper cleaning of parts prior to heat treatment.

INDUCTION HARDENING

In induction hardening, parts are heat-treated using a strong electromagnetic field to create eddy-currents within the part. This process is commonly used for medium carbon steels to form a hard case. After heat treatment, the part is flooded with quenchant, typically containing a polymer quenchant at some nominal concentration. This process is often highly automated and is in-line with machining operations. The quench tanks on many induction machines are quite small, typically less than 500 liters. Induction hardening is fast and capable of processing hundreds or thousands of parts per day.

Minor carry-over of coolant on parts to the induction hardener is a common occurrence in the heat-treating shop. Coolants and hydraulic fluids are often found on parts prior to induction hardening. Over time, these contaminants build up in the quench tank, leading to changes in cooling curve behavior. This can contribute to cracking or inadequate properties. Figure 3 is an example of a poorly controlled polymer quenchant where no washing of parts prior to heat treatment occurs. How can consistent properties be expected, when the contamination of the quench bath exceeds that of the polymer quenchant?

Proper cleaning involves not only removing the various soils from the part but also removing any residual cleaner residue by proper rinsing. This is a critical step and is often the cause of many problems. One-stage washers, with only a wash cycle, can leave a cleaner residue on the parts. The residue must be removed to prevent staining and attack of parts by the residual cleaner fluid. A good analogy would be a dishwasher full of dishes. The soap must be rinsed off the plates so as not to impart a chemical taste to food. Parts must be rinsed to remove any residual cleaner

Figure 3: In use samples of polymer quenchant badly contaminated with coolant from the prior machining operation. A new solution would be a clear, slight amber color.

Figure 4: Rusting and caustic burn resulting from improper cleaning and rinsing of parts prior to heat treatment.

from parts. Failure to remove cleaners during the cleaning cycle can result in problems such as caustic burn or rusting (Figure 4).

CLEANING CONCLUSIONS

In this brief overview, the impact of proper cleaning and rinsing on part quality was discussed and illustrated. The possible soils to be cleaned from parts prior to heat treatment were discussed and their impact of parts during heat treatment was shown.

For high quality parts and parts meeting increasing customer demands, it is imperative that proper washing and rinsing of parts be accomplished. Your local cleaner representative can help you identify improvements to your process.

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COMPANY
PROFILE

Felsomat-USA

Beginning in 1981 with engineered pick-and-place type automation, Felsomat has evolved to providing a modular, turnkey automated system for the manufacture of helical bevel gears. (Images courtesy: Felsomat)

With a history of engineering ingenuity and manufacturing innovation, Felsomat has become a world leader in automated gear manufacturing.

By Kenneth Carter | Editor | Gear Solutions

FELSOMAT'S MISSION STATEMENT, "BETTER products with intelligent solutions," has guided the company to being a world leader in the automated manufacturing of transmission gears. Beginning in 1981 with engineered pick-and-place type automation, Felsomat has evolved to providing a modular, turnkey automated system for the manufacture of helical bevel gears.

"From its inception, management has always sought to develop engineered solutions for optimum speed and cost efficiencies," said Blake Consdorf, president and CEO. "They continually seek to understand the customers' primary manufacturing challenge and address it with value-added machine tools and automation."

Richard Gilchrist, Felsomat-USA chairman, echoed that innovation continues to be the key to the company's almost four decades of success.

"I think that's a theme that runs throughout the company," he said. "And in fact, internally we say that Felsomat is powered by innovation. Very innovative thinking is what we do."

EXPANSION BEGINS

In the last decade, innovation at Felsomat has ramped up a steep curve.

"Up until about 2005, Felsomat was really what we'd call an automation company," Consdorf said. "But in 2005, our expanded product offering also included its first machine tool — a flexible turning machine. In 2007, we continued to expand and introduced the first hobbing machine, migrating Felsomat from being only a robotics company into a machine tool builder with a solution for automated gear production including tooling and fixturing. This move positioned Felsomat to expand into our Flexline automated system."

MODULAR LINE

The 2010 acquisition of Felsomat by Reischauer spurred the advancement of Felsomat's Flexline concept.

Consdorf said Reishauer is recognized worldwide for hard-gear finishing, typically the last process in the gear-manufacturing process. This led Felsomat to re-think all the required processes in front of that and engineering the Flexline system that takes a blank all the way through to a finished gear.

According to Gilchrist, the Flexline is ideal for addressing the changing market conditions facing today's major automobile manufactures.

"Years ago, automotive companies would have dedicated manufacturing lines," he said. "Advances in transmissions and the required gears were nominal so that these lines were rarely outdated."

Today, with all the variations on engines and transmissions, manufacturers can use the same equipment, but it requires continued change-over to meet the expanding transmission demands for greater on-road performance and fuel efficiency, according to Gilchrist.

The innovative design of the Flexline focuses on improved cycle times throughout the entire process.

Consdorf said Flexline's modular concept incorporates stand-alone machines for turning, hobbing, welding, honing, and then finishing with Reishauer gear grinding, all connected by Felsomat's automation expertise. All Flexline components include some innovative work-handling technology. Grippers and fixtures on the machines feature trigger-operated quick-change devices without requiring the use of wrenches or special tools. The resulting part changeover requires only seconds.

WIDE RANGE OF PRODUCTS

The Flexline begins with its FTC module configured in either single or dual spindles for green, hard turning. Initial cutting time of the blank is reduced with chip-to-chip cycles being some of the fastest in the industry. The turned blanks are transferred to the hobbing machines. This multi-process technology eliminates the need for additional machines by combining both roughing and finishing of the gear profile as well as the chamfering and deburring of the tooth flanks. Next, with the integration of the assembly and laser-welding in the manufacturing process, all radial or axial welding processes for idler gears are done in-line.

A Felsomat turning machine.

The Felsomat Flexline.

Integrating the heat-treating process into the chip cutting provides the continuous flow production. With the in-line unit, the work pieces are placed in single layers on the heat-treatment racks, eliminating the usual high volume, off-line batches of a conventional process. The result is fast and consistent heat treatment in all process steps, which guarantees a repeatable result at the lowest distortion possible.

After the heat treatment, all functional surfaces of the gear, including tooth flanks, require a fine finishing to achieve the optimum functionality of the work piece. Once again, a dual spindle turning unit enables rapid machining time in tandem with the load and unload function. The final step features the continuous generating gear grinding process of a Reishauer RZ160. This dual spindle unit, again, results in rapid cycle times while achieving optimum precision of the finished gear.

The other key benefit Felsomat offers with the Flexline concept is a true understanding of the manufacturing process from start to finish. In addition to providing the machine tools and automation, Felsomat also de-couples all of the machining processes, which leads to higher efficiencies, lower costs, and planned maintenance and down time.

The Flexline also delivers an extremely small footprint compared to using stand-alone or machine cells typically required to perform all these diverse processes. The inherent benefits to gear manufacturers is less square footage required for new plant development as well as reduced labor, energy, and consumable expense.

"The total cost of ownership compared to other options is something we stress and put forward as a unique major benefit for companies considering Flexline," Consdorf said.

A FOCUS ON CUSTOMERS

Consdorf said Felsomat's approach to customers was far more than merely transactional.

"By selling a complete manufacturing solution as opposed to simply a machine tool, we focus on all the factors that might impact a customer's ability to produce gears efficiently and profitably," he said.

Gilchrist added that sometimes a customer might be thinking of a system based on what they have already experienced.

"Our job is often to get potential customers to think out of the box," he said. "Part of Felsomat's innovation requires them to rethink what they may already know about gear production. That's not always easy, but when they hit an 'ah-ha' moment, we can roll up our sleeves and really start showing them how we can make a difference in their future operation."

"I know it's often over used, but we make a concerted effort to be a partner to our customers," Consdorf said. "When they allow us to transcend being just a machine tool vendor and allow us to provide consultative input based on their individual requirements combined with what we've seen from our installed base, we can make a real contribution to their bottom line."

FUTURE ENDEAVORS

With machines in North America, Europe and Asia, the numbers show Felsomat's outside-the-box thinking is working.

"In total, we've got over 7,500 automation cells in production worldwide today," Consdorf said. "We have 500-plus turning machines and 350-plus hobbing machines. And now with the innovation of the flexible laser welding system and our relationship with Reishauer, we have nearly 50 cells in production worldwide."

While the Flexline has enabled Felsomat to approach the big automotive companies such as Ford, GM, and Chrysler with the ability to not only automate their processes, but machine gears from start to finish in a modular line, Consdorf and Gilchrist said they are looking to the future. They cited the rapid advancement to electric cars and self-driving vehicles as an area of opportunity. Outside of the gear industry, Felsomat has started to manufacture crankshafts, camshafts, and valve bodies, while exploring other high-volume markets where Felsomat innovations can provide manufacturers with significant competitive advantages.

FOR MORE INFORMATION: www.felsomat.de

Detailed information about the process and load directly on the operating unit. (Images courtesy: Klingelnberg GmbH)

Harnessing Drive Data for Smart Process Design

Graphical support for process optimization in bevel gear cutting leads to increased machine performance and longer cutting tool life.

By Dipl.-Ing. Karl-Martin Ribbeck

OPTIMAL INTERPLAY BETWEEN INNOVATIVE GEAR cutting tools and powerful bevel gear cutting machines results in highly productive cutting processes with extremely high, reproducible gear quality. According to Klingelnberg, the gear cutting process itself can be seen as the link between the two elements.

Increased competition and the pressure that goes along with it — particularly in the automotive industry — call for new and cost-effective production processes to meet growing quality requirements. This also affects the machining of bevel gear teeth to a significant degree, which is why it is essential to exploit the full potential of all components involved in the process: The key is to utilize the machine performance and the tools that are used to their full potential, thereby reducing the cycle time.

Bevel gear cutting is characterized by continuously varying cutting conditions, meaning that "simple" feed regulation-based spindle utilization alone, and without sufficient analysis or knowledge of the process sequences, is far from optimal. Thanks to the ongoing development of the Klingelnberg machine operating software, users can now gain insights into the process sequence. The company's Smart Process Control software module allows technicians to plot the machine utilization and allocate it to the respective process sequences in an initial step. In a second step, the machine response to process changes can be precisely analyzed and tracked. This creates a new basis on which to enable highly productive gear-cutting processes.

PROCESS CHALLENGES

Criteria that make for an optimal bevel gear tooth cutting process:

- The component quality corresponds exactly to the requirements.
- Machining time is minimized.
- The gear cutting tool can be used for as long as possible.
- Primary benefits include reduced machine and tool costs.

This is a very simple checklist at first glance. However, when it comes to streamlining the bevel gear cutting process, conflicts arise between the objective and the technical implementation. Anyone wishing to improve the process has two objectives clearly in mind: higher productivity and improved process reliability aimed at meeting the strict requirements for geometric component accuracy (pitch and topography) in a reproducible and reliable manner without compromising the surface quality of the tooth flank, which acts as a measurement surface. This elevated productivity requires an increase in the machining parameters, though, and this is exactly where the conflict lies, since increased machining parameters have a tendency to worsen the wear behavior of the tools. This in turn heightens the risk of damaging the flank surface due to surface defects such as scratches or even welding marks — scenarios that must be avoided at all costs.

PROCESS DESIGN LIMITS

The options for optimizing a bevel gear cutting process are limited by various factors, the first being the component type and the different process characteristics associated with it. For non-generated components (ring gears only), it is the wear on the tool. For generated components (always pinions but often ring gears as well), it is often the formation of surface defects that sets the limit. The bevel gear cutting machine, on the other hand, usually plays a subordinate role.

TECHNICAL SUPPORT

The control units in modern CNC machines allow the precise recording of signals. This makes it possible to collect and store various types of information at any given point in a process. The technician's task is to identify which key criteria should be used to define a process as optimal. Whereas the "machining time" criterion is easy to read off at the end of the process, the "flank surface damage due to surface defects" criterion is more difficult to assess and evaluate. This is because the wear on a tool changes throughout its service life, and material batch influences also play a part. The most difficult criterion to evaluate is tool load and the resulting cutting edge wear.

Contrary to many other machining processes, the contact situation of the tool cutting edges changes continually during the process sequence in the bevel gear cutting process. The load on the cutting machine also varies accordingly. The special feature of this process is that the resulting tool wear that occurs varies in appearance along the entire cutting edge because of the local loads. If a technician wishes to use information from the machine control unit as a basis for evaluating local tool wear, the only way to do this is by taking into account the cutting edge length involved in the cutting process.

MAXIMIZING PERFORMANCE

Recording the utilization of the tool spindle helps with optimization as well as the monitoring of the process sequences. In bevel gear machining, the processes are defined by

interpolation points from the working position and feed rate. Varying these parameters brings about a change to the tool spindle utilization. The Klingelnberg Smart Process Control software, which is directly available to the user on the machine, makes it possible to carry out precise visualization of the machine load for every machining situation. The process sequence can therefore be assessed and easily understood at a glance. Following a short training session provided by an experienced company technician, machine users will then be able to analyze and subsequently optimize their processes independently using the control. Automatic real-time logging of the spindle utilization (for a meaningful number of workpieces) enables continuous process monitoring over a freely definable time period. The data documented during this time can easily be evaluated using the usual Microsoft Office programs. This long-term monitoring makes it possible to work out the impact of changes to the process.

Long-term monitoring can also be used to identify material irregularities or changes to the wear characteristics of the tool.

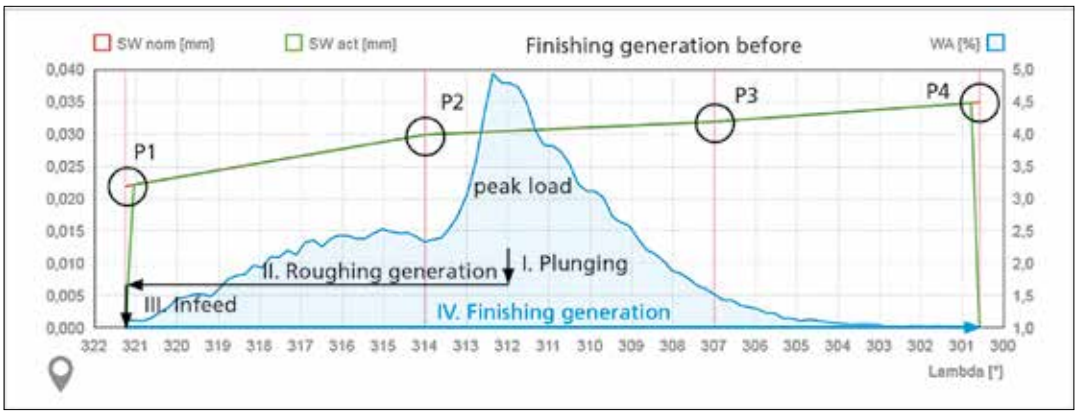

Figure 1: Tool utilization curve before optimization (blue), finishing-generation process.

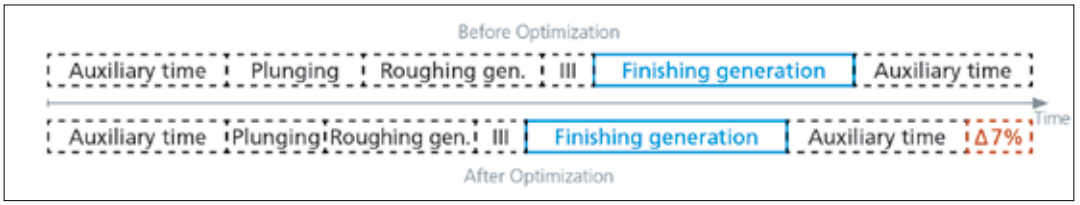

Figure 2: Processing time.

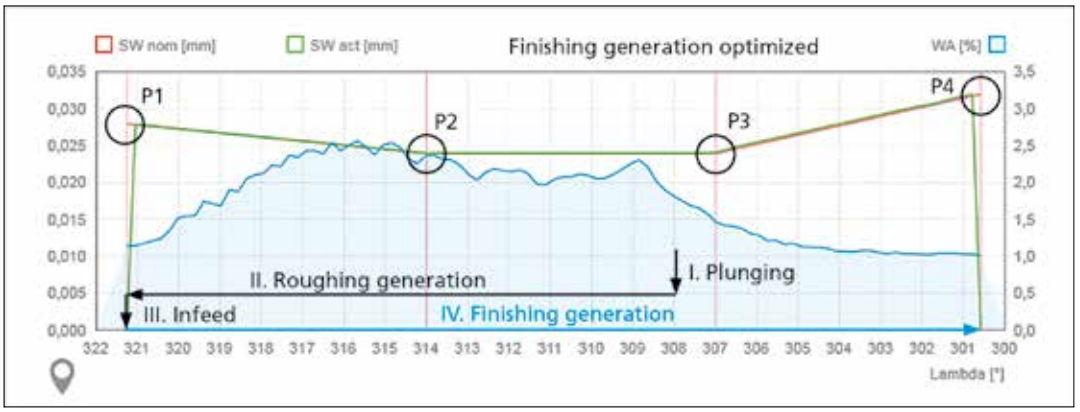

Figure 3: Tool utilization curve after optimization (blue), finishing-generation process.

PRACTICAL APPLICATION

Bevel gear teeth are typically manufactured in a multiple-step process. For most components, the tooth profile is generated by means of a rolling motion of the gear cutting machine. After the initial plunging process and subsequent roughing-generating, finishing-generating is the final step in the bevel gear tooth cutting process. Figure 1 shows the plotted utilization curve (in blue) of the tool spindle used in this type of finishing-generating process. Since the example deals with a gear set that obtains its final quality by means of lapping after heat treatment, the main focus during machining is on component accuracy. The process to be optimized (see Figure 1) starts with a plunging operation (I) at a lambda working position of approximately 312°. Once the tool has reached its working depth, it generates an initial area of the tooth flank (roughing-generating, II from lambda 312° to 321°). After a short infeed (III), the gear teeth are finish-generated at the tool utilization shown (WA [%]). The tool starts the finishing-generating (IV) at a lambda generating angle of 321° and stops at a lambda generating angle of approximately 301°. When doing so, it passes through the roughing-generated area. The load increase (or load surge) around the 312° generating angle is clearly visible. This is the result of the transition from the roughing-generated area to the non-generated area.

A measurement of the component under observation showed abnormalities in the flank topography that were exactly in the vicinity of the load increase, i.e. at 312°. Based on this information, the technician is able to identify the need for process modification. As a modification, the working position of the plunging operation was moved from lambda 312° to lambda 308° to enlarge the roughing-generating area. An adjustment was also made at interpolation points P1 to P4 by entering suitable chip thicknesses (SW [mm]). The result is spindle utilization that is significantly more uniform during finishing generation, without a local load increase around the plunging position lambda 308° and with a normal flank topography. On this basis, it is now possible to raise the uniform load level by shifting the interpolation points P1 to P4 at the same time, thereby achieving a shorter machining time.

The use of the Klingelnberg Smart Process Control also makes it possible to increase the feed rates for the plunging and roughing-generating area in a controlled way. In total, a 7-percent reduction in productive time was achieved in this example process, as illustrated in Figure 2.

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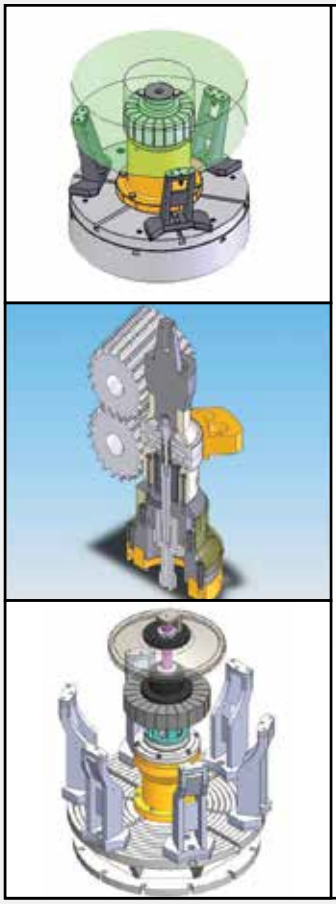

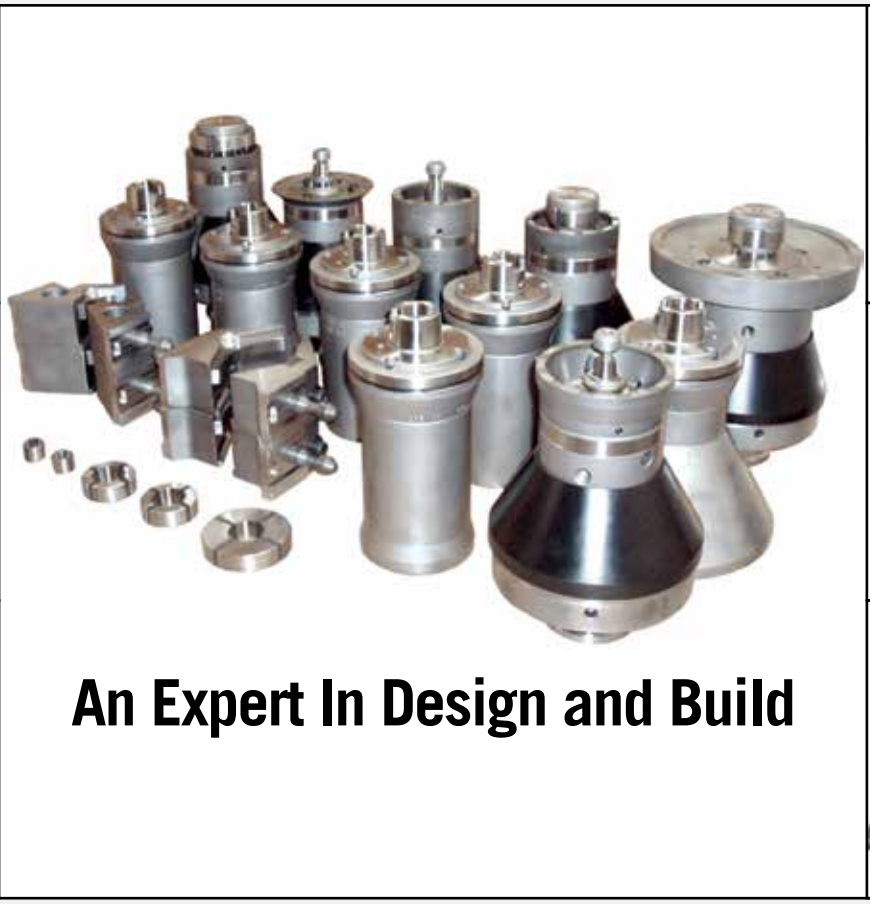

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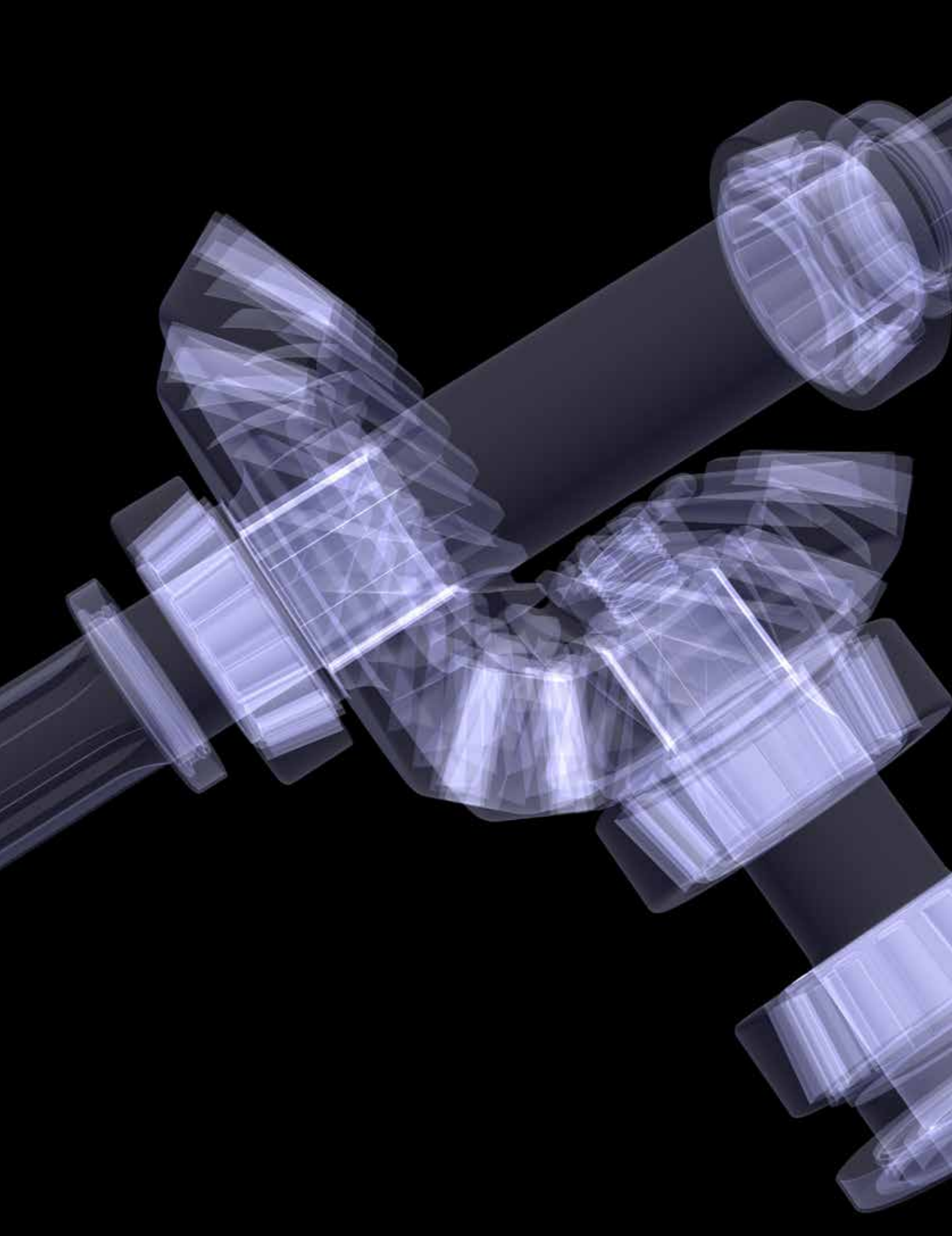

AGMA/ANSI/ISO Standards on Bevel and Hypoid Gears

An examination of how standards for bevel and hypoid gearing benefit from the latest achievements in gearing theory.

By Stephen P. Radzevich, Ph.D., Dr. (Eng.) Sci.

THIS PAPER DEALS WITH GEARINGS THAT operate (a) on intersected shafts and (b) on crossed shafts. The gearings that operate on intersected shafts are referred to as "intersected-axes gearings," or just "I_a–gearings" for simplicity. Similarly, the gearings that operate on crossed shafts are referred to as "crossed-axes gearings," also referred to as "C_a–gearings[1]." Hypoid, spiroid, and a few other gear systems are covered by the terms "crossed-axes gearings."

INTRODUCTION

The main goal of the paper is to show how the ANSI/AGMA/ISO standards for bevel and hypoid gearing; that is, [1], [2], [3], [4], and others can be benefited by the latest achievements in the theory of gearing[2] [5]. All the standards, including but not limited to ANSI/AGMA/ISO standards, must provide a user with a complete and consistent information on the subject. Often, unfortunately, this is not observed.

As an example, the principal features of the determination and inspection of the design parameters of a gear and a mating pinion that directly affect the gear mesh efficiency are considered in this paper. In particular: (a) the geometrical dimensioning and tolerancing; (b) the contact pattern; (c) the mounting distance, and (d) the backlash in I_a–gearing, as well as in C_a–gearing, are discussed as examples.

As is well known, the "kinematics" and the "geometry" of a gear and a mating pinion tooth flanks are investigated in the theory of gearing. Therefore, only the kinematics of a gear pair and the geometry of the gear and the mating pinion tooth flanks are covered in this paper. However, it should be noted that use of the approach developed in the theory of gearing enables one to solve numerous problems in the field of gear dynamics, transmitted power density, noise excitation and vibration generation in a gear pair, calculating of the tolerances for the design parameters of a gear pair, and so forth.

It is shown that the theory of gearing could be a powerful tool to improve ANSI/AGMA/ISO standards [1], [2], [3], [4], and others. Some inconsistencies in ANSI/AGMA/ISO standards are discussed as the examples. The geometrical dimensioning and tolerancing, the contact pattern, the mounting distance, and the backlash are among them. A more detailed discussion of these issues would take a far lengthier paper. It makes sense to begin the discussion on bevel and hypoid gearing with an analysis of the recommended [1], [2], [3], [4], geometrical dimensioning.

GEOMETRICAL DIMENSIONING

The set of the geometrical dimensions recommended for bevel gearing by ANSI/AGMA/ISO standards ([1] in particular), is shown in Figure 1. All the geometrical dimensions shown in Figure 1, and those not shown here, can be subdivided into two groups; that is, the geometrical dimensions that directly affect the conditions of the gear teeth engagement, and those indirectly affected by the conditions of the gear teeth engagement. Let's take a brief look at the terminology and geometrical dimensioning recommended by ANSI/AGMA/ISO standards ([1] in particular).

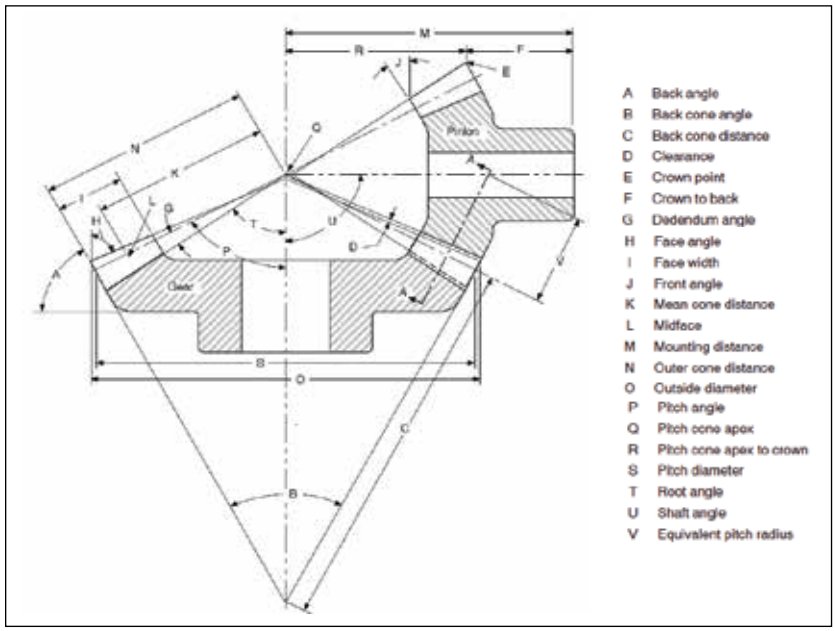

Figure 1: A set of the geometrical dimensions for bevel and hypoid gearings recommended by ANSI/AGMA 2005-D03 standard [1].

The set of the recommended geometrical dimensions[3] illustrated in Figure 1 is far from being aligned with the best practice for national and international standards on design dimensioning. An excessive plurality of datum surfaces (and sometimes the physical absence of the datum surfaces) is the main reason for that.

For example, the back cone and the back face are used as the datum surfaces for the specification of the back angle, *A*. The back cone angle, *B*, is specified as the apex angle of the back cone. The back cone distance, *C*, is specified as a distance between the back cone apex (the back cone apex physically does not exist) and the pitch cone that physically also does not exist, and so forth.

Importance (and usefulness) of the items such as the crown point, *E*, is at least doubtful, as this datum element of poor quality. The geometrical dimension shown in Figure 1 and labeled as *M* is not a mounting distance at all, as the mounting distance cannot be specified in terms of the location of point *M* outside of the gear tooth flank (see following section on Contact Patterning).

An alternative set of the geometrical dimensions is illustrated in Figure 2. This set of geometrical dimensions is sufficient for both the gear production as well as for the gear inspection. The gear common reference surface and the gear bore are used as the main set of datum surfaces for the gear. Similarly, the pinion common reference surface and the pinion bore are used as the main set of datum surfaces for the pinion[4]. All the geometrical dimensions that directly affect the condition of meshing are required to be specified with respect to the corresponding set of the main datum. The rest of the design parameters are also to be associated with the corresponding set of the main datum. Because of this, the geometrical dimensioning of a bevel gear pair in Figure 2 are advantageous over those in Figure 1.

Again, an excessive plurality of datum surfaces (and sometimes the physical absence of the datum surfaces) have to be eliminated in all possible ways. In the best-case scenario, only main sets of the datum surfaces of a gear and a mating pinion are used to specify all the geometrical dimensions of a gear, of a pinion, and of the gear pair.

Next, ANSI/AGMA/ISO standards ([1] in particular) refers to the so-called "mean section" as illustrated in Figure 3. Bevel and hypoid gearings only of poor quality can be analyzed in the mean section. Moreover, many of the design parameters — such as the (a) addendum, (b) dedendum, (c) circular pitch, (d) circular thickness, (e) clearance, (f) whole depth, (g) backlash, and (h) working depth — are considered as linear dimensions [1]. All of these design parameters are angular values in nature [5]. The common vertex of all of these angles coincides with the base cone apex of the gear (of the mating pinion) [5]. The angular design parameters (a), (b), (e), (f), and (h) are specified in a section of a gear or a pinion by a plane through the centerline. The angular design parameters (c) and (d) are specified in the pitch plane, *PP*, of a gear pair. Finally, the angular design parameter (g) — that is, the backlash — is specified within the pitch plane, *PP*, of a gear pair.

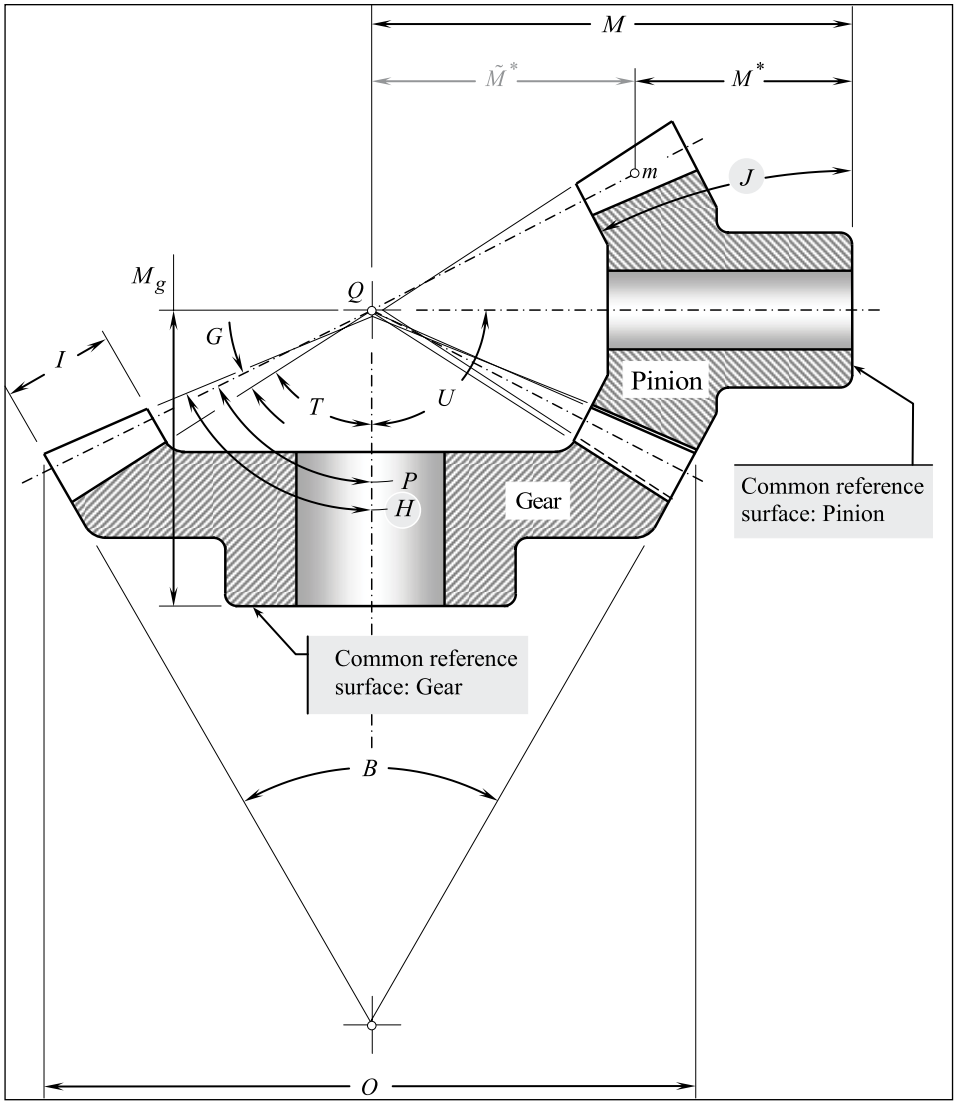

Figure 2: An alternative set of the geometrical dimensions for bevel and hypoid gearings.

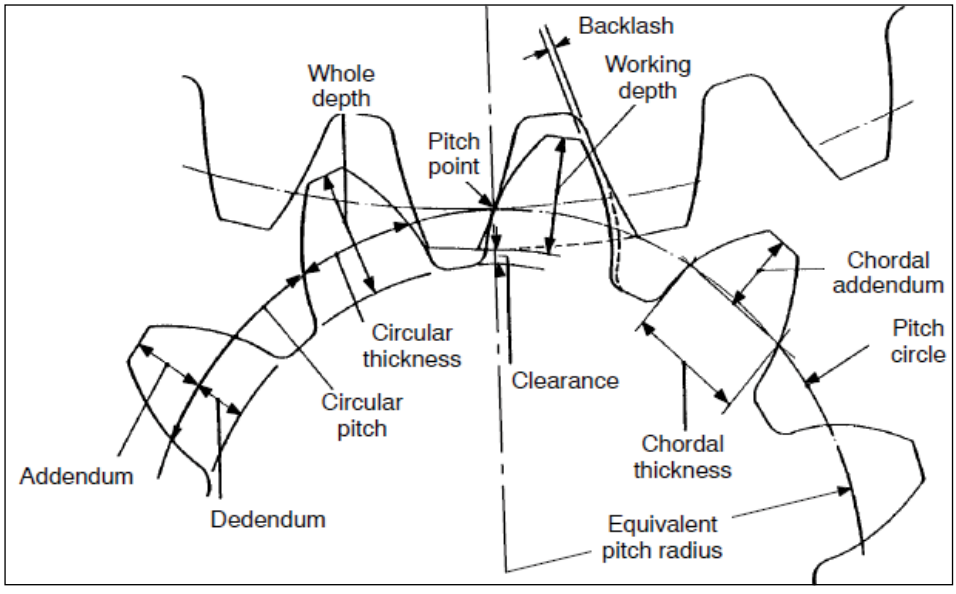

Figure 3: Bevel gear nomenclature in the mean section of Figure 1.

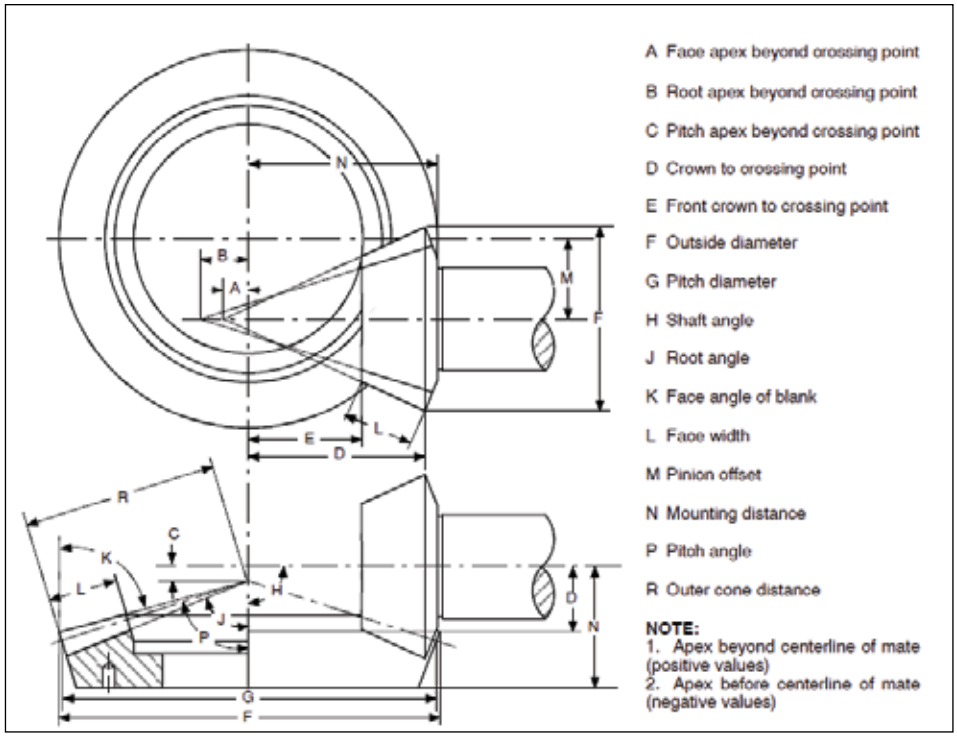

Figure 4: Hypoid nomenclature as recommended by ANSI/AGMA 2005-D03 standards [1].

Other design parameters of a bevel/hypoid gear, such as (i) chordal addendum and (ii) chordal thickness, also need to be construed as the corresponding "angular" design parameters having the gear/pinion vertex as the common vertex [5]. It is wrong practice to try to express the design parameters of a bevel/hypoid gear in terms of "pitch circle" and "equivalent radius." All correctly engineered bevel and hypoid gearings need being considered only in 3D space, and not in equivalent plane sections as in [5].

Finally, not the "pitch point" but the "pitch line" (or the "axis of instant rotation, P_{ln}" — preferred), instead has to be considered in all I_a–gearings, as well as in all C_a–gearings [5]. In C_a–gearings (Figure 4), the design parameters of a gear, of a mating pinion, and of a gear pair fall in three groups.

The design parameters of a gear pair that directly affect the conditions of meshing of the interacting tooth flanks of a gear and of a pinion. They are as follows: the shaft angle, *H*; the pinion offset, *M*; the mounting distance, *N*; and the pitch angle, *P* [5]. The actual values of the tolerances for all of these design parameters of a gear pair must be very tight. All of them have to be calculated (and not just set) in terms of permissible variation in shape, size, and configuration of the desirable contact pattern. It should be stressed here that the pitch cone angle, *P*, can be expressed in terms of shaft angle, *H;* pinion offset, *M*; and gear ratio of the gear pair.

The design parameters of a gear pair that directly do not affect the conditions of meshing of the interacting tooth flanks of a gear and of a pinion. They are as follows: the face apex beyond crossing point, *A* ; the root apex beyond crossing point, *B*; the crown to crossing point, *D*; the front crown to crossing point, *E*; the outside diameter, *F* ; the pitch diameter, *G*; the root angle, *J*; the face angle of blank, *K*; the face width, *L*; and the outer cone distance, *R*. The tolerances for all of these design parameters of a gear pair are not as tight as for the first group of design parameters of a gear pair.

The incorrect design parameters of a gear pair. This is the "pitch apex beyond crossing point, *C*." In correctly engineered C_a–gearings this distance must be of a zero value [5].

The set of the design parameters of a C_a gear pair shown in Figure 4 also can be "cleaned up" similar to that in Figures 1 and 2. No numerical values for geometrical tolerances are recommended by ANSI/AGMA/ISO standards for the design parameters of a gear, a pinion, and the entire gear pair; those directly affect conditions of meshing of the gear and the pinion. The discussion on geometrical dimensioning and tolerancing of bevel and hypoid gearings is briefly summarized here:

The geometrical dimensioning of a bevel gear pair shown in Figure 1 is inconsistent as the principle of common datum surfaces is violated; that is, too many datum surfaces are used in Figure 1.

The geometrical dimensioning of that same gear pair proposed in Figure 2 strictly follows the principle of common datum surfaces — the bore and the common reference surface in a gear (as well as in a pinion) are used for the purposes of geometrical dimensioning of the gear pair.

The geometrical dimension labeled as *M* shown in Figure 1 is not a mounting distance at all.

It is of critical importance to stress here that the base pitch, which is a design parameter No. 1 in gearings of all types, is missed in ANSI/AGMA/ISO standards for bevel and hypoid gearing. Neither base pitch of a bevel/hypoid gear, $\phi_{b.g}$, nor base pitch of its mating pinion, $\phi_{b.p}$, nor the operating base pitch, $\phi_{b.op}$, of a gear pair are specified by ANSI/AGMA/ISO standards. Equality of the angular base pitches $\phi_{b.g} = \phi_{b.op}$ and $\phi_{b.p} = \phi_{b.op}$ is vital for: (a) the reduction of noise excitation; (b) the reduction of vibration generation; (c) an increase of power density, and so forth [7], [8], [9], [10], [11], [12], [13]. This considerable mistake in ANSI/AGMA/ISO standards for bevel and hypoid gearing needs to be fixed (the sooner, the better).

A more detailed discussion on geometrical dimensioning and tolerancing of bevel and hypoid gearings is desirable, aiming at the elimination of all possible inconsistencies. Correct dimensioning and tolerancing is a "must" in the design and production of high quality bevel and hypoid gears.

Conclusion: In intersected-axes, as well as in crossed-axes gearings, drawings for a gear, for a mating pinion, and for a gear pair must be properly dimensioned. The principle of common reference surfaces is a must to follow when dimensioning the components of a gear pair. Out-of-date terms and corresponding dimensions must be eliminated from the drawings.

CONTACT PATTERN

Bevel and hypoid gears have to be assembled in a specific way to ensure smooth running and a favorable load distribution between gears. To attain this goal, a contact pattern between the interacting tooth flanks of a gear and a mating pinion is commonly used.

The contact pattern is a critical attribute of any and all bevel/hypoid gear design (Figure 5). Simply stated, the contact pattern is the area in which the gear teeth come in contact as they engage and disengage during their rotation. When a gear is installed in a gearbox and is powering the designated application, there are varying degrees of pressure, or load, on the gear teeth. These pressures are influenced by box deflections, bearing movement and temperature changes. When the gear teeth are subjected to these variables, the contact pattern will change. There is a general rule of thumb stating that the heavier the load, the larger the contact pattern and vice versa. For a gear to perform properly under operating load, the contact pattern must be of a certain shape and at a certain location. Typically, an ideal tooth contact pattern under load should encompass the bulk of the tooth surface while avoiding any contact with the edges of the tooth flank. So far, the contact pattern is more a "qualitative" than a "quantitative" indicator of gear pair quality.

The permissible variation in contact pattern location, orientation, and shape, can be used to calculate the tolerances for design parameters of a gear pair[5]. Unfortunately, in contemporary gear practice, contact pattern is a qualitative, and not quantitative, measure of the gear pair quality.

The discussion on contact pattern in bevel and hypoid gearings is briefly summarized as follows:

Figure 5: An example of acceptable shape and configuration of contact pattern under a low load.

- The contact pattern cannot be measured similar to that (and with a corresponding accuracy) as other design parameters of a gear are measured, for example, as a bore diameter, a face width, a face angle, and so forth.
- The measurements of the contact pattern are not reliable.
- The actual misalignment in bevel/hypoid gearing cannot be expressed in terms of the actual geometry and configuration of the contact pattern.
- Efforts of the gear experts must be focused toward searching possible ways to express the bevel/hypoid gears misalignment in terms of geometry, size, and configuration of the contact pattern.

Instead of the contact pattern analysis, the teeth flank geometry along with the actual value of the mounting distance should be measured. No contact pattern analysis is necessary if a bevel/hypoid gear is machined and assembled according to the properly designed blueprint. A more detailed discussion of the contact pattern in bevel and hypoid gearings is desirable.

Conclusion: This is an out-of-date practice to use contact pattern as a tool to improve the accuracy of gears for intersected-axes, and crossed-axes gear pairs. Instead, the teeth flanks geometry, and the mounting distance have to be properly specified and inspected. These can be done on the basis of a broader application of the results the theory of gearing returns. Use of the lapping process, pairing of bevel and hypoid gears, nowadays practice for the calculation of mounting distance, and tolerance for the mounting distance, reveal the lack of knowledge in the scientific theory of gearing.

MOUNTING DISTANCE

Mounting distance is a vital design parameter for intersected-axes gearings (that is, for bevel gearings), as well as for crossed-axes gearings (that is, hypoid, spiroid, double-enveloping worm gearings, and so forth). The specification, inspection, and tolerancing of the mounting distance is challenging to understand by practical gear engineers as this issue is insufficiently outlined in ANSI/AGMA/ISO standards. Numerous publications on the topic [14], [15], [16], [17],

and many others reveal this. At the beginning, let's clarify what the term "mounting distance" stands for.

First, and the most critical, by means of mounting distances the location of tooth flanks in axial direction of a gear and a mating pinion are specified in relation to the centerlines in the gear housing. Apex point of a tooth flank of both, of the gear, A_{fg}, and the pinion, A_{fp}, must coincide either with the point of intersection of the centerlines in the gear housing (for I_a-gearings), or with the "pitch plane"/"plane of action" apex (for C_a-gearings) [5]. The pitch plane apex is commonly designated as A_{pp}, and the plane of action apex is commonly designated as A_{pa}. These two conditions can be expressed as follows: $A_{fg} \equiv A_{pp} \equiv A_{pa}$ and $A_{fp} \equiv A_{pp} \equiv A_{pa}$

Second, the pitch cone apex of a gear, Ag, (and of a mating pinion, A_p) must coincide with the apex point of a tooth flank of both, of the gear, A_{fg}, and the pinion, A_{fp}. These two conditions can be expressed as follows: $A_g \equiv A_{fg}$ and $A_p \equiv A_{fp}$

Third, the base cone apex of a gear, A_{bg}, (and of a mating pinion, A_{bp}) must coincide with the apex point of a tooth flank of both, of the gear, A_{fg}, and the pinion, A_{fp}. These two conditions can be expressed as follows: $A_{bg} \equiv A_{fg}$ and $A_{bp} \equiv A_{fp}$.

Fourth, there are two outer cones. One of them is for the gear and another one is for the mating pinion. There are also two root cones. Again, one of them is for the gear and another one is for the mating pinion. Neither outer cones nor root cones directly affect the actual value of the mounting distance. However, these cones need to be mentioned here as in current practice outer cones are commonly used when determining the mounting distance.

In a precision gear pair, it is recommended to inspect the mounting distance at nominal operating load and the preloaded bearings.

The plurality of the apexes is confusing and results in misunderstanding of the terms "mounting distance" in acting ANSI/AGMA/ISO standards. To make things clear, it is necessary to outline to the best possible extent what the term "mounting distance" stands for. As an example, consider tooth flank of a straight bevel gear[6] as illustrated in Figure 6. The tooth flank of the gear, G, can be construed as a family of straight lines through each point of the gear tooth profile and the gear tooth flank apex, A_{fg} (the gear tooth flank apex, A_{fg}, is an equivalent to the gear base cone apex, A_{bg}). Only the gear tooth flank apex, A_{fg}, should

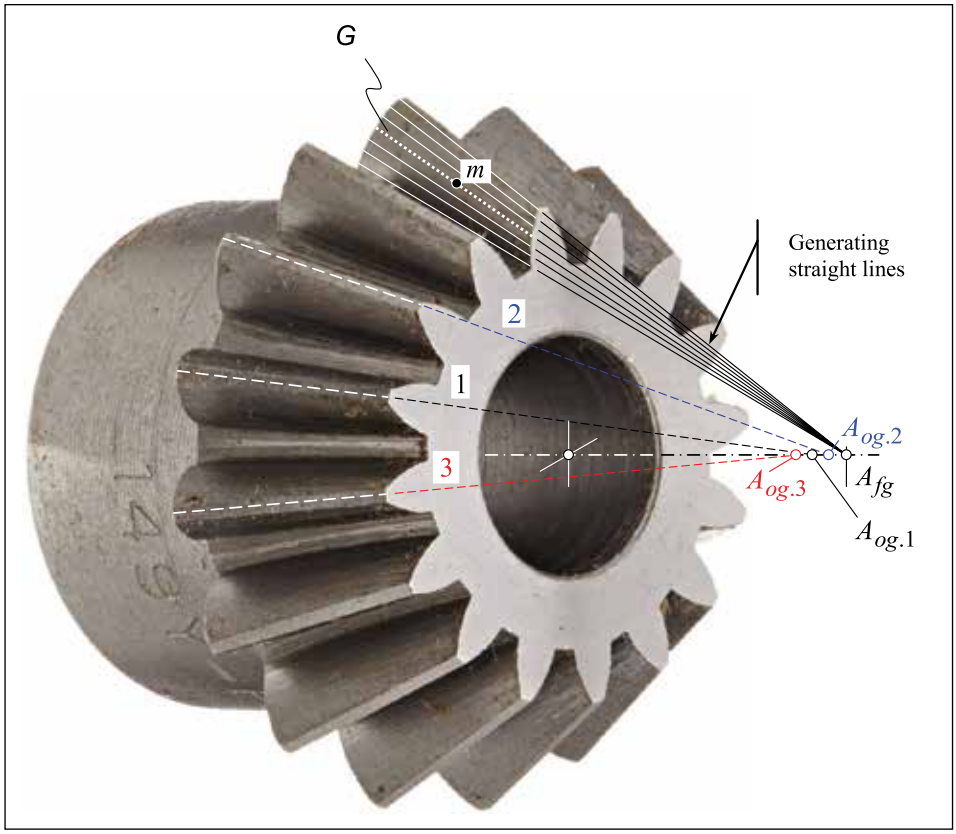

Figure 6: On the definition of the "tooth flank apex," A_{fg}, in intersected-axes and crossed-axes gearings.

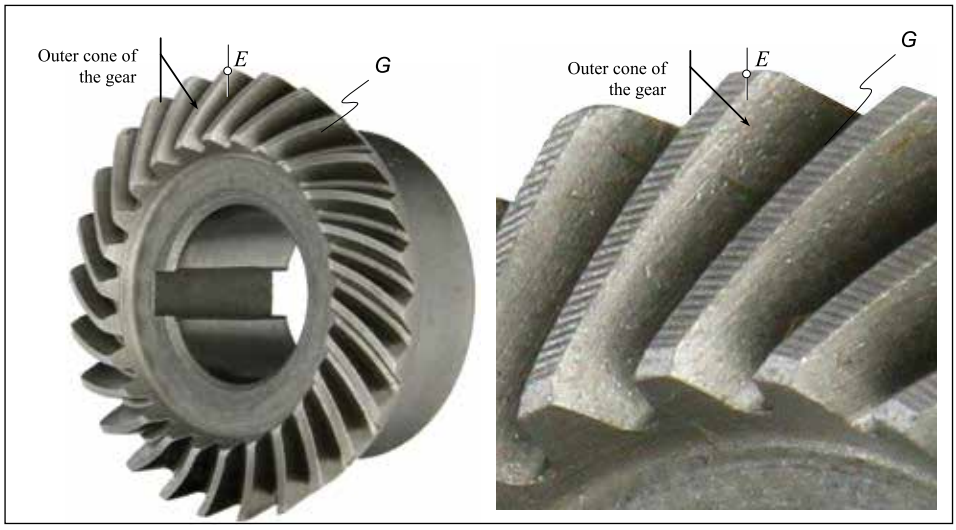

Figure 7: "Crown" in intersected-axes and crossed-axes gearings. Note on rough surface of the outer cone of the gear; this rough surface is used to specify the crown, *E*; that is, it is used to specify the crown to back, *F*, and ultimately the mounting distance, *M*.

be used for the specification and inspection of the mounting distance, *M*. Commonly, the outer cone apex of the gear, $A_{og}.1$, is inward in relation to the gear tooth flank apex, A_{fg}, as shown for the straight generating line 1 in Figure 6. However, this is not a must as the gear outer cone apex, $A_{og}.2$, can be located either outward, or the gear outer cone apex, $A_{og}.3$, can be located inward in relation to the apex $A_{og}.1$, as it is illustrated in Figure 6 for the straight generating lines 2 and 3 of the outer cone of the gear. The actual location of the gear outer cone apex (either $A_{og}.1$, or $A_{og}.2$, or $A_{og}.3$) does not affect the conditions of meshing of the gear, G, and the pinion, P, tooth flanks. The conditions of meshing of the gear, G, and the pinion, P, tooth flanks depend only of the actual location of the gear/pinion tooth flanks apex, A_{fg}. Therefore, the tolerance for the mounting distance (the mounting distance is measured in relation to the gear tooth flank apex, A_{fg}) is tight, while the configuration of the apex of the outer cone of the gear, A_{og}, is a free dimension with no specified tolerance.

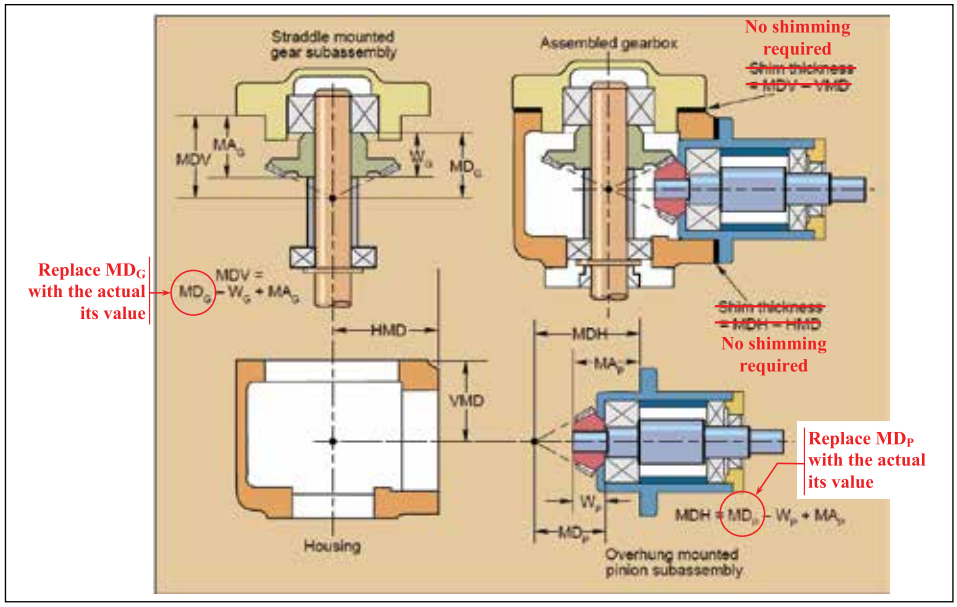

Figure 8: Measurements recommended in [15] for mounting both overhung and straddle-mounted bevel gears in a typical gearbox.

Depending on the accuracy of the set up parameters when cutting straight bevel gears, the axial position of the tooth flank, G, can be changed. After being assembled, the gear tooth flank apex, A_{fg}, must be coincident with the centerlines in the gearbox housing. Therefore, the mounting distance of a gear is the distance from the gear tooth flank apex, A_{fg}, to the common reference surface of the gear. A similar definition is valid with respect to the mounting distance of a pinion. In reality, as it is recommended by ANSI/AGMA/ISO standards, the mounting distance is specified differently from the preceding.

As it is shown in Figure 2, two dimensions — that is, the crown to back, *F*, and the pitch cone apex to crown, *R* — are used to specify the mounting distance, *M*. The crown is used to specify both the dimensions. It is right to point out here that a crown is not a reliable datum for the inspection of the mounting distance. Taking into account that tolerance for the mounting distance is very tight, it is nonsense to use the crown for precision measurements. This is the first issue that makes the crown inappropriate datum for such an inspection.

Then, the crown is not geometrically associated with the gear tooth flank, G. An analysis of Figure 7 reveals that, depending on the accuracy of the set up parameters when machining straight bevel gears, the axial position of the tooth flank, G, and the gear tooth flank apex, A_{fg}, can be variable.

A bevel/hypoid gear tooth flank must be correctly specified in relation to the common reference surface. For this purpose an arbitrary point, *m*, either within the tooth flank or within extension of this surface can be used. The tooth flank apex, A_{fg} (Figure 6), is convenient to be used for this purpose. It is incorrect practice to use the wedge, *E*, and the dimension, *F* (Figure 7), to specify the mounting distance in bevel/hypoid gearing as shown in Figure 1.

With that said, it is the right point to proceed with a discussion of a nowadays practice to specify and inspect the mounting distance in intersected-axes, and in crossed-axes gearing. The current practice is outlined in [15] and is illustrated in Figure 8. The procedure for assembling the bevel gears in this gearbox by the measurement method is as follows [15]:

1. On the housing, measure the distance from locating surface to bore centerline in both horizontal and vertical directions (HMD and VMD).
2. Record the gear and pinion mounting distances (MDG and MDP);
3. Measure the gear and pinion thicknesses (WG and WP).
4. Assemble the gears into their subassemblies.
5. Measure the length that controls gear position in each subassembly (MAG and MAP).
6. Calculate the distance from shim mounting surface to crossing point for each subassembly (MDV and MDH): $MDV = MD_G - M_G + MA_G$ and $MDH = MD_P - M_P + MA_P$ correspondingly (Figure 8) [15].
7. Calculate the required shim thicknesses and assemble the gearbox with shims in place.

Items No. 1 through No. 5 are correct. In the item #6, when calculating the dimension MDV, the actual, MD_G^{actual}, and not the

nominal, MDG, value of the mounting distance must be entered into the equation for the calculating of MDV. Similarly, when calculating the dimension MDH, the actual, MD_P^{actual}, and not the nominal, MD_P, value of the mounting distance must be entered into the equation for the calculating of MDH.

Neither the dimension MD_G, nor the dimension MD_P can be measured as the gear tooth flank apex, A_{fg}, (as well as the pinion tooth flank apex, A_p) does not physically exist. The pitch cone apexes A_g, A_p, and base cone apexes A_{bg}, A_{bp}, also do not exist physically. Therefore, the use of the gear tooth flank, G, (and the pinion tooth flank, P) is the only possibility to measure the dimensions MD_G^{actual} and MD_P^{actual}. For this purpose, a method for inspection of the mounting distance in bevel and hypoid gearing is proposed by the author[7]. The proposed method of inspection is based on use of a ball of a pre-specified diameter in a space between two neighboring teeth of a gear to be inspected. A prescribed point of contact, m, (see Figure 3) is located reasonably close to the mid of the face-width gear, and to the line of intersection of the gear tooth flank by the pitch cone. It is assumed that the rest of the gear tooth flank deviations either are zero, or are known and can be incorporated in the procedure of the calculations.

For a specified point m within a gear tooth flank the dimension M^*_{actual} is measured. The measured distance M^*_{actual} is compared with its nominal value, M^*. In this way a decision can be made on whether or not the actual dimension M^*_{actual} is within the tolerance.

Item No. 7 is useless. No shimming is necessary if the gears are machined to properly calculated tolerances. It is no longer required to machine gears and pinions in sets, and gears and pinions can be assembled with no regards of the sets, that is, no gear pairing is required if the gears are machined to the correctly calculated tolerances. Therefore, if engineered properly, it is possible to manufacture all gears to the nominal mounting distance specified on the drawing with no additional cost. Under such a scenario, no pairing in bevel/hypoid gearing is required, and the gears can be engaged in a correct mesh with any bevel/hypoid pinion if both of them are correctly engineered and manufactured. Moreover, if one gear in a set fails, the entire set should not be replaced, but only the failed gear is required to be replaced.

Because of dimensional variations between parts, each gear will have a unique value for the mounting distance [16]. For the mounting distance, it is common to set a tolerance of ± 0.05 mm up to ± 0.1 mm [16]. For correctly engineered bevel and hypoid gears, the tolerance for mounting distance must not be set but, instead, it must be calculated and must be expressed in terms of the permissible variation in contact pattern location, orientation, and shape. No methods to calculate the tolerances for the mounting distance are available in the public domain. No methods to verify whether or not the actual errors for the mounting distance are within the corresponding tolerance are available in the public domain.

The discussion on mounting distance in I_a– and C_a–gearings in bevel and hypoid gearings is briefly summarized as follows:

In the current practice of bevel/hypoid gear production and application, there are no means to ensure whether or not the actual value of the mounting distance is within a specified tolerance for this dimension.

An actual geometry and configuration of the contact pattern is an evidence that the mounting distance is of a reasonable value, but no one can guarantee that the actual value of the mounting distance is not out the specified tolerance.

An incorrect mounting distance is not the only reason for a shift of the contact pattern. Even if the mounting distance is within the tolerance, an unfavorable contact pattern can be observed because of: (a) the deviations of the actual tooth flank geometry from it desirable geometry; (b) the gears are designed and cut as approximate gears (even ground bevel and hypoid gears are not perfect, that is, they are not geometrically accurate), and; (c) distortions after heat treatment (especially for a gear).

Direct measurements of the mounting distance[8] are necessary. This can be done, for example, by means of laser scanning of the machined tooth flank, and creating on premise of that a CAD model of the actual tooth flanks. Comparison of two CAD models, that is, of the desirable and of the actual tooth flanks returns an exact number of the mounting distance in a machined bevel/hypoid gear. Simpler methods and means for the direct inspection of the actual mounting distance in bevel/hypoid gearings can be proposed.

No reliable methods for the calculation of the tolerances for the mounting distance in bevel/hypoid gearings are known. This particular problem needs to be addressed. A more detailed discussion on mounting distance in I_a– and C_a–gearings in bevel and hypoid gearings follows:

Conclusion: Reliable methods to inspect the mounting distance can be developed on the premise of the results derived from the theory of gearing. A correct alignment (snapping of the base/pitch cone apexes in cases of I_a–gearings, and correct configuration of the base/pitch cone apexes in cases of C_a–gearings) depends on the mounting distance of both; that is, of a gear and its mating pinion. Therefore, shimming in/out of the gear/pinion is an obsolete practice. Tolerances for the mounting distance neither of a gear, nor of its mating pinion cannot be properly calculated/inspected in the contemporary production of gears.

BACKLASH

Bevel and hypoid gears are designed and manufactured to provide a specific amount of backlash. That is, the space between mating gear teeth or the difference in width of the gear tooth and pinion tooth of the mating gear to let the gears mesh without binding and to provide space for a film of lubricating oil between the teeth. This prevents overheating and tooth damage. The backlash is necessary for proper operation of the gear pair.

To optimize the performance of any two bevel gears, the gears must be positioned together so that they run smoothly without binding and/or excessive backlash. In the current practice of gear production, unless otherwise specified, the minimum amount of total backlash of a pair of

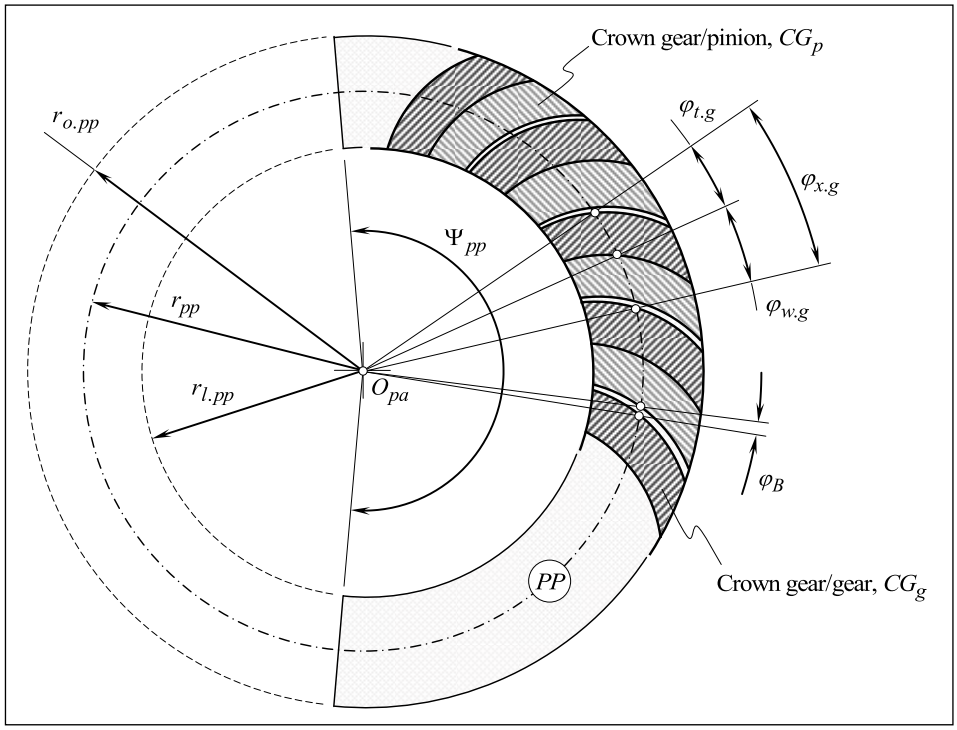

Figure 9: On definition of the: (a) "angular tooth thickness, ϕ_t," (b) "angular space width, ϕ_w," and (c) "angular backlash, ϕ_B," in intersected-axes gearing by means of CG_g-to-CG_p mesh. [Note: The interaction of the tooth flank of the gear, G, (not shown) and the tooth flank of the pinion, P, (not shown) occurs within the plane of action, *PA*, and not within the pitch plane, *PP*]. A similar schematic is valid for crossed-axes gearing as well.

bevel/hypoid gears is measured at the tightest point of mesh with a dial indicator on a bevel gear testing machine. Unless otherwise specified, backlash is assumed to be normal backlash[9] and cannot be measured in the plane of rotation. Backlash is necessary to achieve correct operation of the gears and varies with the size of the tooth and operating conditions. Bevel gears are cut to have a definite amount of backlash when correctly assembled together. But excessive backlash or play, if great enough, can cause a sudden impulse or shock load in starting or reversing that may cause serious tooth damage. Excessive or insufficient backlash can also result in noise, excessive wear, and damage.

Numerous inconsistencies are observed in the definition and interpretation of backlash in bevel and hypoid gearings. To avoid the above discussed inconsistencies in the definition of backlash in bevel and hypoid gearings, the backlash in bevel/hypoid gearing can be defined in the following manner.

Consider a phantom crown gear that is engaged in correct mesh with the gear. This crown gear can be referred to as a "crown gear/gear," or simply as CG_g. The outer diameter of the crown gear is labeled as $r_{o.pp}$, the inner diameter is labeled as $r_{l.pp}$, and the pitch diameter is labeled as r_{pp}. Face width, F_{pp}, of the crown gear is equal to $F_{pp} = r_{o.pp} - r_{l.pp}$. The central angle Ψ_{pp} spans over the active portion of the crown gear, CG_g. The axis of rotation of the crown gear, CG_g, is labeled as O_{pp}. Here, the subscript "pp" indicates that the parameters relate to the pitch plane, PP.

The angular tooth thickness, $\phi_{t.g}$, and the angular space width, $\phi_{w.g}$, in a gear is measured within the pitch plane, PP, of the crown gear/gear, CG_g, as shown in Figure 9 (a similar schematic is valid for crossed-axes gearing, as well). The angular pitch of the gear teeth in Figure 9 is labeled as $\phi_{x.g}$.

Similarly, consider a phantom crown gear that is engaged in correct mesh with the pinion. This crown gear can be referred to as a "crown gear/pinion," or simply as CG_p. The angular tooth thickness, $\phi_{t.p}$, and the angular space width, $\phi_{w.p}$, of a gear is measured within the pitch plane, PP, of the "crown gear/pinion, CG_p" (not shown in Figure 9). The angular pitch of the pinion teeth is labeled as $\phi_{x.p}$ (not shown in Figure 9).

The angular pitches of the gear, $\phi_{x.g}$, and the pinion, $\phi_{x.p}$, are equal; that is, the equality $\phi_{x.g} = \phi_{x.p} = \phi_x$. Therefore, the further designations for these angular pitches are replaced with ϕ_x.

When the crown gear, CG_g, and the crown gear, CG_p, are engaged in mesh, they are free to turn about the O_{pp}–axis in relation to one another through a certain angle, ϕ_B. The angle, ϕ_B, is referred to as the "angular backlash." The "angular backlash, ϕ_B," can be calculated as:

$$\phi_B = \phi_{w.g} - \phi_{t.p} \qquad \text{Equation 1}$$

or as:

$$\phi_B = \phi_{w.p} - \phi_{t.g} \qquad \text{Equation 2}$$

Novel instrumentation can be developed for the direct measurement of the design parameters in a gear ($\phi_{t.g}$,$\phi_{w.g}$, and $\phi_{x.g}$) and in a pinion ($\phi_{t.p}$,$\phi_{w.p}$, and $\phi_{x.p}$). Then either Equation 1 or Equation 2 can be used for the calculation of the angular backlash, ϕ_B.

In a bevel/hypoid gear pair the backlash is measured at a configuration of a gear and a pinion when "two pairs of teeth are engaged in mesh."

The discussion on backlash in I_a– and C_a–gearings in bevel and hypoid gearings is briefly summarized below:

- The existing practice to set and to inspect backlash in a bevel/hypoid gear pair is inconsistent.
- The angular backlash is a reliable design parameter of a bevel/hypoid gear pair.
- The angular backlash is measured within the plane of action in a gear pair (and not perpendicular to the gear teeth as it is recommended by ANSI/AGMA/ISO standards). It makes sense to specify the angular backlash as an angle within the pitch plane at a corresponding configuration of the gear and the pinion in relation to one another, and not as an angle through which the gear (the pinion) turns about its axis as values of these two angles are different: the angle for the gear is smaller compared to that for the pinion (gear ratio).

If the backlash does not fall within the recommended limits, no corrections to the mounting distance are allowed to adjust the backlash. If possible, the tooth thickness can be corrected (reduced) by additional machining. For strength calculations, the normal backlash can be expressed in terms of the backlash in the plane of rotation.

There is a trade-off when setting an actual value of backlash: The backlash must be large enough for operating of the gear pair, and it must be small enough when reversing the rotation. With the discussed approach, the contact ratio in bevel and hypoid gearing can be accurately calculated (spiral bevel, and others).

More details on the kinematics and the geometry of intersected-axis, and in crossed-axis gearing can be found in numerous recently published papers [7], [8], [9], [10], [11], [12], [13], and others.

Conclusion: Backlash in intersected-axes, and in crossed-axes gearing is an "angular" parameter, and not a "linear" parameter. Backlash is measured within the pitch plane of the gear pair. Appropriate methods of and means for inspection of the angular backlash can be developed on the premise of the developed theory of gearing [5].

SUMMARY

In a brief overview on the acting ANSI/AGMA/ISO standards for bevel and hypoid gearings, it is shown that the geometrical dimensioning in ANSI/AGMA/ISO standards differs from the best practice of part dimensioning and in most cases can be significantly improved. Violation of the principle of common datum surfaces is the root cause for that. An alternative geometrical dimensioning for a bevel gear pair is discussed. Base pitches of a gear, of a mating pinion, and the operating base pitches of a gear pair must be incorporated into the set of the design parameters for bevel and hypoid gearings.

Use of the contact pattern for the purpose of evaluation of bevel/hypoid gear performance is briefly discussed. It is illustrated that (a) the measurements of the contact pattern are not reliable and (b) the actual misalignment in bevel/hypoid gearing cannot be expressed in terms of the actual geometry and configuration of the contact pattern. Therefore, the efforts of gear experts must be focused toward searching possible ways to express the bevel/hypoid gears misalignment in terms of geometry, size, and configuration of the contact pattern.

It is shown that in current practice of bevel/hypoid gear production and application, there are no reliable means to ensure whether the actual value of the mounting distance is within a specified tolerance for this dimension. The commonly used design parameter referred to as the "mounting distance" is not the mounting distance at all. A method for the inspection of mounting distance in intersected-axes, and in crossed-axes gearings is necessary to be developed. Once the actual value of the mounting distance is known, and the gears are cut to the correctly calculated tolerances, then: (a) the gears no longer need to be produced in sets; (b) there is no necessity to replace the entire gear pair when one of the components of a gear pair is brakes; only the broken component can be replaced instead if the gears are correctly designed and properly manufactured; (c) no pairing is necessary, and (d) potentially, lapping process in manufacturing of precision bevel and hypoid gearings can be eliminated at all.

No reliable methods for the calculation of the tolerances for the mounting distance in bevel/hypoid gearings are known (in the public domain). This particular problem needs to be addressed.

It is demonstrated that the existing practice to set and to inspect backlash in a bevel/hypoid gear pair is inconsistent. It is proposed to use the "angular backlash" when designing bevel/hypoid gear pairs.

Ultimately, the discussed examples of inconsistencies in the acting ANSI/AGMA/ISO standards for bevel and hypoid gearings show that the latest accomplishments in the scientific theory of gearing need to be taken into account when revising the acting ANSI/AGMA/ISO standards for bevel and hypoid gearings.

FOOTNOTES:

1. C_a–gearings also include "worm gearings." However, worm gearings could be a subject of a separate article.
2. Per the author's observation, the current gear industry, both, the gear practitioners, as well as the gear researchers, do not value properly the accomplishments attained in the theory of gearing. The ignorance of the output from the theory of gearing is one of the root causes of insufficient gear quality, problems with the gear inspection, too-high costs of produced precision gearings, and so forth. No one has a chance to succeed with bevel, hypoid, and worm gearing having no correct knowledge of the gear kinematics and the gear geometry. Knowledge of the theory of gearing is a must for all gear experts involved in precision gear design and manufacture.
3. The similar recommendation are provided in Figure 2.7 on page 22, and in Figure 2.8 on page 23 in the recently published book by J. Klingelnberg [6].
4. It is worthy to stress here that the fewer the overall number of the datum surfaces, the higher the accuracy of the part machining can be attained, and vice versa.
5. In much, the contact pattern is a subjective (and not objective) parameter. Neither the dimensions and orientation, nor the tolerances for the dimensions and orientation of the contact pattern can be assigned (and be directly measured on the shop floor). The contact pattern is an insufficiently engineered parameter of quality of a gear pair. The contact pattern is not measurable; that is, it cannot be reliably measured by means that are commonly available on the shop floor. It is desired to substitute the contact pattern with another reliably measurable design parameter of a gear pair. The mounting distance is a promising candidate for that.
6. This concept can be easily extended to bevel gears of any and all other types [5].
7. A method for inspection of the mounting distance in bevel and hypoid gearing is a subject of a separate article.
8. Important: In addition to the mounting distance, in C_a–gearings, one more design parameter must be inspected. This is an angle that a gear/pinion axis of rotation forms with the centerline, ℄. A tolerance for this angle needs to be specified, and the actual deviation of the angle from required value of it needs to be inspected. An appropriate tolerance for the center distance.
9. A straight line along which the so-called "normal backlash" is measured cannot be perpendicular to both, to the gear tooth flank, G, and the pinion tooth flank, P, at the same time.

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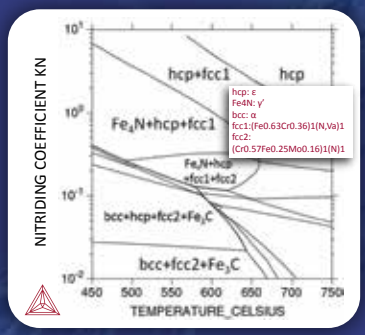

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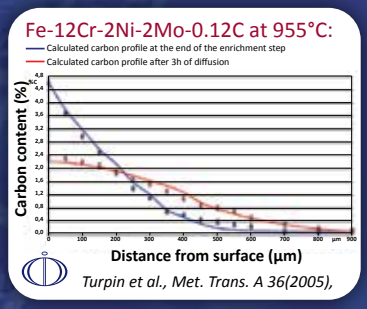

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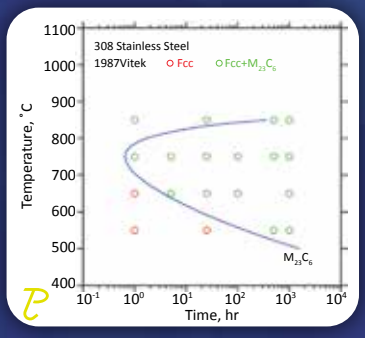

Calculated TTT diagram for precipitate phases

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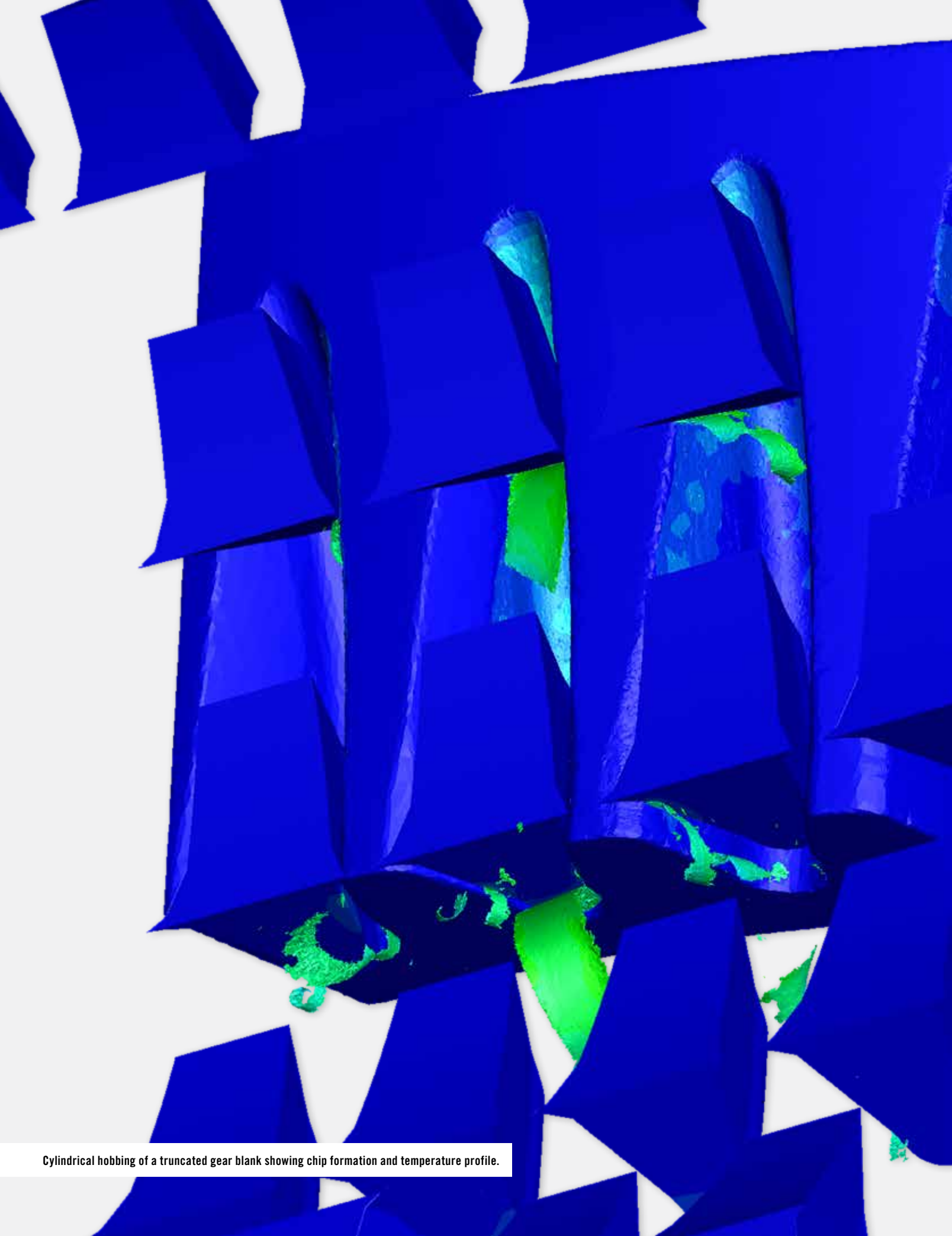


Cylindrical hobbing of a truncated gear blank showing chip formation and temperature profile.

A New Wave in Virtual Machining

Finite element gear cutting simulation helps identify process solutions more quickly than conventional trial-and-error testing.

By Cory Arthur

THE CUSTOM NATURE OF GEARS AND THE HIGH cost of cutting tools have continued to put pressure on manufacturers to reduce the cost of gear machining quickly and with minimal disruption on the production floor. To make timely improvements without costly capital expense, more and more companies are looking to squeeze additional productivity out of existing equipment. However, improvement usually comes at a cost of interruption of production processes to allow for trial-and-error implementations. Virtual machining using finite element gear cutting simulation may help alleviate these problems and lead to finding solutions faster than conventional trial and error testing.

With finite element simulation of gear cutting, engineers can investigate results and understand how process or tooling changes affect the temperature, chip shape, and stresses during the cutting process. This data enables more informed decisions and offers the ability to test a wide range of ideas prior to investing in new cutters or making process changes on the floor. For example, instead of guessing why a cutter fractured, virtual machining simulation allows users to simulate their process conditions to see the areas of high stress and high temperature which indicate tool failure.

In 2017, Third Wave Systems released AdvantEdge Gear Machining for simulating the gear-cutting process. Previously the capabilities of the software package have focused on modeling traditional metal cutting for milling, turning, and drilling processes. It is used globally to better understand the metal cutting process and test changes in a virtual environment. Users reduce time to solution, limit machine downtime, and lower prototyping costs.

The counterpart to AdvantEdge, an NC optimization software package, Production Module, focuses on full toolpath optimization for milling and turning machining processes used in the initial turning of gear blanks and finishing of gear components.

The machining industry and current customers have been asking about gear machining in AdvantEdge for many years. Modeling requests included understanding chip evacuation, tool life, and the effect of machining on the workpiece surface material. With a combination of internal investment and funding from a NAVAIR SBIR program award, Third Wave Systems developed AdvantEdge Gear Machining, which can simulate cylindrical gear hobbing and spiral bevel gear tooth cutting for ring gears. Both face-milling and face-hobbing methods can be modeled.

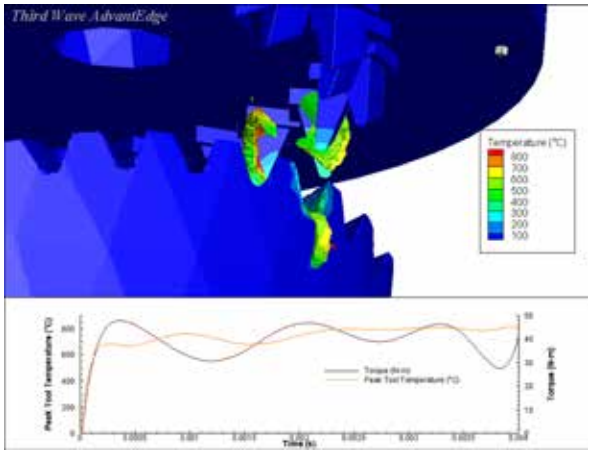
Unlike general-purpose finite element software, this package is specifically designed to be used by engineers with a wide variety of backgrounds, not finite element alone. Features such as automated calculation of meshing parameters and the results analysis wizard enable new finite-element users to get to a solution more quickly without sacrificing the manual inputs and functionality an experienced user requires.

Due to the complexity of gear cutting and wide range of potential users, an industry focus group was formed including cutting tool, machine tool, and gear manufacturers. This enabled improvement of the user experience and a streamlining of inputs to the simulation with the software handling the other necessary calculations in the background.

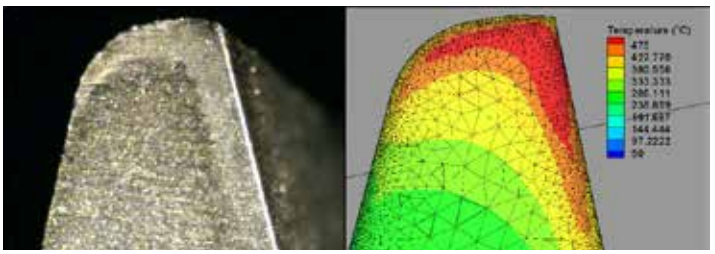
With the help of its industry partners, Third Wave Systems has been able to create a simulation package that contains separate processes specific to cylindrical hobbing, face milling, and face hobbing. This includes inputs for defining the uncut gear blank, the tool, process parameters, and materials along with advanced setup features for manual mesh definition for experienced users. The simulation captures the custom nature of the gear tooling through use of a CAD solid model import. With the advent of digital manufacturing, a solid model may also be imported from scanned cutters found on production equipment. The ability to use both scanned and CAD-generated solid models allows for high fidelity simulation of the true manufacturing environment.

The process parameters are specific to the process type and can be found directly from the dimension sheet. The simulation allows users to set up the simulation at the beginning, middle, or end of the cutting process, capturing the specific area of interest for the engineer. This enables a user to study a single rotation of the cutting tool or single cutting tooth pattern in high detail while still receiving a solution in a reasonable amount of time.

Simulation results can quickly be compared using the analysis tools included with AdvantEdge. The quick



Face hobbing of a spiral bevel gear (non-generating motion) showing: chip formation and temperature contours (top), time history plot of torque and peak tool temperature (bottom).



HARDAC cutter wear comparison showing good correlation between experimental wear marks and predicted simulation temperature contours for single indexing spiral bevel gear machining of case hardening steel gear with HSS blades.

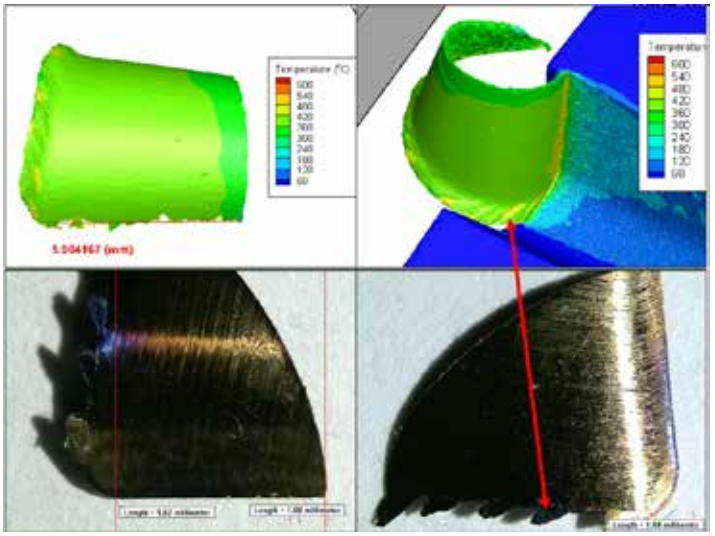
analysis window gives the user control to analyze specific variables on the tool, chip or workpiece contour plots and investigate global force, torque, and maximum tool temperature time histories. A results-analysis wizard and report-generation capability enables users to create a detailed simulation report to be distributed to co-workers, management, and customers.

The materials library for this software system includes standard materials for both the cutter and gear. The cutter can be modeled with different grades of carbide or HSS. The large standard material library available includes common gear materials AISI 1020, 1045, 4140, and 9310. These materials have been specifically created for the high strains, strain rates, and temperatures that occur during machining. A rigorous process is used for adding materials to the database that includes force validation and chip-shape collection. New materials are frequently added through TWS material modeling service.

CAPTURING THE PROCESS

After the user completes the initial setup of the simulation, the software takes over. Using the input parameters and imported cutter, the initial geometry setup is created. First, the gear blank is generated and cutter correctly positioned. The gear blank and tool are then rotated and a Boolean process is applied to create an in-cut gear geometry. This allows the user to start simulation anywhere during the gear-cutting process. Meshing of the gear and cutter is applied automatically followed by boundary conditions completing the setup process.

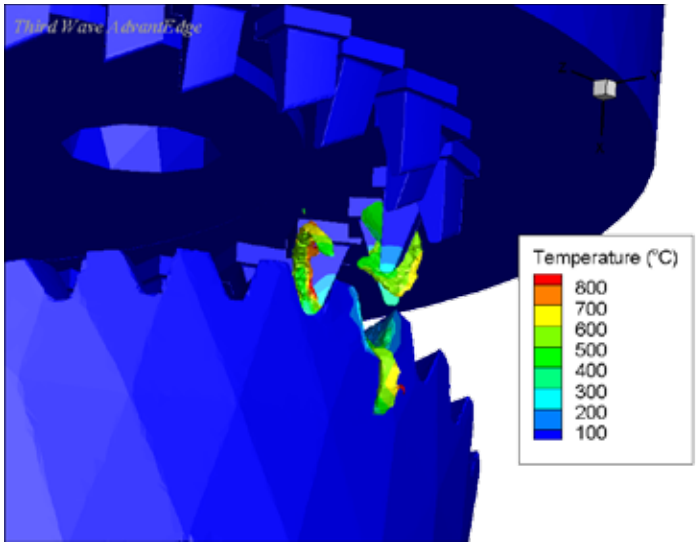
The motion of the cutter and gear are defined by the specific process kinematics. Cylindrical hobbing includes both conventional and climb cutting. For spiral bevel gear machining this includes face milling and face hobbing for the non-generating motion. Further study continues for



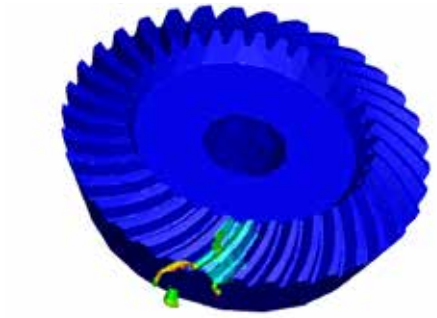
Chip shape comparison showing correlation between: chip width (left), indications of segmentation shown in experiment and temperature bands shown in simulation for simplified cylindrical hobbing of case hardening steel gear with an HSS hob (right).

representing the spiral bevel gear machining generating process.

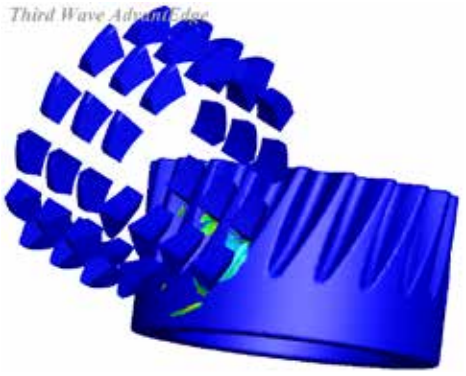
To ensure the accuracy of both the initial workpiece geometry and kinematics, initial validation was conducted by the company using a Mori-Seiki NH6300 DCG 5-axis horizontal machining center. The testing setup included a Kistler 9255B table mounted dynamometer for measuring forces and chip collector for comparing chip shapes. Some simplifications were made due to the limitations of the machining center and to ensure high quality data collection. Both cylindrical hobbing and spiral bevel gear machining processes were tested using case-hardening steel material from a project partner. Chip load and speed were varied over a wide range to cover common industry practices. Concurrently with the experimental testing, simulations were set up and run for comparison. The simulated forces were found to accurately predict trends, and magnitudes were on average within 20 percent of experiment for both cutting and thrust forces. The chips were qualitatively analyzed and matched for both shape and size between simulation and experiment.



Face hobbing of a spiral bevel gear (non-generating motion) showing chip formation and temperature profile. (Images courtesy: Third Wave Systems)



Face hobbing of a spiral bevel gear (non-generating motion) showing chip formation and temperature profile (tool hidden).



Cylindrical hobbing chip formation and temperature profile.

"The advanced ability to model the complex cutting process needed for hobbing cylindrical gears and cutting spiral bevel gears has the potential to reduce the cutting cycle time and improve the tool life, which will lower the cost to manufacture all gears," said Jack Masseth, director of Gear Design and Technology at Meritor. "This extension to Third Wave System's proven capabilities takes the gear-machining process to the next level."

THE NEXT LEVEL

With the complexity of gear manufacturing, the software company is continuing to expand the number and type of processes that can be simulated. The current focus is on the automotive industry and companies with smaller diameter gears. For the larger size gears and cutters, TWS applications engineering group may be able to solve the problem through service work, but there are still some improvements necessary to release software for larger gears. Continued work with industry partners enables TWS to better understand requirements and priorities for future development for additional software features including simulation of the generating process in spiral bevel gear machining, adding more gear specific materials and expanding the size range we can simulate.

ABOUT THE AUTHOR: Cory Arthur is a product manager with Third Wave Systems in Minneapolis, Minnesota. For more information, go to www.thirdwavesys.com.

GLEASON INTRODUCES VERSATILE NEW CUTTER SYSTEM

Gleason's new Pentac®Mono-RT is the world's first cutter system which uses identical blades in both the outside and inside slots. The unique blade geometry — in conjunction with the patent-pending cutter head design — makes the blade which is placed in an inside slot an inside blade, and the same blade placed in an outside slot an outside blade. The Pentac®Mono-RT cutter system is specially designed for the face milling process with Pentac seating parallels, which cover a wide range of gear designs.

The technology makes it possible to reduce the number of different blade blanks by 50 percent, while also doubling the tool life by swapping the blades from the outside slots to the inside slots, and vice versa, and using the cutter with the same blades for a second run.

FOR MORE INFORMATION:
www.gleason.com

Gleason's new Pentac®Mono-RT uses identical blades in the outside and inside slots. (Courtesy: Gleason)

HAAS MULTIGRIND FOCUSES ON PRECISE, RELIABLE GRINDING

Hob cutters for manufacturing gears and worm gears need to meet the highest standards when it comes to precision and service life. Haas Multigrind customers require gear qualities q1–q3. This is true whether it's a very small tool, or a 600-kilogram gear-cutting tool used to manufacture gear wheels for the winches on freighters and container ships.

The dimensional accuracy and surface quality of a gear component are absolutely key to an efficient transmission of power and smooth operation. On the Multigrind® CB and CA grinding centers, grinding gears from solid is just as easy as processing premilled blanks that are subsequently hardened. Haas grinding software enables users to quickly and easily define the respective workpiece, including clearance angle calculations and collision avoidance simulation. Thanks to our machines' kinematics, large grinding wheels can be used when rough grinding. For the operator, this means a longer service life and more material removed.

Using a compensation program that mathematically compensates for the hysteresis of the probe, the components can be probed in the machine. The deep grooves and fine contours of the teeth can also be processed in one clamping, regardless of the size of the workpiece. The intelligent integrated 3-D probing system guarantees maximum precision during the entire grinding process. This is how to achieve repeatability and accuracy of a few microns, and avoid time-consuming clamping and unclamping.

The grinding wheels can be trued in the machine using the integrated dresser unit. This is another way our machines save time and offer added precision.

The dimensional accuracy and surface quality of a gear component are key to an efficient transmission of power and smooth operation. (Courtesy: Haas Multigrind)

FOR MORE INFORMATION:
www.multigrind.com

KOEPFER AMERICA TO FEATURE NEW TECHNOLOGY AT GEAR EXPO

Koepfer America continues to supply gear manufacturers with the latest technology in machines, tools, and services, and will demonstrate that at Gear Expo 2017. At the Expo in Columbus, Ohio, the company will show three important features for hobbing, shaping, and deburring that all gear manufacturers will want to see.

First, gear manufacturers will see the proven technology of the Koepfer Model 200 CNC gear hobbing machine with a completely redesigned control interface.

This new Vektor control ushers in the latest generation of Koepfer's user-friendly control concept. It optimizes functionality by using a minimum number of control elements. Instead of a fixed menu structure, the Vektor control's adjustable apps make operation more intuitive. The control panel interface is 50 percent larger compared to the previous generation, and the panel has complete touch and swipe technology. The front panel is also flush and sealed, allowing for effortless cleaning. Other updates with the Vektor control include a compact design, integrated NC and PLC, and a USB interface for data backup and easy updates.

The next feature in the Koepfer America booth at the Expo will be a gear deburring machine that is new to the North American market: the Tecnomacchine ("TM") 200 R3. Gear manufacturers will be familiar with the deburring concept, which uses five work stations that produce a fully deburred and brushed part in approximately 25 seconds. CNC work stations also allow automatic tool wear compensation. What makes the TM 200 R3 stand apart from yesterday's deburring machines is its CNC automatic loading and unloading system. The TM 200 R3 features two rotary magazines, each comprising eight adjustable turrets, making this a versatile, flexible deburring solution for job shops with parts up to 200 mm (7.874").

Third, Koepfer America continues to innovate by showing the CLC 200-SZC CNC gear-shaping machine. As with all CLC machines, the 200-SZC features robust components, such as direct drive torque motors, for maximum quality and machine life. This show machine will feature CNC cutter relief, crowning, and taper. Traditionally, these CNC features have limited stroking speeds; however, a new design

Koepfer America will show the CLC 200-SZC CNC gear shaping machine at Gear Expo 2017. (Courtesy: Koepfer America)

The TM 200 R3 stands apart from previous deburring machines due to its CNC automatic loading and unloading system. (Courtesy: Koepfer America)

Bright Spots at Gear Expo

You'll find all the latest gear production, automation, design software, tooling and inspection technologies to improve your applications. One booth, Total Gear Solutions.

Find your invitation at: www.gleason.com/gearexpo

GEAR EXPO 2017
THE DRIVE TECHNOLOGY SHOW

Booths 1411 & 1628

Total Gear Solutions Gleason

concept from CLC provides both CNC cutter control as well as mechanical control. This allows up to 2,000 strokes per minute. No longer must gear manufacturers choose between flexibility and speed. That is not all to see on the CLC 200- SZC; this machine will also feature on-board robotic loading and unloading with Koepfer-style gravity and conveyor parts magazines.

Gear Expo 2017 in Columbus will be an exciting show. Koepfer America will be celebrating 30 years of service to the industry in tandem with Koepfer Germany's 150th anniversary. All gear manufacturers are welcome to join Koepfer America in booth 807 to celebrate and see the new TM 200 R3 gear deburring machine, the new CLC 200-SZC CNC gear-shaping machine, and the new Koepfer Model 200 Vektor control.

FOR MORE INFORMATION:
www.koepferamerica.com

Koepfer's new Vektor control optimizes functionality with features such as adjustable apps, a control panel interface that is 50 percent larger compared to the previous generation, and touch and swipe technology. (Courtesy: Koepfer America)

LIEBHERR DEBUTS TURNKEY SKIVING3 PROGRAM

At Gear Expo 2017, Booth 1015, Liebherr Gear Technology will introduce gear skiving machine series LK 300 and 500 based on the tried-and-tested components of the corresponding large hobbing machines but with greater rigidity and more powerful spindles. A gear skiving machine requires a table with a direct drive owing to the high workpiece speeds required. This drive works with an automatic control that constantly has the optimal parameters. Liebherr designs the complex clamping fixture, which links the workpiece and the machine.

As skiving is a highly dynamic process, the machine is supplied on a "turnkey" basis with individual clamping fixtures for each workpiece, precise rigidity, and contour accuracy. "This overall view is an important part for the production success," said Siegfried Schmidt, team leader in development and design of skiving. "A complex process such as skiving has many specific obstacles, which we overcome with very specific mathematical solutions."

With its skiving3 program, Liebherr not only provides the LK 300 or 500 skiving machine, but a whole process, including machine, tools, and technology for gear production. This integrated approach from Liebherr has already been tried and tested in practice. For many customers, the process of skiving is new, and therefore the operators of the machines need comprehensive training and assistance. On top of that, the tool design is a very complex issue

Skiving3 is popular especially for internal gearing with medium size and quantity as it is much faster than shaping, and more economical than broaching. In situations where gear skiving is not possible or appropriate, owing to interfering contours or quantities

Liebherr LK 500 gear skiving machine. (Courtesy: Liebherr)

that are too low, Liebherr still offers technological alternatives with gear shaping and gear hobbing.

The newly developed LHGe@rTec control system also contains the mathematical formulas for pressure angle corrections. This way, quality improvements can be easily achieved via the kinematics of the machine.

The optional tool changer, which can be used to change between roughing and finishing tools, for example, is new. Liebherr offers a ringloader as a standard option for the workpiece changing device; other automation solutions, such as belts and robots, can also be realized upon request.

FOR MORE INFORMATION:
www.liebherr.com

ROHM TO FEATURE POWERFUL WORKHOLDING TECHNOLOGIES AT CMTS 2017

Rohm Products of America will make its case as a one-stop clamping and gripping supplier with exhibits of its top workholding innovations at CMTS 2017 in Hall 2, booth 2200. Those innovations will include the Captis clamping system, the DURO-NCSE power chuck, the RZM 5-axis centric vise and the KZFS gear chuck. All of these products fulfill industry demands for increased efficiency and shorter setup times, ergonomics, weight reduction and convenience.

For manufacturers in search of new ways to maximize production, the modular Captis workpiece clamping system provides a wide range of workholding options for turning, milling and drilling applications, and features a forward-thinking quick-change capability that permits conversion from external to internal clamping in less than a minute. The system produces strong clamping forces without deformation of delicate workpieces, while offering high repeatability and minimal runout. Captis is compatible with the industry standard BZI collet interface.

At the show, Rohm will also highlight its DURO-NCSE power chuck with quick-acting jaw-change system. The specially designed jaws unlock individually for easy handling/changeover and fast setup. The DURO-NCSE accommodates large, work-

piece-specific customized jaws, and operators can offset, exchange, or turn the jaws with minimal effort. The chuck is available in a variety of sizes and with several jaw options to tailor-fit many applications. Special large jaw pads make part handling particularly easy for big parts.

Another show special at Rohm's booth will be the RZM centric vise that provides exceptional workholding rigidity and contributes significantly to higher accuracy 5-axis machining. The vise's design features clamping jaws positioned relatively high and a horizontal spindle situated at the top of the vise and closer to the jaws for unmatched stability. The double jaw-guidance system moves jaws smoothly along their axes to accommodate a wide range of part sizes without having to remount the jaws.

For visitors interested in external clamping chucks for gear surface grinding, Rohm's KZF-S collet chuck is especially well-suited for clamping gears/workpieces that have an external plane, or gear teeth geometries accessible from the outside. Additionally, the chuck allows face and ID diameters to be turned or ground concentric to outer gear pitch diameters. Compact in design, the KZF-S chuck provides high clamping forces, optimal workpiece stability, and maximum axial accuracy achieved via axial draw-in of the workpiece against a rigid work stop.

Application specialists will be on hand to show how Rohm's workholding and automation technology can help increase productivity through lights-out and just-in-time manufacturing.

FOR MORE INFORMATION:
www.rohm-products.com

The modular Captis workpiece clamping system provides a range of workholding options for turning, milling, and drilling applications. (Courtesy: Rohm)

NEW SECO FACE MILLING CUTTER BODY DOUBLES TOOL LIFE

Seco Tools face milling cutter insert. (Courtesy: Seco)

GEAR EXPO 2017
THE DRIVE TECHNOLOGY SHOW

October 24–26, 2017
Columbus, OH
www.gearexpo.com

If you're craving it, someone in Columbus has it on the menu

Columbus' food scene features top-ranked chefs, a rich farm-to-table movement, one-of-a-kind restaurants, and desserts, beers, and wines to lift any spirits.

According to www.experiencecolumbus.com, there are more than 100 restaurants within walking distance of the convention center, including the North Market public market, a symbol of the city's rich history and a hub of the its modern-day food and shopping scene. North Market is open daily, and regular merchants of the market offer a range of locally produced goods, from soft pretzels and handmade pastas to spices and craft hot sauces and salsas.

No matter what you're craving, you'll find it in "Cbus." Famous brunch spots Skillet and Katalina's offer hearty, stick-to-your ribs fare, while The Refectory (French inspired) and Basi (Italian) are more refined options. If you're screaming for ice cream, check out the homemade ice cream at Jeni's Splendid Ice Cream. Other eateries of note include Golden Donuts and Diner and pastry cafés such as Pistacia Vera.

Once your stomach is full, you might want something to drink. The Brewers Row corridor near downtown features six breweries, all within a few blocks of the free CBUS downtown circulator. They include North High Brewing, Seventh Son Brewing, Hoof Hearted Brewpub and Kitchen, Barley's Brewing Company, Wolf's Ridge Brewing, and Elevator Brewery and Draught Haus.

SKILLET
410 E Whittier Street
(614) 443-2266

THE REFECTORY
1092 Bethel Road
(614) 451-9774

KATALINA'S
1105 Pennsylvania Avenue
(614) 294-2233

BASI
811 Highland Street
(614) 294-7383

Artistry and flavor come together at Basi. (Courtesy: Basi Italia)

The new R220.88 face milling cutter family from Seco features inserts with eight cutting edges and optimized geometries that provide excellent tool life and reduced cutting forces. The cutter body's 88-degree lead angle allows for large depths of cut with smaller insert sizes, as compared to 45-degree lead-angle face mills. Its design also allows the new cutter to machine closer to workpiece side walls as well as intricate part clamping workholding systems when necessary.

Designed for roughing and semi-finishing applications, the R220.88 is ideal for machining cast iron and steels in the general machining and automotive segments. The cutter body is made of Idun material, a corrosion-resistant stainless steel that offers longevity and durability along with being environmentally friendly due to the elimination of the nickel coating process.

The cutter body is available in diameters ranging from 2.00" to 6.00" (50 mm to 160 mm) with the size 12 insert, and 3.00" to 6.00" (63 mm to 160 mm) with the size 16 insert. Each diameter is offered with a standard pitch variant and a close-pitch variant to provide the best match to an application's specific needs. The size 12 R220.88 achieves a maximum depth of cut of 0.35" (9 mm), while size 16 reaches an impressive 0.51" (13 mm) maximum depth of cut. Right-hand versions of the cutter body are standard with left-hand versions available on special order, allowing integration into systems with dual spindles performing simultaneous milling operations.

The R220.88 is compatible with Seco's SNMU inserts, which are secured with a center lock screw, eliminating the need for wedges to secure the insert in the pocket. The eight cutting edges on these inserts offer double the cutting edges over four-edged inserts to help reduce tooling costs.

With its neutral design, the SNMU insert can be applied in right-hand or left-hand milling applications. Available insert geometries include M10 and MD13 for size 12 and M10 and MD16 for size 16, with an insert grade offering that includes MK1500, MK2050, MP1500, MP2500, MS2500 and F40M. An integrated wiper flat ensures a good surface finish for semi-finishing applications, and optimized geometries for reduced cutting forces with the M10. The heavy edge protection with the MD13 and MD16 inserts are ideal for difficult face milling operations, such as interrupted cuts.

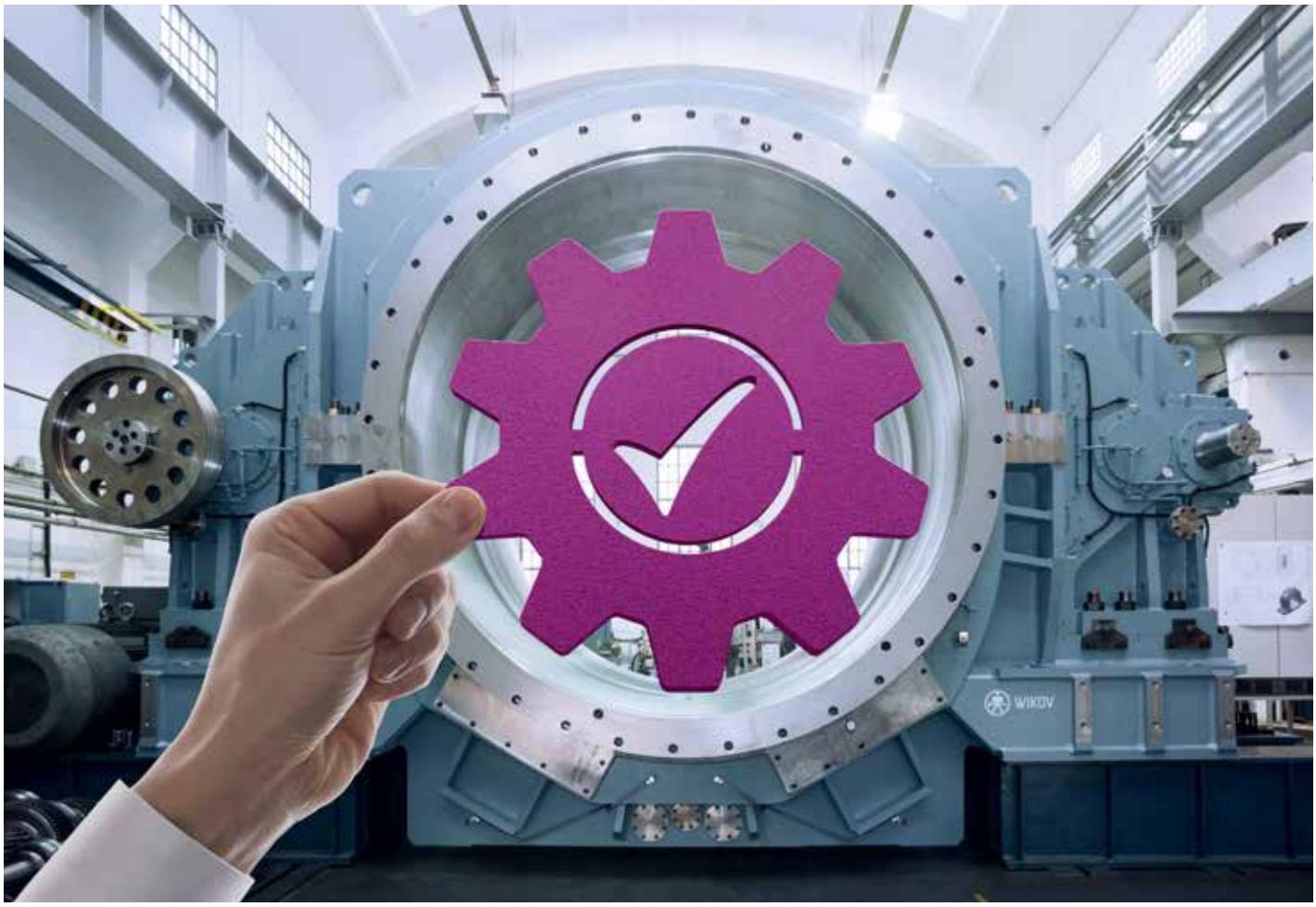
FOR MORE INFORMATION: **www.secotools.com**

SHOP FLOOR AUTOMATIONS TALKS SOFTWARE BENEFITS

One of the items decision makers may have been mulling over as 2017 nears its end is investing in machine monitoring software for the shop floor. You have likely heard about how monitoring machine utilizations will help improve productivity. The truth is, there are three other benefits to machine monitoring that aren't so obvious.

Reason 1: Machine monitoring is flexible – it's not just for CNC machines and it's not limited to the shop floor. Monitors can work with manual machines, autoclaves, paint lines, PLC-driven machines, and more. Shop Floor Automations prides itself on unconventional machine monitoring, and also the mobility of machine monitoring. Monitor machines away from the shop floor with notifications sent via email or text. Employees can also monitor from a mobile device, such as a smart phone or a tablet.

Reason 2: This software can integrate with a CMMS system to provide customers with a more accurate PM schedule. If you



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EVONIK
POWER TO CREATE

are currently using a calendar-based system to schedule PMs, you might be performing maintenance too soon, or too late. Shop Floor can monitor actual run times on machines and feed that information to CMMS to create a PM schedule.

Reason 3: Machinists have a voice, via machine monitoring. The men and women running the machines have valuable feedback that is not easily communicated to upper management. They are the ones in the trenches and they usually know why a machine is not running. Data entry screens and tablets on the shop floor give machinists the ability to add notes and let those in the back office know the reasons machines are down. This will allow for trends to be seen and corrections to be made.

FOR MORE INFORMATION:
www.shopfloorautomations.com

Shop Floor Automations touts the benefits of machine monitoring, including communication and mobility. (Courtesy: Shop Floor Automations)

HIGH-PERFORMANCE TOOLHOLDER FOR MICRO MACHINING

Special consideration must be made for micro-machining, which is why Schunk is offering the Tribos-RM precision toolholder as the best solution for micro machining with the ISO interface. The one-piece, rotationally symmetric design ensures long life of the machine spindles and the complete transmission of power.

The one-piece, rotationally symmetric design of the Tribos-RM toolholder ensures long life of the machine spindles. (Courtesy: Schunk)

Knowing exactly how to optimize your production quality.

ZEISS DuraMax

// RELIABILITY
MADE BY ZEISS

The right measuring equipment for the shopfloor

ZEISS DuraMax eliminates the need for fixed gauges. Equipped with the VAST XXT scanning sensor from ZEISS, it can even be used to capture contours and freeform surfaces. The standard shopfloor DuraMax is perfect for a rough production environment, now with enhanced models offering a smaller footprint, a rotary table option and an even higher operating temperature range. Integrate it into your production line or configure it as a specialized gear measurement tool.

Visit ZEISS at Gear Expo, booth 214

www.zeiss.com/duramax

ZEISS

The Pronto quick-change jaw system is easy to use. (Courtesy: Schunk)

Unlike heat-shrink clamping, the Tribos-RM achieves steady tool clamping that will not distort the toolholder. The user will always benefit from a precise run-out accuracy of less than 0.003 mm, which is optimal with small tools for micro machining.

The Tribos-RM is designed for high spindle speeds of up to 60,000 rpm in high-speed cutting, making it ideal for the high speeds involved in micro-machining. Sizes ISO 10 D 1 - 6 mm are available. The balancing grade is G 2.5 at 25,000 rpm.

FOR MORE INFORMATION:
www.schunk.com

REDUCE JAW CHANGE-OVER TIME TO FIVE SECONDS

Schunk Pronto quick-change jaw system could shave minutes off of your current set-up times, drastically improving your productivity.

In addition to the time-saving benefits, there is also considerable versatility and extended clamping range to the Pronto quick-change system. The complete system is suitable for O.D. clamping of machined and finished parts, and consists of support jaws and clamping inserts that have a clamping range of up to 16mm without having to reset the supporting jaw –an impressive 300 percent increase on the standard clamping range.

The Pronto quick-change jaw system is incredibly easy to use – the lock is released with an Allen key, and the jaw is then removed and replaced by another, thereby eliminating incorrect positioning and ensuring excellent repeatability. When in the locked position, the six-sided form-fit clamping is at maximum stability, providing high force and torque transmission.

The Pronto system can be used in a wide variety of applications to adapt to any specific need. The features and benefits include:

- Three supporting jaw variations available for small, medium, or large clamping ranges.
- Four hard-claw inserts for various diameter and clamping ranges.
- Soft, interchangeable inserts for finished parts processing.
- Once turned, the inserts can be used repeatedly on a system.
- Clamping depth can be adjusted by using a work piece stop.

FOR MORE INFORMATION:
www.us.schunk.com

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CONTENTS PAGE NO.

Q&A

VINCE MARLOWE
DIRECTOR OF SALES AND MARKETING
MIJNO-USA

What is Mijno-USA's mission?

Our mission is to provide custom gear drive solutions, driven by our passion and expertise, to serve the customer above and beyond their expectations while promoting leadership, integrity, and continued improvement throughout the manufacturing and customer service processes.

How did Mijno-USA begin?

In 2007, Allied Precision Machining teamed up with Mijno and entered into a gigantic manufacturing co-op of primarily the critical down-hole oil tool drive systems for conveying tools down to the locations required in the deviated wellbores. So, as the oil and gas industry grew, rather than rely on the experience of our co-operatives, we pretty much continued to assist them despite their concerns about becoming larger and larger shares in our company. We did manufacture precision drive components and assemblies for what we call wellbore tractoring systems. And these were both electrical and hydraulic, so they had an arm that would deploy with a gear-drive reduction system through the arm. It was a little bit different from Mijno's typical expertise in planetary reduction and rack-and-pinion type stuff. And the exotic materials required down there in the caustic environments were requiring the engineering and the expertise of the two companies.

But due to the downturn in 2014 in the oil and gas industry, I was forced to close Allied Precision Machining. That was the company here in California. The resulting concern was loss of knowledge and capability in this particular field of expertise, primarily by our largest customer, one of the world's largest oil well service companies. Consequently, Gregory Mijno, president of Mijno-France, which is where the factory is, solicited me with the intent of Mijno maintaining and serving that level of expertise while gaining representation in the North American marketplace, which would be the Canadian and U.S. territories. And thus, Mijno-USA was born. We're still somewhat in our infancy, because we officially started Mijno-USA in December 2016.

What products and services does Mijno offer?

Primarily gear-drive solutions, whether they're custom designed or standard. We offer high precision, full service machining and assembling of gearboxes and gearbox-related products. But a lot of the stuff we're getting into is part of the expertise brought aboard from the previous company, and these are typically your hydraulic blocks. They're the manifolds you'd mount the solenoids in, and they control the hydraulic circuits. Primarily for down-hole oil tools that we have grown with the expertise with the company. We also have a standard line of gearboxes — planetary reduction, right-angle reduction, rack-and-pinion. We'll do servo and gear drive integration, whatever you need, whether it's for military, nuclear, or aerospace. Our largest sector is aerospace and defense in the European theater.

We also support machines through automation. A lot of your CNC turning machines have live tools for milling and your multi-axis machines that are pretty much doing it all now. You've got what we used to call lathes and mills, and now, the industry is building machines that are doing so much more. And that requires a lot more gear-drive solutions. We still support the oil and gas sector, despite the downturn. And some of it is coming back, and we're happy to see it.

What are some of Mijno's proudest achievements?

We redesigned and improved the efficiency of some hybrid transportation vehicles. They're basically large buses, and they were having problems with the efficiency and the design, and we stepped in and pretty much saved the day. Nowadays, we're turning toward electric or hybrid transportation, which makes total sense, especially for large metropolitan areas.

We designed and manufactured the azimuth elevation controls for the shipboard anti-missile defense systems for the French Navy. Last year, we deployed the satellite solar panel rotational system. They basically open up like an umbrella, and we built the drive system and the servo drive integration that does that in the satellites for the European space defense agency.

And I came up with the catchphrase for Mijno: "Whether it's way high above, far down below or right here in between, we have your gear drive solution."

What sets Mijno-USA apart when it comes to what you can offer a customer?

Primarily, we've got 90-plus years of passion-driven expertise in proprietary design and manufacturing processes and technologies that allow Mijno to provide innovative custom solutions to its customers backed by complete in-house capabilities, whether it's direct cutting, grinding, or more.

Our progressive thinking ensures the continued improvement for current and future customers for years to come. So we really kind of have a reputation. The company started out by making gears for bicycles and has grown to what you see today.

Where do you see Mijno-USA in the next 10 years?

The current hope is — market conditions supporting it — a U.S.-based manufacturing facility with interchangeable staffs, so we can do cross training with French and American expertise, kind of like an international exchange program similar to what some of the colleges are doing. I want to support the current growth initiative with the resourcing acts in America.

I'm really hoping we can capitalize on that and continue to grow the company with a worldwide presence. The diversification would be the big issue. The hope would be to continue supporting the energy field, especially with the dominance of the oil and gas field in America now, as well as support the new generation of technologies.

FOR MORE INFORMATION: www.mijno-usa.com

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