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Dear Gear Solutions Reader,

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.

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In this issue, we highlight the latest advancements in gear manufacturing technology, covering topics such as material selection, mounting accuracy, and carbon potential. Our contributors provide insights into the latest research and developments in the field, ensuring that our readers stay informed and ahead of the curve.

Best regards,

Joe Wright
General manager and technical expert at Exact Metrology

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As the world continues to slowly move toward a bit of normalcy, thanks for checking out the current issue of Gear Solutions, where we’re always keeping that window open on the world of gear manufacturing.

Judging from some of the news releases we’ve received from various companies, it would appear that, at least as far as gears are concerned, business continues to grow at a steady pace.

That being said, April’s Focus section takes a look at a variety of subjects important to gear manufacturing that are as essential as they are innovative.

This month’s issue has some great information in it as we set our sights on the topics of workholding and cutting tools. Without these workhorse areas, producing gears would be a lot more difficult.

Starting with our cover feature article, Helios Gear Products President Adam Gimpert takes a look at hob quality and how it’s critical to high-quality gear manufacturing.

On the subject of workholding, Gleason’s Brian Baldeck and Ian Schickling share their insights on a new fixture design that minimizes runout and helps ensure great accuracy for hard finishing and inspection.

In this month’s company profile, I had the pleasure of talking with Scott Thielman, president and owner of Machine Tooling Technology. In the article, Baker shares MTT’s story on how the company offers compatible parts and tooling for keyseater machines and much more.

And as always, this month’s issue has a wealth of information from our regular columnists, so make sure you check them out as well. I am always learning something new from them, and I’m sure you will, too.

Keep in mind that Gear Solutions is here to get your message out to your customers, whether that be with news releases that we happily share with our readers or advertising that can drive home what your company can offer. There are options available, and Gear Solutions’ primary goal is to help you with your company’s mission in any way we can.

In the meantime, keep wearing that mask, practice social distancing, get vaccinated when you can, and, as always, thanks for reading!
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Amorphology demo center shows Starrag Bumotec s191H

Amorphology, a NASA spinoff company founded from technology developed at the Jet Propulsion Laboratory (JPL) and the California Institute of Technology, is a leader in applying advanced materials and manufacturing technologies toward improving gear production for robotics and other industrial applications using amorphous metals, also known as bulk metal glass (BMG).

The demo center will be at Amorphology’s Pasadena, California, headquarters where Starrag’s Bumotec s191H CNC machine will be showcased, machining a wide variety of parts from mold inserts to rapid prototype gears, as well as other production BMGs and traditional metal parts.

“We are targeting high-precision parts with tolerances often <5μm on certain dimensions,” said Jason Riley, Amorphology’s chief operating officer. “The majority of our work is focused on rapid prototyping and production quantities in the hundreds of parts per month.”

“Establishing a laboratory environment to showcase the precision, quality, and capabilities of the Bumotec s191H will enable aerospace and defense engineers to experience this real-time machining that could be used in their manufacturing operations,” said Greg Dunkley, Starrag Bumotec’s vice president of precision engineering.

BMGs have several material advantages over traditional steel, titanium, and aluminum metals and alloys. Amorphology’s patent portfolio includes several patents focused on high-precision gears for space and other extreme cold temperature applications. Amorphous metals are a non-crystalline class of alloys that cut and chip differently than other materials.

“The Bumotec s191H provides mill-turn capabilities as well as a higher production capacity,” Riley said. “Bumotec can take our alloys and machine single pieces. Or instead of machining one part at a time, it can produce hundreds of pieces lights-out.”

Amorphology’s gears are made for use in cobots, robots, and medical devices. For example, most cobots use strainwave gears — the main component being a flexspline. It is complex, thin-walled, and fulfills an important role — to precisely move the arm of the robot.

Many of the cobot, robot, and medical device parts can be cast or injected molded, but, at times, the micro-parts need to be post-processed to extremely high tolerances.

“Bumotec ‘cut its teeth’ in designing machines for the Swiss watch industry,” said Dunkley. “Bumotec has a talent for machining micro-size high-value gears.”

Riley believes the Bumotec s191H will make Amorphology’s own micro gearboxes without lubrication for robots and medical devices. “We will be machining our patented alloys to very small sizes where production quantities don’t require our injection molding process,” he said.

MORE INFO
www.amorphology.com
www.starrag.com

United Grinding adds new automation to old grinders

To further enhance the overall customer benefits of its machine rebuild and remanufacture services, United Grinding North America now offers customers with older Walter Helitronic Power Series tool grinding machines the option of new advanced automation technology seamlessly retrofitted as part of a machine rebuild. The option replaces original gantry beam-type loaders that are now obsolete with faster, more productive FANUC LR Mate 200i robots, the same as are featured on brand new Walter Helitronic machine models.

In addition to speed, the new robots handle an increased number of workpieces/tools, are more compact, and consume less power.
energy. They also support the latest Walter Helitronic Tool Studio and Robot Manager software that allows users to load multiple trays with various workpiece diameters for lights-out unattended production.

To allow for retrofitting modern automation when rebuilding the machines, Walter reengineered and reconfigured its controls because the original offering lacked the functionality to support today’s robots. Now, as part of a rebuild, United Grinding outfits machines with the new FANUC CNC as well as all new electrics (FANUC drives and motors) that accommodate the robots and all necessary software.

The new FANUC CNC extends machine lifespan as well as adds features, functions, and convenience. They can provide user-friendly conversational programming and advanced functions available on a machine that reached the market before these operator-oriented approaches debuted.

The primary benefit of rebuilding existing equipment through United Grinding North America rebuild department is cost. On average, a rebuilt grinding machine costs roughly 75 percent of new equipment. Once rebuilt, a machine looks, works, and produces like new, with recommissioned geometry, renewed guideways, and enhanced precision. Plus, depending on how a company classifies expenses, a rebuilt machine may qualify as a maintenance cost rather than as capital outlay, further contributing to potential savings.

MORE INFO  www.grinding.com

NUM adds software option for power skiving to CNC solutions

CNC specialist NUM has further extended the functionality of its well-known NUMgear family of gear production technology with the addition of an extremely flexible software option for power skiving.

NUM’s new power skiving option provides the enabling technology for CNC machine tool companies to address a key market opportunity in the nascent compact gearbox manufacturing industry. It is now possible to create an entirely new generation of gear production automation that offers combined hobbing and skiving capabilities on a single machine.

Gear manufacturers currently employ a variety of machining processes, including hobbing, shaping, broaching, and grinding. To a large extent, the processes that are used are dictated by the type and size of the gears and splines being produced. Hobbing is ideal for external gears, while shaping and broaching are best suited to the production of internal gears — but the latter is only really practicable with small gears. Power skiving, on the other hand, is potentially a much faster and more efficient way of creating external and internal gears of any size.

However, despite being developed and patented more than 100 years ago, it is only recently, with the advent of multi-axis machine tools, capable of precision high-
NUM adds power skiving to its portfolio of gear production CNC solutions. Here, a hobbed helical gear and a skived straight gear on the same shaft. (Courtesy: NUM)

speed synchronization, that the technique of power skiving has become a practicable proposition for industrial-scale use.

Based on NUM’s high performance Flexium+ CNC platform, the new power skiving solution forms the latest addition to the company’s NUMgear suite of gear production software. Originally developed specifically for gear hobbing applications, NUMgear is continually enhanced to meet industrial requirements and nowadays offers solutions for a broad range of gear manufacturing processes; it is used by many leading manufacturers of gear production machines.

The new power skiving software capitalizes on the speed and precision of NUM’s advanced multi-level electronic gearbox (MLEGB). This very high-performance unit is capable of unprecedented speed and accuracy — it can handle up to 25,000 rpm on the leading axis and uses look-ahead algorithms to predict both the speed and the acceleration of axes in order to minimize synchronization time.

The characteristics of the MLEGB are user-defined in the part program. Any axis can be nominated as leading or following, linear or rotary, and the ratio between the leading and following axes can be controlled by a user-defined fixed parameter or a dynamic machine-cycle variable (curve table). Flexibility is even further enhanced by the fact that multiple MLEGBs can be cascaded, a following axis in a dynamic gearbox can be used as a leading axis in another MLEGB, and either the leading or following axis in an EGB can be real or virtual.

A single multi-role CNC machine tool that offers gear manufacturers the ability to hob large gears and to power skive smaller gears on one shaft, or whenever tool space is constricted — such as in a compact gearbox — would almost certainly enjoy rapid industry take-up. Thanks to NUM, the CNC control technology, together with the necessary precision servomotors and drives, is now a reality.

NUM’s new power skiving software option can be installed and used on any Flexium+ CNC system running Flexium software version 4.1.00.00 or higher.

MORE INFO www.num.com

Motion announces two promotions to executive vice president

Motion Industries, Inc., a leading distributor of maintenance, repair, and operation replacement parts, and a premier provider of industrial technology solutions, has promoted James Howe to executive vice president — eCommerce, sales excellence, strategic pricing, and corporate accounts, and Joe Limbaugh to executive vice president – supply chain, operations support, marketing, and enterprise excellence, effective April 1, 2021.

Howe most recently served as SVP – eCommerce, sales excellence, and strategic pricing throughout 2020, and as of January 1, 2021, took on the additional responsibilities of Motion’s corporate accounts group. He has been with Motion since 2002 and held numerous field roles, including group executive for the West Group. In the last couple of years, Howe has led the strategy and development of all aspects of Motion’s digital strategy, including the new Motion.com website released last year. He has also transformed Motion’s pricing strategy, delivering immediate and consistent impact across all aspects of the company’s business. As EVP, Howe will continue to lead in his respective areas, while also assisting in other strategic areas of the business and customer development.

Limbaugh began his career with Motion in 1983 in Bourbonnais, Illinois. During his time with Motion, Limbaugh has held numerous field and corporate positions, giving him a unique perspective on Motion and its customers. He most recently served as SVP, responsible for Motion’s procurement and inventory, distribution center operations and productivity, branch support, facilities and lease management, and marketing strategy.

In 2018, Limbaugh led the renovation of Motion’s corporate campus, finishing the project on time and under budget in late 2019. In 2020, under his leadership and guidance, Motion installed the first “goods-to-person” automated retrieval systems in the Birmingham distribution center, resulting in a 540 percent productivity improvement. As EVP, Limbaugh will continue to lead strategic initiatives throughout the company to improve customer service levels and increase Motion’s productivity in an effort to create additional stakeholder value.

“With their expertise and substantial achievements, James and Joe are both prov-
en, integral leaders and key to Motion’s success,” said Motion president Randy Breaux. “Both promotions are well-deserved, and we look forward to seeing continued company success under their guidance.”

MORE INFO  www.motion.com

Software provider FactoryWiz names Eastern sales manager

FactoryWiz, a leading provider of machine and asset monitoring software, recently named John B. Lucier as Eastern sales manager. Lucier previously served as the national automation manager for Methods Machine Tools.

Born and raised in central Massachusetts,

New additions expand Jergens’ OK Vise Multi-Rail capability

Jergens Inc. expanded its Multi-Rail solutions for its OK Vise range of low-profile modular clamping. The additions include a number of parallels and side guides for positioning, as well as clamp and stop modules to hold workpieces securely during machining.

T Slot, magnetic (including a tall version), and snap-in parallels assist in the positioning of a workpiece on the RM rail, avoiding contact with the serrations through a raised datum surface. Choose from Tnut, magnetic mount, or snap-in for even faster installation. Mechanical and magnetic side guides also assist in positioning the workpiece on the Multi-Rail. They are mounted either to the tapped holes in the side of the rail or via the strong magnet for a wide range adjustment and the ability to move rapidly from one location to another. Users can adjust each side guide for a specific product while keeping the guide ready for the next production batch.

Holding workpieces securely with OK Vise is done with clamp and stop modules. New B and D Series clamp modules feature a standard clamp combined with a riser plate (B Series only), socket head cap screw, and Tnut, as well as a choice of jaw faces — smooth, serrated, mixed, and mounting jaw. Stop modules hold fast against clamping pressure and are available in several styles including smooth, serrated, knife, V-stops — both vertical and horizontal — and more.

In total, these workholding innovations perform with high repeatability on the Jergens OK Vise Multi-Rail system, a unique general-purpose workholding solution. Several advantages of this system include near-endless fixture configurations, holding and machining challenging workpieces both large and small (including multiples clamped simultaneously), and the ability to mount to the Jergens QLS grid system.

MORE INFO  www.jergensinc.com

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Partnering with QualityReducer to provide Gearbox repair, rebuilding and reverse-engineering.
Lucier began his career in manufacturing as a shop floor machinist, then after a few years of shop programming and setting up CNC machines, he moved into the world of machine tools. Lucier spent the next 28 years at Methods Machine Tools, first as an applications engineer, eventually advancing to national automations manager.

Lucier used his machine tool knowledge, together with his automation knowledge, to develop, build, and sell automation solutions for the metalworking industry.

“John is the right guy for the continued growth of FactoryWiz,” said Richard Hefner, FactoryWiz president. “John’s extensive machine tool background and sales experience should help FactoryWiz strengthen channel partnerships, develop strategic alliances and expand our brand presence. We believe his strong experience will help FactoryWiz during our continued expansion and growth.”

“I first became acquainted with the team at FactoryWiz more than 20 years ago, and back then, they were already pushing the limits on using machine controls in ways others had not,” Lucier said. “I’m excited to be part of the team and to use my knowledge to help customers realize the benefits of FactoryWiz Monitoring and DNC. I look forward to helping our industry become more connected and to embrace IOT and Smart Manufacturing.”

MORE INFO  www.factorywiz.com

Mazak INTEGREX i-630V AG cuts guesswork out of cutting

During its recent All Axes LIVE virtual event, Mazak showed shops how they can add gear cutting to their part-processing repertoires and eliminate contracting out such work by using the company’s INTEGREX i-630V AG HYBRID Multi-Tasking Machine. The machine is built on Mazak’s powerful INTEGREX milling and turning platform and performs gear milling, hobbing, and skiving with its Smooth Gear Cutting software suite featuring Smooth Gear Milling, Smooth Gear Hobbing, and Smooth Gear Skiving.

Equipped with Mazak’s MAZATROL SmoothAi control, Smooth Gear Cutting software and additional rotary axis scale feedback, the INTEGREX i-630V AG eliminates the guesswork often associated with gear cutting, particularly in terms of programming and the synchronization of turning/milling spindles at high rpm. The results are a far more refined cutting action and smoother gear teeth surface finishes.

Designed for heavy-duty 5-axis machining and large, highly complex parts, the INTEGREX i-630V AG employs a powerful turning spindle with C-axis control and a rigid milling spindle with B-axis tilt of -30/+120 degrees, both of which are monitored via rotary axis scale feedback. During the All Axes LIVE event demonstration, the machine power skived a 35-inch diameter gear made from 4140 steel.

For effective gear skiving, the mill spindle and the turning spindle must be synchronized, as any fluctuation in the turning spindle or milling spindle speeds will cause vibration and poor surface quality. If either spindle starts to fluctuate or drift off target speed, the Smooth Gear Cutting software automatically adjusts cutting parameters. Without the software, such corrections are very difficult to make in real time, if not impossible.

The software eliminates the need to program the part offline or on a CAM system and ensures synchronization. It provides a graphical user interface on the machine’s control, and users simply fill in various fields with information such as number of gear teeth, pressure angles and the like. With this information, the control will then generate a program that runs in the background as the toolpath is created.

The SmoothAi control runs the Smooth Gear Cutting software and delivers powerful digital enhancements that add efficiency and value throughout the machining process with the power of artificial intelligence (AI), machine learning and advanced data management technology. The control incorporates a wide variety of advanced programming functions for complete ease of use and to ensure high-speed, high-accuracy machining performance.

MORE INFO  www.mazakcorp.com

Authors address gear design, theory in new book

Stephen P. Radzevich, PhD, Sci.Dr., a retired professor of mechanical engineering and manufacturing engineering in Michigan, edited the new book Recent Advances in Gearing: Scientific Theory and Applications. A team of world leaders in the field cover topics intended to:

» Maximize reader understanding of the foundations of the gear theory.

» Systemize the earlier accomplishments in the field.

» Illustrate improvements in power density in gear drives.

» Provide detail on the most up-to-date measures for reduction of noise excitation,
vibration generation in gear drives, and increase of durability of gear transmission.

This book presents the most up-to-date accomplishments in gear design and gear production, detailing theory of gearing and its application. As an enormous number of gears are used in such sectors as automobiles, aerospace, machines, and similar industries, even a very small improvement in the gear design or production, for example a 10-cent savings on each gear, can result in huge savings in manufacturing, underscoring critical importance of the subject of the book.

Giving a solid background in theory together with the latest advances in design and production, the book is ideal for product designers working in numerous industries. The volume also serves as a useful supplement to required texts for students in mechanical and industrial engineering as it helps establish a scientific foundation to the subject, and facilitates a systematic learning process of gear kinematics, gear geometry, gear design, gear production/finishing operations, and related competencies.

MORE INFO www.springer.com

U.S. Navy, Air Force fund Senvol machine learning software

Data-driven machine learning software analyzes the relationships between additive manufacturing process parameters and material performance. Senvol has received further funding from the U.S. Navy and U.S. Air Force to develop additional capabilities for its additive manufacturing (AM) machine learning software, Senvol ML. Funding from the U.S. Navy is being provided by the Office of Naval Research (ONR), Naval Sea Systems Command (NAVSEA), and Naval Air Systems Command (NAVAIR). Funding from the U.S. Air Force is being provided by the Air Force Research Laboratory (AFRL).

Senvol’s AM machine learning software, Senvol ML, can be used to analyze data from any AM process, any AM machine, and any AM material. The Senvol ML software currently contains capabilities that can be used to:

- Rapidly optimize AM process parameters.
- Support qualification of AM machines and materials.
- Predict material properties.
- Gain insights from in-situ monitoring data to support quality assurance.
- Minimize data generation costs.

The Senvol ML software was made commercially available in November 2019, coinciding with the completion of Senvol’s Phase II Base STTR effort with ONR. The new funding, exercised in support of the Phase II Option, is going toward the development of new capabilities that will be rolled into the software.

Senvol President Annie Wang said, “We are very excited about the continued support from several of our Department of Defense partners. Our collective objective is to enable organizations to quickly characterize or qualify additive manufacturing materials and processes. The new capabilities that we are developing are quite compelling and will augment the Senvol ML software’s existing suite of capabilities.”

Users of Senvol ML include organizations in aerospace, defense, oil and gas, consumer products, medical, and automotive industries, as well as AM machine manufacturers and AM material suppliers.

MORE INFO www.senvol.com

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Siemens launches Sinumerik One Dynamics technology packages

Siemens recently launched three powerful technology packages exclusively for its new Sinumerik One control system. The Sinumerik One Dynamics packages are available in three different variants: ONE Dynamics Operate, One Dynamics 3-axis milling, and One Dynamics 5-axis milling. The software functions contained in each technology package support users from machine-oriented programming in the job shop to high-performance machining of CAD-CAM-programmed workpieces with high surface quality.

The One Dynamics Operate package supports the machine tool user in efficient programming in the machine shop with the proven Sinumerik machining cycles and high-quality CNC simulation for milling and turning applications. In addition, the user is given a wide range of options for accessing NC programs and workpiece documentation. Users have the option of paperless manufacturing and can, for example, visualize 3D CAD data on the shop floor within a very short time. For the execution of CAM-generated CNC programs for freeform surface machining, One Dynamics 3- and 5-axis milling packages offer the Top Surface and Top Speed Plus CNC functions for excellent motion control and perfect workpiece surfaces.

With Top Surface, the geometric data from the CAM system is checked and optimized during processing on the CNC using an intelligent algorithm. This ensures high surface quality when milling complex freeform surfaces. This is particularly advantageous for geometrically complex mold components that place special demands on surface quality, mold accuracy, and production efficiency — for example in tool- and mold-making, aircraft construction, or medical technology. Top Speed Plus ensures with new filter technology that increased dynamics are made possible without activating mechanical vibrations of the machine and that the contour accuracy is reliably maintained. Depending upon the specific application, this can reduce machining times by up to 30 percent. As a result, unit costs for milling with CAM-generated CNC programs can be reduced and production efficiency increased.

With a few exceptions, the functions of Sinumerik One Dynamics do not require any commissioning effort by the machine tool builder. Once activated, they are available to the user for immediate use on the CNC machine. Since they are CNC software functions, no intervention at the machine or in the machine’s mechanics is required. For users who have particularly challenging requirements when it comes to machining quality and speed, the machine tool builder can add additional optional CNC functions of the Sinumerik control that go beyond the Sinumerik One Dynamics packages. These additional functions must then be activated and parameterized by the machine builder for the user’s individual machine and adapted to the machine statics and dynamics.

Wayland Additive recently unveiled its breakthrough metal additive manufacturing (AM) technology NeuBeam with the commercial launch of its first platform — Calibur3. During a virtual launch hosted by the executive team from its headquarters in Huddersfield, U.K., attendees from all across the world were introduced to the new Calibur3 machine.

The full capabilities of the NeuBeam process, embedded into the Calibur3, were explained in detail to the audience by Ian Laidler, CTO at Wayland Additive. Laidler’s presentation, as well as those given by CEO Will Richardson and business development director Peter Hansford, are online at the Wayland website.

Takeaways from the launch event:

- NeuBeam introduces a step-change in performance and capability compared with existing metal AM machines on the market today.
- This is not a me-too, copy-cat product. NeuBeam is an entirely new, ground-breaking powder bed fusion (PBF) process and offers the opportunity to 3D print metal parts that cannot be produced now, due to current metal AM process limitations.
- The potential for new applications is greatly increased because NeuBeam offers the opportunity to use a much wider range of metal materials.
- NeuBeam enables the production of large parts without having to worry about residual stress or gas cross flow and without having to pre-sinter the powder bed. The printable area of the Calibur3 system is 300 x 300 x 450 mm.
- NeuBeam offers substantially reduced energy consumption and print times.
- A simplified powder removal process and significantly less post-processing are ensured with NeuBeam compared with existing EBM processes.
- The ability to produce fully dense parts in a wide range of metal materials.
- The introduction of a built-in, real-time in-process monitoring control system for an
industrial and stable production platform.
Will Richardson, CEO of Wayland, said, “It was a privilege for me to explain the genesis of our work at Wayland Additive and the ‘why’ behind the NeuBeam process and Calibur3. I think the headlines speak for themselves, and all the hard work by the Wayland team that has gone into the development of the process and this new hardware platform has been realized today. I am so proud of our team and their dedication to the launch initiative. Now it is our mission to really demonstrate the difference that Calibur3 can make for metal AM applications.”

Peter Hansford, Wayland’s director of business development, said, “The Calibur3 system featuring the NeuBeam process offers a true third way that sits between SLM & EBM systems, and provides a leap forward compared with any existing alternatives. In addition, Calibur3 promotes innovation, which should be key to any advancement in technology. And because it overcomes the compromises that most companies have to contend with when using metal AM, they can now revisit applications that were previously seen as troublesome or impossible and/or begin development projects with a clearer view of the process and more room to operate in. NeuBeam is a metal AM process that saves both time and money from end-to-end, one that can benefit commercial objectives through true production partnerships.”

Wayland Additive is planning an in-person launch event for the May, 19, 2021. Anyone interested in visiting the production studio to see the Calibur3 up close can register on the website.

MORE INFO  www.waylandadditive.com

SHINING 3D introduces the FreeScan UE metrology scanners

SHINING 3D®, a leading global provider of technologies for 3D digitization and 3D inspection, introduces the latest member of the proven FreeScan series of handheld Metrology 3D scanners with the FreeScan UE.

“Innovatively adapting blue laser 3D scanning technology, convincing with high accuracy and stable repeatability capacities rounded off by easy and convenient hardware and software handling, the FreeScan UE will empower professionals across industries to effectively and precisely upgrade their digital workflows in engineering and everyday working life. The SHINING 3D team has thus developed the latest FreeScan handheld laser 3D scanner to foster excellence and high performance even in complex and difficult operation environments, suitable for expert users and beginners alike.

Main features of the FreeScan UE include:
- High accuracy and stable repeatability: FreeScan UE boasts 0.02mm accuracy and stably delivers highly precise results independently and in many diverse application environments.
Portable and lightweight: The device weights only 670 grams, facilitating handheld scanning more easily and avoiding fatigue due to long working time.

Wide range of material adaptations: Supporting the scan of black and reflective surfaces to accommodate a wider range of scanning applications.

High efficiency: The scan area can reach 510 x 520mm, providing larger field of view for a smoother and more efficient scanning experience.

Easy operation: Totally new UI software provides a user-friendly operating system with simple software setup and guidance through the whole workflow process, allowing users to master the operation at ease.

Seamless docking to inspection software: The scan data can be imported into inspection softwares such as Control X, Verisurf Inspect, and Einsense Q with one click, increasing the inspection efficiency.

MORE INFO  www.shining3d.com

New president at Mitsubishi Machine Tool Division

After nearly six years, Atsuhiro Kawaguchi, general manager of Mitsubishi Heavy Industries America, Inc.’s Machine Tool Division, will return to Japan. Katsunori Nakamura fills the new role of president.

Nakamura has served numerous roles for Mitsubishi, most recently leading the cutting tool division in Ritto, Japan. Nakamura said, “We will work together to ensure a smooth transition and maintain the USA Machine Tool Division to be in a strong position for the sustainable growth, smooth operations and profitability, all with keeping our concept of ‘Legendary Reliability’ for the future.”

In other personnel actions, Neil Sawyer has been promoted to senior vice president — service and administration. Sawyer has more than 20 years with Mitsubishi and will take on more duties including development of suitable organization structure and strategic planning for the future needs of MTD.

The Machine Tool Division in Wixom, Michigan, provides service, support, and sales for Mitsubishi Heavy Industries machine tools. These include gear hobbers, shapers, shavers, gear grinders, as well as large machines such as the MVR-Ex double column milling machine.

MORE INFO  www.mitsubishigearcenter.com

Mitsubishi Machine Tool Division’s Katsunori Nakamura, left, accepts the symbolic torch from Atsushiro Kawaguchi. (Courtesy: Mitsubishi)
Trade Update: Key trade challenges, opportunities facing the gear industry in 2021

Last year was a momentous year for the gear industry, with COVID-19, a shortage of semiconductors that slowed vehicle production, and rapid swings in consumer demand all contributing to one of the most challenging environments that the industry has seen in decades. Add to this the many trade issues — from the on-going U.S.-China trade dispute to new trade and investment rules for U.S. manufacturers, importers, and exporters, and 2020 was truly one for the record books.

Thus far, 2021 shows no sign of any slowdown in the trade issues facing the industry. This article addresses what are arguably the most important of these issues and provides tips on how to best position yourself in the months ahead.

1. RENEWED FOCUS ON CROSS-BORDER SUPPLY CHAINS IN THE TRANSPORTATION INDUSTRY

The COVID-19 epidemic and on-going trade dispute with China have focused attention in Washington on the supply chains that are so critical to U.S. national and economic security — including the transportation industry. This has prompted a flurry of new initiatives that will affect the gear industry throughout 2021:

- In February, President Biden ordered a review of transportation industry supply chains. This review is expected to result in multiple executive branch initiatives focused on the R&D and manufacturing capabilities of the U.S. industry and the degree to which it relies on overseas supply chains.
- Congress is also considering new funding, trade regulations, and tax incentives to promote investment in the U.S. transportation industry and U.S. supply chains.
- Closely linked to these initiatives are new efforts to use a nearly 100-year-old law — the “Buy American Act” — to give preference to U.S.-made goods in federal contracts. Specifically, on January 25, Biden signed an Executive Order that makes changes to how the Buy American Act is implemented, including raising domestic content requirements and changing how domestic products can qualify for preferential treatment. The federal body that administers U.S. procurement rules [i.e., the Federal Acquisition Regulations (FAR) Council] must develop new regulations to implement these changes by July 24, 2021.

These initiatives represent just the tip of the iceberg of the changes that are likely to affect U.S. procurement and trade flows this year. Indeed, according to the website GovTrack, as of the writing of this article, nearly 50 bills already have been introduced in the Congress to expand or modify federal contracting rules or provide new funds for investment in U.S. contractors — including in areas like transportation that directly concern companies in the gear industry.

Companies that supply products to the federal government or are looking to expand in that area should make sure they understand both the existing FAR rules and the new proposals coming out of Washington. Investing in advice from a government contracts specialist can mean the difference between sales lost or won and can help companies to avoid the many traps for the unwary that government contracting rules can sometimes present. At the same time, companies should consider engaging with policymakers to make sure their views are heard. As they formulate the new rules of the road, policymakers will benefit from this feedback to help ensure that the new rules achieve their intended objectives.

2. CONTINUED FOCUS ON EXPORT CONTROLS AND NATIONAL SECURITY ISSUES

This year is also unlikely to see any slowdown in new U.S. export control and national security initiatives — with a continued emphasis on China.

- Many technologies used or produced by the gear industry — including advanced materials, precision equipment, and design and production software, among others — have long been subject to export-licensing requirements. Changes to the U.S. export control laws that began last year have further restricted the export or transfer of these technologies — especially to customers in China, Hong Kong, Russia, and Venezuela. In many cases, products that could once be exported freely to these countries now require a license — particularly to major companies in China and Russia that the United
Upcoming Education

April 29, 2021

**External Helical Gear Contact Mesh Analysis***

Evaluation of loaded tooth contact and development of tooth modifications using commercially available software to improve Khb and optimize power density. Two real life gearing examples will be presented in the course, one will have a cantilever mounted pinion, the other a shaft pinion straddled non-symmetrically by bearings. This course is IACET accredited and worth 0.3 CEUs.

*Deadline to sign up is April 22, 2021.

May 12-13, 2021

**How to Read and Interpret a Gear Inspection Report***

This new and expanded eight-hour online course is intended to provide you with a thorough understanding of the attributes of a gear and how their design are critical to ensure the required operation and function of the gear system as expected. This course is IACET accredited and worth 0.6 CEUs.

*Deadline to sign up is May 4, 2021.

Emerging Technology Webinar Series starts In April

The goal of the AGMA Emerging Technology committees is to identify, investigate, and inform AGMA members of emerging technologies that may disrupt or significantly affect the power transmission industry. To fulfill this promise, AGMA introduces a high-level Emerging Technology Webinar Series. Join us the first Wednesday of the month for a speaker on a topic chosen by one of the four AGMA committees: IIoT, electric drive, robotics & automation, or 3D printing:

**APRIL:** Let’s Understand How to Comply with CMMC — Jon Powvens, Director of Cybersecurity for MxD.

**MAY:** Learn more about Center for Automotive Research Industry X — Brett Smith, Director, Technology for CAR.

**JUNE:** How Software Can Level the Playing Field for Robot Integration — Dr. Kel Guerin, Co-Founder and CIO for READY Robotics.

**JULY:** Harness the Power of Machine Data — Graham Immerman, VP of Marketing for Machine Metrics.

**AUGUST:** When Discussing Electric Vehicles, You Must Talk About the Consumers — Ike Dovorany, VP, Automotive & Mobility for Escalent.

**SEPTEMBER:** AGMA’s Emerging Technology Efforts – What’s Next? — Mary Ellen Doran, Director, Emerging Technology for AGMA.

These webinars are free for members. Register today at www.AGMA.org.
TRADE UPDATE: KEY CHALLENGES FOR 2021
CONTINUED FROM PAGE 17

States has designated as "military end users" or has listed on the U.S. "Entity List."

At the same time, the U.S. government continues to scrutinize investments in the gear and related industries under the Committee on Foreign Investment in the United States (CFIUS) national security laws. Importantly, CFIUS scrutiny can extend to overseas joint ventures and other transactions outside the United States that give non-U.S. companies access to U.S. technology.

Broad bipartisan support for these initiatives means there is unlikely to be any significant rollback or change of course this year. Indeed, we may see further restrictions imposed as the Biden Administration and Congress examine whether and how best to use export controls and CFIUS-like reviews to strengthen U.S. manufacturing and supply chains in critical industries.

Companies in the gear industry that export from the United States or that use U.S. technologies in their products and research and development should closely monitor these changing requirements and invest in compliance — including close scrutiny of their customers, investors, and supply chains. Companies should recognize many projects that previously could occur in China or Russia without a license may now require careful licensing review and may need to be paused or put on hold until a license can be obtained.

3. TRADE AGREEMENTS

2021 will be a busy year for trade agreements, although we are unlikely to see significant new agreements before the end of the year. Close to home, the United States, Canada, and Mexico continue the hard work of implementing the U.S.-Canada-Mexico Agreement (USMCA), the successor to NAFTA. Among the issues that may affect the gear industry under USMCA are changes to the rules of origin for duty preferences and new environmental and labor chapters.

March 2021 has also seen a significant thaw in U.S.-EU-U.K. trade tensions, with the United States, EU, and U.K. suspending tariffs imposed in response to the ongoing dispute over subsidies for civil aircraft production and the United States and EU reportedly making progress on the EU’s proposed carbon-tax on imports. These developments may signal a renewed opportunity for further U.S.-EU-U.K. cooperation on trade issues, including potentially a new U.S.-U.K. trade agreement and reduction in U.S.-EU trade tensions.

Finally, while the prospects of an end to the U.S.-China trade dispute and a lifting of Section 301 and Section 232 tariffs seems remote at present, the Biden Administration has signaled that it intends to engage with China and other trading partners where possible and to review existing tariffs to ensure they appropriately balance U.S. trade interests while minimizing adverse impacts on U.S. companies and workers. How fast or how far these initiatives can go remains to be seen, but companies with interests in these markets have an important role to play and should ensure their views are known to policymakers and Congress.

4. TRADE LAW ENFORCEMENT

Laws generally known as the U.S. "trade remedy" or "antidumping and countervailing duty" laws allow companies with production facilities in the United States to petition the U.S. government to impose duties on imports of merchandise found to be unfairly subsidized or sold at less than fair value, causing injury to a U.S. industry. Such laws have been used with increased frequency in recent years. Indeed, there have been more than 160 successful AD/CVD cases since 2018 alone. In many instances, the duties imposed have been higher than 150 percent of the value of the imported merchandise.

Recently, trade remedy cases have focused on key components used in the transportation and related industries, including steel wheels, for a variety of vehicles. Cases are also increasingly being filed against more advanced products, materials, and systems (such as internal combustion engines). Those cases already have had a significant impact on U.S. manufacturers of those products — leading to a sharp reduction in imports from countries subject to the orders — notably China — and allowing affected U.S. companies to recover or even expand their own production and sales.

There is unlikely to be any slowdown in case activity this year. Indeed, 17 new antidumping and countervailing duty orders have gone into effect since January 1, 2021, and more than 20 more are under consideration.

Moreover, the trade remedy laws are playing an even more important role as the Biden Administration and Congress look to strengthen U.S. manufacturing. For example, key congressional stakeholders, including Sen. Robert Casey (D-PA), are reportedly considering new legislation that would enhance the ability of the U.S. government to “self-initiate” AD/CVD cases where foreign subsidies, dumping, or other market distortions are reducing investment in U.S. development and manufacturing of critical technologies and products. As leaders in many of the priority technologies that Congress and President Biden have highlighted as essential to U.S. national and supply chain security — such as transportation, advanced materials, and aerospace, to name a few — companies in the gear industry will undoubtedly be affected by these and similar proposals.

CONCLUSION

The bottom line is 2021 will see many critical trade policy decisions and new trade laws that will shape the direction of the gear industry for years to come. Companies that engage with policymakers and closely monitor these developments will be well positioned to minimize any adverse impacts and take advantage of the new opportunities that our ever-evolving trade laws present.

To help you better understand and prepare for these challenges and opportunities, AGMA is continuing its regular trade webinar series for the remainder of 2021. This year, we are excited to be partnering with the law firm DLA Piper LLP and its more than 80 offices around the world to examine cutting edge trade issues from an expanded global perspective. Be sure to check regularly for further details on the webinar series at www.agma.org/education/online/webinars.

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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.

APRIL
- April 15 — Lubrication Committee Meeting — WebEx
- April 22 — Gear Accuracy Committee — WebEx
- April 27 — Nomenclature Committee — WebEx
- April 27 — Robotics & Automation Committee Meeting — WebEx
- April 29 — Metallurgy & Materials Committee — WebEx

MAY
- May 6 — Market Intelligence Committee Meeting — WebEx
- May 12 — Bevel Gearing Committee Meeting — WebEx
- May 13 — TDEC Meeting — WebEx
- May 20 — Lubrication Committee Meeting — WebEx
- May 27 — Nomenclature Committee Meeting — WebEx

JUNE
- June 3 — Metallurgy & Materials Committee — WebEx
- June 9 — Gear Accuracy Committee — WebEx
- June 18 — 3D Printing Committee Meeting — WebEx
- June 29 — Robotics & Automation Committee Meeting — WebEx

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With 70 years of experience, we can handle all your custom workholding needs. Drewco Corporation is a family run business led by a team of engineers and machinists. We are backed by original patents, years of experience, and proven effective designs.
Dissimilar material and/or hardness as a function of gear size

Poor performance in terms of the application of material properties and/or heat treatment can make a good theoretical gear design provide unsatisfactory service.

Some say that metallurgy is a “black art.” Actually, it is a very skilled art, demanding in its precision and consistency. The people who practice metallurgy and tribology are very skilled in these arts, techniques, and technologies. The appropriate selection and specification of material for a gear pair design, coupled with the precise implementation of the requirements of heat treatment to optimize material performance, as we all know, can make a gear design perform admirably. Just as easily, poor performance in terms of the application of material properties and/or heat treatment can make a good theoretical gear design provide very unsatisfactory service.

As we have learned from our studies and through implementation of the various calculations and design techniques, materials play an integral role in gear design, specifically in expected or predicted service life, either through high cycle fatigue as in surface compressive stress or tooth root failure. Certainly, there are considerations regarding the environment, specifically as resistance to corrosion, magnetic fields interference, food, and medical environments. Some materials are even used to dampen or attenuate NVH issues as a function of their properties and/or internal structure.

There are many considerations when selecting a material for a gear pair. As we all know, the design of a gear set is influenced by the application and even more by the anticipated failure mechanism; long life versus catastrophic tooth bending. The presence or absence of shock loading, temperature extremes and even external sources of vibration may add to the frequency response spectrum of the gear mesh and support bearing pass frequencies. Even more detailed considerations are required for the selection of two differing materials in a gear pair or, as a minimum, the difference in metallurgical properties of the same or similar materials in mesh.

This is a wide-ranging subject, and the expanse is beyond the room we have here. The concentration will therefore be on the subset of the topic; material dissimilarities within the contact patch. As well, an in-depth discussion of microstructure is beyond the scope of this article. It is worth mentioning that the degree of martensitic structure is one of the prime indicators of a material’s quality. AGMA 2004-B892 does a good job of identifying other microstructural aspects that must be considered.

Base material properties are also considered in wear rates. As the most obvious example, balancing wear of a worm relative to the wheel it runs with is the analytic mechanism used to determine the service life of a worm and wheel gearset. Generally speaking, the material of the wheel is selected to provide good performance in terms of sliding by either providing self-lubrication or, as a minimum, enhancing the function of the elastohydrodynamic shear layer in the lubricant between the two gear surfaces.

As designers, we can reverse the use intent and solve for desired strain energy distribution as a function of material properties, thus gear material, condition, quality, and heat treatment become a design variable.

The specific effect of differences in material properties, specifically surface hardness, case depth, and microstructure are embedded in even the basic form of the Lewis equation. Two factors of interest are the Load Distribution Factor \( K_m \) and \( K_H \) and the Elastic Coefficient \( C_p \) and \( Z_b \). The Load Distribution Factor is a mathematical means to describe the distribution of contact stress (applied load) across the surface of the gear tooth. The contact interface area (contact patch) is defined by the amount of local elastic deformation that occurs within the tooth surface and as a function of the induced stress by contact with the mating tooth. The local elastic deformation is basically a ratio of the flexibility of the surface of one tooth, within its elastic range, as a function of the interfacial geometry shared between the two teeth at the instantaneous point of contact and the load distributing effect of the elastohydrodynamic shear layer. This also has the effect of positioning the maximum sub-surface shear stress below the surface of the gear tooth. This effect is a combination of two factors, the thickness of the elastohydrodynamic shear layer causes the shear strain energy (induced by the sliding velocity and the resistance to shear in boundary layer lubrication) to induce a couple or moment at the surface of the gear tooth, which in turn causes the reaction (counter-couple) to reach maximum strain energy a non-negligible, measurable distance below the surface of
the tooth. This separation of the position of maximum strain energy (e.g. compressive and shear) explains why the loaded tooth deflects locally just enough to stay below the yield limit of the material. The functional definition of yield limit in this case is the applied load that would cause the material to transition from its elastic range to its plastic range.

How do different materials and optimized heat treatment enhance this effect? By making the induced strain energy in both the driver and the driven tooth equal in both surface compressive and sub-surface shear stress. This is very theoretical and the actual calculations, etc., are beyond the scope of this article, but the procedure is well documented in the various standards and implemented in any number of analysis tools.

The other factor or effect, the Elastic Coefficient, ratios the induced strain energy into the surface of each gear (driver and driven) in a manner that compares by a simple weighting factor the differences in both Young’s modulus and Poisson’s ratio of the two materials. The AGMA development based on the Lewis equation calculates the effect of the differences in the material attributes (Young’s modulus and Poisson’s ratio) to attempt to evenly distribute the strain energy in both gear tooth surfaces. As designers, we can reverse the use intent and solve for desired strain energy distribution as a function of material properties, thus gear material, condition, quality, and heat treatment become a design variable. I encourage anyone interested in exploring this effect to take a fairly standard gear design and run through a small number of simulations by varying both material properties (different materials) and heat treat (basically surface hardness) for one of the two gears.

Another aspect of dissimilar material selection and heat treat specification is the ability to use these design variables in the prediction of high cycle fatigue. As discussed earlier, the difference in or balance of material properties as a function of high cycle fatigue is affected by the distribution of strain energy within the contact patch (2D surface) and sub-surface (depth of effect). As we know, work hardening is a function of both base material properties and the effect of surface heat treatment. For a high-cycle gear design, the designer can use material dissimilarities as a means to predict localized work hardening. All these techniques are based on theory and although there is a great deal of empirical evidence to support these theories, as always, the best way to ensure your result is through testing.

About the Author

Dr. William Mark McVea, P.E., is President and Principal Engineer of KBE+, Inc. which develops complete powertrains for automotive and off-highway vehicles. He is the Principal Engineer with Kinatech, a joint venture with Gear Motions / Nixon Gear. He has published extensively and holds or is listed as co-inventor on numerous patents related to mechanical power transmissions. Mark, a licensed Professional Engineer, has a B.S. in Mechanical Engineering from the Rochester Institute of Technology, a Ph.D. in Design Engineering from Purdue University.
Mounting accuracy key issue in gear system design

Understanding how mounting accuracy affects gearing performance.

Some assembly required. These dreaded words are frequently found on the packaging of many weekend projects. Whether it is assembling a desk for that new pandemic home office or building the new BBQ grill you received as a Father's Day gift, we always hope that all of the parts are included and that they fit together as expected.

When it comes to gearing, there is a misnomer that in order to design the best gear system you must use the most precise gears. However, even if the gear is produced with high accuracy, if the gear is not mounted properly, it is not possible to avoid the problems of bad tooth contact: noise, wear, and breakage.

One of the errors that can occur in assembly of gear pairs occurs with the center distance. Errors occurring with the center distance of two gears directly influence the backlash of the gear mesh. If the center distance value is increased, then the backlash value is increased. As a result of this increased center distance, the gear teeth cannot mesh deeply enough into each other, and the contact ratio decreases. If the center distance value is decreased, then the backlash value also decreases. If the backlash decreases too much, the gears’ ability to rotate is inhibited. Table 1 shows the center distance tolerances for spur and helical gears. The tolerance values in this table are quoted from JGMA 1101-01 (2000) and are applicable for involute spur and helical gears that are made from steel.

Another error that can occur in assembly of gear systems occurs with the axial parallelism of the pair. The accuracy of two parallel axis gears is composed of the parallelism error and shaft offset error. These errors influence the tooth contact in the tooth trace direction. They may also result in bad tooth contact occurring at the tip of tooth width. Any increase of these errors results in the decreasing the backlash and will cause both noise and tooth breakage. Tables 2 and 3 detail the shaft parallelism error tolerances and the offset error tolerances for spur and helical gears, as detailed in JGMA 1102-01 (2000). Figure 1 details the location of these tolerances.

Being aware of the different tolerances during assembly is necessary and will allow the gears to perform as designed. Setting the gears at the proper center distance and axial alignment will help to maintain the proper backlash and the desired tooth contact. With these two factors in check, the gear system will exhibit minimal noise and will achieve the designed gear life.

Table 1: Center distance tolerance of spur and helical gears ± \( f_a \)

<table>
<thead>
<tr>
<th>Center Distance (mm)</th>
<th>Accuracy Grade of Gears</th>
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<tr>
<td>More than 5</td>
<td>Less than 20</td>
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<tr>
<td>5</td>
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</tr>
<tr>
<td>280</td>
<td>560</td>
</tr>
</tbody>
</table>

Table: 1: Center distance tolerance of spur and helical gears ± \( f_a \)

Figure 1: Shaft parallelism error and shaft offset error.

ABOUT THE AUTHOR

Brian Dengel is general manager of KHK-USA, which is based in Mineola, New York. Go online to www.khkgears.us
Table 2: Allowable in-plane deviation with respect to parallelism of axes per facewidth $f_x$

<table>
<thead>
<tr>
<th>Reference diameter $d$ (mm)</th>
<th>Facewidth $b$ (mm)</th>
<th>Accuracy grades</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N5</td>
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<td>$5 \leq d \leq 20$</td>
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</table>

Unit: $\mu$m

Table 3: Allowable out-of-plane deviation with respect to parallelism of axes per facewidth $f_y$

<table>
<thead>
<tr>
<th>Reference diameter $d$ (mm)</th>
<th>Facewidth $b$ (mm)</th>
<th>Accuracy grades</th>
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</thead>
<tbody>
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<td></td>
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Unit: $\mu$m

April 2021 25
Determining carbon potential for neutral hardening or carburizing

Effect of steel alloying content on the effective atmosphere carbon potential.

To successfully heat-treat or carburize the many different alloys seen in the heat-treating shop, it is necessary to properly control the carbon potential of the atmosphere. In neutral hardening, this means that the carbon potential is neutral to the part and is neither carburizing nor decarburizing. In carburizing, this means that the desired surface carbon content is achieved so that the desired case depth is achieved.

A typical heat-treating atmosphere for steel is shown in Table 1. The CO₂ concentration will vary depending on the desired carbon potential. Regardless of the source of the atmosphere, it is important that the carbon monoxide, CO, content be maintained at 20 percent (23 percent in the case of propane). If the carbon monoxide percentage is not maintained at 20 percent, then the oxygen probe will not read the correct carbon potential. If propane is used, then the carbon analyzer must be adjusted to reflect the percentage of CO from propane. All the charts and graphs used to determine carbon potential from dewpoint are based on a carbon monoxide content of 20 percent.

An oxygen probe or carbon probe consists of platinum electrodes separated by a yttrium-doped zirconia tube. The probe is inserted into the furnace or generator. An air supply of approximately 0.5 CFH of air is supplied to the probe as a reference. The differential oxygen partial pressure between the furnace atmosphere and the reference atmosphere sets up a voltage across the probe. By measuring this small voltage (measured in millivolts), the carbon potential can be determined. Thus, the furnace atmosphere carbon potential can be controlled by air and natural gas additions by monitoring the voltage potential across the probe. In modern instruments, this is done internally using microprocessors. In many ways, it operates in a similar fashion to the O₂ sensor in a car for proper combustion.

The advantage of an oxygen probe is that it is accurate and fast. A direct read-out of the carbon potential of the atmosphere is common. The probe has a high temperature range suitable for high temperature carburizing. Little maintenance is required.

The primary disadvantage of the oxygen probe is that it assumes a fixed CO content (typically either 20 percent for natural gas or 23 percent for propane). If the CO content is not at this fixed value, then the readings obtained by the probe are erroneous. The oxygen probe is also a ceramic tube, and prone to thermal or mechanical shock. It must be routinely replaced at roughly yearly intervals, depending on the application. Heavy carburizing can shorten the life of the probe. However, the accuracy, ease of use and lack of maintenance, generally outweigh the disadvantages.

**CONTROL OF CARBON POTENTIAL**

While it has been previously established that it is critical for the atmosphere composition to consist of 20 percent CO for the carbon probe to be read accurately, this carbon content is not necessarily that seen by the part. In atmosphere control during heat treatment, there are different reactions that occur:

- Reactions in the gas phase.
- Diffusion in the gas phase.
- Reactions at the steel surface.
- Diffusion in the steel.

The kinetics of the reactions in the gas phase can be neglected because they are sufficiently fast compared to the kinetics of carbon diffusion in the steel, and if the atmosphere is stable. It has been shown [1][2] that diffusion in the gas phase is not rate determining. A properly calibrated carbon probe will provide an accurate representation of the atmosphere carbon potential provided that the atmosphere is stable and near equilibrium (and at 20 percent CO).

The activity of carbon in steel, \( a_c \), in dilute solutions, is [3]:

\[
a_c = 1.07q \left( \frac{c}{100 - 19.5c} \right) \exp \left( \frac{4798.6}{T} \right)
\]

Where \( T \) is the temperature in degrees K and \( q \) is the adjustment in carbon activity due to alloying element additions. The adjustment in the carbon activity coefficient, \( q \), is given by [3]:

\[
q = 1 + \%\text{Si}(0.15 + 0.033(\%\text{Mn}) + 0.365(\%\text{Ni}) - (\%\text{Cr}(0.13 - 0.0005(\%\text{Cr})) + (\%\text{Ni}(0.03 + 0.0365(\%\text{Ni}) - (\%\text{Mo})(0.025 - 0.01(\%\text{Mo})))) - (\%\text{V}(0.22 - 0.01(\%\text{V}))
\]

This data has been compiled for multiple alloys (Table 2). The calculations have been shown so the reader can check his/her (and my) work.

For the most part, the effective carbon potential is higher than the carbon content in the steel. In some steels, the effective carbon potential is slightly lower than the carbon content. In these cases, it is best to use the carbon content in the alloy. These equations are powerful when trying to neutral harden alloys with very tight decarburization or carburization limits. They enable precise and repeatable carbon control.
CONCLUSIONS
In this short article, we described a method for determining the proper carbon potential to use with a given alloy to reduce the chance for decarburization or carburization when neutral hardening. It can also be used to obtain the necessary carbon potential when carburizing and selecting the proper surface carbon content.

Should you have any questions regarding this article, or suggestions for future articles, please contact the author.

REFERENCES


ABOUT THE AUTHOR
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Table 2: Effect of alloying concentration on the effective activity of carbon.

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<th>SAE Steel</th>
<th>%C</th>
<th>%Si</th>
<th>%Mn</th>
<th>%Cr</th>
<th>%Ni</th>
<th>%Mo</th>
<th>%V</th>
<th>HT T (°C)</th>
<th>HT T (°K)</th>
<th>a_v</th>
<th>q</th>
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<td></td>
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<td>1118</td>
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Hob quality is critical to high-quality gear manufacturing, and this concept begins with the purchase of certified, high-quality hobs that meet AGMA standards.

By ADAM GIMPERT

The quality of a hob directly affects the final quality of the gear it generates. AGMA has developed a standard covering the allowable tolerances for fine and coarse pitch hobs. This standard is ANSI/AGMA 1102-B13, Tolerance Specification for Gear Hobs, which is the latest revision of AGMA120.1. If there is a quality problem in the hob, a manufacturer can usually identify it in the profile of the gear. Some considerations follow to help avoid and troubleshoot this problem.

Naturally, the price of a hob is directly related to its quality. Today’s higher quality gear requirements demand the use of higher quality cutting tools, typically AGMA AA or AAA. For example, a AAA carbide hob may carry a 30 percent price premium compared to its AA version. Such high standards ensure no hob errors generate poor gears. When weighing the costs and benefits of high-quality hobs, manufacturers should analyze the per-part cutting tool cost based on tool life experience or estimates provided by the hob vendor.

HOB MOUNTING

The first item to consider when eliminating sources of error in a hobbed gear is the mounting of the hob. The condition and the cleanliness of the hub and hob arbor surfaces are critical, and these surfaces should be free of any particles, chips, grinding dust, nicks, burrs, or damage. Manufacturers must use high-precision hob arbors. Please keep in mind that something that was once high precision may lose all precision due to everyday wear. Hob arbors must be maintained with the utmost care. Any damage that occurs to this item could produce errors in sharpening and subsequent hobbing. If spacers are used, the faces must be parallel to within 0.0001”. On arbors that use a threaded nut, the clamping face of the nut must be perpendicular to the threads to within 0.0001”. It is also recommended that the threads be ground. (Figure 1)

When mounting a hob, the following procedure should be used: The hob should first be mounted on the arbor with the nut hand tight and checked for excessive runout. If the hob does not run true, the centers should be checked for particles or chips of any type. If there is nothing in the centers, the arbor should be checked for runout along its entire length, as it may be bent. The nut should next be tightened and the hob checked once again. If spacers are being used and the hob does not run true, the spacers should be rotated. After rotating the spacer, the nut should be tightened, and the hob should be checked again. If there is still runout after two or three times, the spacer should be checked for parallelism.

INSPECTION OF HUB DIAMETERS AND FACES

Hob manufacturers pay close attention to the hub diameters and the faces of the hubs. These features are the reference surfaces that are used during the manufacturing of the tools. Extreme care must be taken to ensure these surfaces are kept free from

Figure 1: Arbor for hob.

Figure 2: Example of indicating hub radial runout.
nicks and other handling damage. The hubs and the faces are used to true-in the hob every time it is mounted in either the hobbing machine or the hob sharpener.

Hob manufacturers normally use the end faces to mark the hob data, such as diametral pitch, pressure angle, lead angle, quality, etc. This marking may be done using a chemical etching process or by burning the data into the face using a laser. In both cases, material buildup is avoided, unlike regular engraving or milling. The latter cases dig into the surface of the tool and will raise high spots in the surface in the process. In this case, manufacturers can make sure the surface is stoned smooth prior to mounting the tool onto any arbor. Any material buildup could cause the hob to not run true during mounting.

As shown in Figure 2, the radial runout of the hubs can be measured by mounting the hob on a test arbor between centers. A test indicator with a 0.0001” resolution is then placed so that its stylus is positioned on the outside diameter of the hub. The hob is then rotated, and the radial runout is measured. Both hubs should be checked to ensure that both hubs are running true.

In Figure 3, the axial, or face runout of the hubs, can be measured in the same way, except the stylus of the indicator is placed on the face of the hub instead of the outer diameter. Before any other inspections are made, you must ensure that these two checks are verified, and that the radial and face runout is within the tolerance limits set by the ANSI/AGMA 1102 standard for the hob’s quality specification.

RAKE INSPECTION

Most hobs are designed with a zero (radial) rake cutting face. Radial rake hobs are the easiest to sharpen and check for errors. After sharpening a hob, the rake should be inspected and conform to the hob’s quality standard. While most hobs are designed with a radial rake, special application tools, such as skiving or dry hobbing, may require a negative- or positive-rake hob. When the hob is resharpened, the rake of the tool must be returned to the original rake design; otherwise, gear profile errors will be generated during hobbing.

Rake error affects the generated pressure angle that the tool will produce. Figures 4 and 5 show the results of a gear that is hobbed with a tool with rake errors.

If the rake error exceeds the hob’s quality standard tolerance, the hob sharpening process should be adjusted and the hob sharpened again until the variation is brought within tolerance. On most hob sharpening machines, correcting the rake error is accomplished by moving the grinding wheel to the centerline of the hob for zero rake tools or moving to the correct offset for positive and negative rake tools.

HOB SHARPENING

A critical aspect of maintaining hob quality is proper resharpening
of the tool. If the hob is sharpened incorrectly, the original tool geometry will be lost. Since the correct tool geometry is what produces the desired profile, any flaws in the tool geometry will show up on the finished profile.

When hob sharpening, some areas to address are the grinding wheel spindle, work spindle, and tailstock. First, the grinding spindle should be extremely rigid and without any end play. If there is end play or rigidity problems in the system, the hob will most likely have a bad finish, and teeth could be chipped during grinding. A loose grinding wheel nut can cause the same problems. Second, the work spindle must run true. If there is any runout in this spindle, it will be transferred to the hob during grinding. Third, the tailstock must be in line with the work spindle. If the tailstock is out of alignment, there is a good chance the hob will be sharpened with gash lead error.

SUMMARY
In closing, the above issues do not exhaust the many issues important to hob quality, but they offer a good start for the novice gear manufacturer. Hob quality is critical to high-quality gear manufacturing. This concept begins with the purchase of certified, high-quality hobs that meet AGMA standards. Applying these hobs successfully requires proper inspection of the mounted hob before its use in a hobbing operation. Lastly, rake error and poor sharpening are straightforward errors to troubleshoot from their effects on inspected gear profiles.

ABOUT THE AUTHOR
Adam Gimpert is president of Helios Gear Products.
Gleason has developed a Pitch Line Ector that will average gear member runout to within 0.0005" (0.0127 mm) to the pitch line — and can be as accurate as 0.0002" (0.005 mm). (Courtesy: Gleason)
A new fixture design minimizes runout and helps ensure greater accuracy for hard finishing and inspection.

By BRIAN BALDECK and IAN SCHICKLING

Gear manufacturers are turning to workholding to help reduce costs without compromising quality. Pitch Line Fixtures, for example, can be used to provide a more precise relationship between the pinion/gear member datums and the gear teeth, thus reducing the amount of runout on those datums relative to the pitch diameter (pitch line) of the gear or pinion. Since undesirable runout results from heat treatment and other manufacturing processes that can cause distortion, Pitch Line Fixtures are particularly well suited for hard finishing and inspection applications.

A BETTER MOUSETRAP

Gleason has developed a Pitch Line Fixture that will average gear member runout to within 0.0005” (0.0127 mm) to the pitch line — and can be as accurate as 0.0002” (0.005 mm). The application determines the required accuracy. If used in a grinding application where normally 0.004” (0.1016 mm) of stock is removed off each gear flank, then the runout to the bearing journals of 0.0005” (0.0127 mm) would be sufficient. However, if used for hard turning with no subsequent finishing or lapping applications, then 0.0002” (0.005 mm) would be more appropriate.

Gleason Pitch Line Fixtures are designed with the pitch pins perpendicular to the gear tooth pitch diameter for optimized strength, accuracy, and wear. This offers significant advantages over conventional designs, where the pins in a pitch line fixture point straight up (parallel to the axis of the part) resulting in a reduction in radial accuracy and stiffness of the centering function. For example, in pinions with a slim pitch angle of 20°, the forces on the balls and the pins are not directed in the axial pin direction, thereby reducing the force perpendicular to the pitch angle to only 34 percent (sin20°) in the axial pin direction and 94 percent (cos20°) perpendicular to the pin. This high perpendicular force will ultimately wear the pin sleeves and also bend the pins. In the case of ring gears, this effect is smaller, but the same accuracy and wear issues will occur over time.

APPLICATION VERSATILITY

Pitch Line Fixtures can be designed to meet the needs of a wide range of customer workholding applications: mechanically or hydraulically actuated, tailstock driven, compatible with quick change base equipment, incorporating a spring-loaded pre-centering mechanism, and including mechanically activated holding jaws.

The recommended clamping method is determined by the application. For example, a pinion being held in the Pitch Line Fixture by a tailstock would not require clamp blocks on the pinion head for holding the pinion in place.

For a ring gear member, straps are often used on the back angle if the process requires that the bore be machined as well as the mounting surface. These pitch line features would be incorporated as required into the design of the fixture.
Another significant workholding breakthrough is Gleason’s new Modular Standard Workholding, which puts the performance benefits of tool-less quick change workholding into a system of standard, interchangeable, and readily available modules.

In recent years, Gleason’s Quik-Flex® and Quik-Flex®Plus systems have revolutionized workholding changeover for small- and medium-size cylindrical gears with a system of modules that can be installed on a base arbor permanently mounted in the work spindle with just the twist of an activation handle.

These new solutions can be installed and removed in just seconds, with only a single tool, and by even a novice.

With introduction of a system of Modular Standard Workholding, Gleason puts this same Quik-Flex performance into a system of small, medium and large standard interchangeable modules that span the most common range of gear diameters.

Now, there’s an in-stock, off-the-shelf solution available to users almost overnight to meet the latest workholding requirements of many of the most common cylindrical gear bore sizes and diameters.

End result: elimination of many weeks of waiting, and the inherent cost, for special tooling whenever a new application arises.

Each module consists of an interchangeable clamping head connected to an interchangeable arbor body, both of which come in a variety of sizes to form a multitude of standard combinations to fit the user’s part specific application requirements.

No other tools are required, nor are there any of the usual mounting bolts, set screws, or ejector screws to deal with.

Note that an internal cam locking mechanism built into the base ensures that modular collecting tooling is centered and drawn firmly against the seating face of the base.

Most importantly, Modular Standard Workholding makes no compromises on quality. Accuracies and repeatability of 5 microns (0.0002”) TIR — identical to other Gleason workholding — are guaranteed.

ABOUT THE AUTHORS

Brian Baldeck is manager of Design, Engineering & Assembly for the Tooling Products Group, Ian Schickling is Lead Tool Design Engineer with Gleason Corporation. For more information on how Gleason Pitch Line Fixtures can be used to help reduce cost and improve accuracy, go to www.gleason.com.
At MPT Expo, you’ll see the full range of power transmission solutions, including hybrid solutions, utilizing mechanical power transmission, pneumatics, hydraulics, electric motors, and drives.
PREDICTING GEAR SLIDING LOSSES
Incorporating the effect of lubrication characteristics, gear geometry, surface finish, and operating conditions into an algorithm can accurately predict sliding losses over a range of operating conditions for a standard set of gears.

By PARVIZ MERATI, JOHN BAIR, CARLOS WINK, and FARRUKH QURESHI

Gearbox efficiency is becoming increasingly important for vehicle manufacturers to help achieve their overall fuel savings goals. Enhancing gearbox efficiency is also critical in saving the up-front cost and overall unreliability of gearbox cooling. It is well known that at high power levels, for current low-speed gears, gear sliding losses dominate the overall gearbox losses. Therefore, accurately predicting frictional losses is crucial for increasing overall gearbox efficiency. Previous work by these authors has shown that available closed-form calculations do not provide the range of important inputs or accuracy required to perform reliable design estimates of the sliding losses that are so important to the thermal and efficiency characteristics of the gearbox. This paper documents an approach used to incorporate the effect of lubrication characteristics, gear geometry, surface finish, and operating conditions into an algorithm that accurately predicts sliding losses over a range of operating conditions for a standard set of gears. This study provides a method for accurately calculating gear sliding losses based on all the important design variables early in the process so that efficiency can be more easily assured. The methodology developed for simple contacts is used to predict gear sliding losses for much more complicated cases of spur and helical gears, where load and rolling and sliding speed of the contact patch varies at each roll angle during the mesh cycle.

INTRODUCTION
The prediction of the coefficient of friction and resulting sliding losses in lubricated sliding-rolling contacts is a challenging problem. Under heavy loads and varying shear rates, the behavior of the shear stress, which determines the traction coefficient, is complex. The traction coefficient magnitude is highly influenced by the viscosity of the lubricant, which varies with pressure and temperature within the contact. To evaluate the traction coefficient, the shear thinning of the non-Newtonian lubricant with increasing shear rate under varying contact pressures, which dominates in the region of contact pressure studied, must be considered. Finally, the limiting shear stress of the lubricant because of its viscoelastic behavior must be calculated.

For typical operating loads, the contacting surfaces also undergo elastic deformation. If the materials of the contact surfaces are exposed to extreme pressures, the possibility of failure of the gear tooth because of pitting, scuffing, and wear exists. The contacts, by design, operate under the elasto-hydrodynamic (EHL) lubrication condition. In this piezo-viscous-elastic regime, the lubricant behaves like a viscoelastic material with high magnitudes of viscosity because of large Hertzian pressures. In addition, the lubricant viscosity changes with temperature due to the viscous shear caused heat generation within the contact. Thus, there is a strong coupling between the traction force, sliding and film temperature.

This paper describes a methodology developed to incorporate the effect of lubrication characteristics, gear geometry, surface finish, and operating conditions to accurately predict sliding losses over a range of operating conditions.

Initially, the results of the methodology used to predict the traction coefficient obtained from a mini traction machine (MTM) are presented. A close agreement is observed between the experimental results and the predictions. Then, this methodology was used to predict the sliding loss for FZG Type-C gear sets at several speed-load combinations. Results from comparing predicted and experimental results are presented. The close agreement between predictions and experimental results provide confidence in using this technique in predicting gear sliding losses.

The initial calculations are focused on obtaining the friction coefficient for λ values larger than 3, defined as film thickness to mean surface roughness ratio, where the contact is in the thick film region.

The Ree-Eyring formula, incorporating lubricant viscosity at a low shear rate corrected for the contact pressure and temperature, is used to compute the shear stress. A model describing the pressure-temperature-viscosity relationship developed by Bair [1] was integrated into the traction loss prediction methodology.

After the traction loss prediction methodology was developed, it was used as a basis of calculating sliding losses in the FZG TYPE-C gear set at the various operating conditions. For the target gear set, the mesh cycle was broken in 25 segments. Then AGMA 925-A03 [2] was used to calculate the normal force, rolling speed, sliding speed, and effective tooth radius at each segment. These operating conditions and the oil rheology
## NOMENCLATURE

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<th>SYMBOL</th>
<th>DESCRIPTION</th>
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</tr>
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<td>$U_{1,2}$</td>
<td>Speed of the body at contact region (body1, body2)</td>
</tr>
<tr>
<td>$U_{1,2}$</td>
<td>Rolling speed of the driver and driven gears, respectively</td>
</tr>
<tr>
<td>$W$</td>
<td>Applied load</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Pressure viscosity coefficient</td>
</tr>
<tr>
<td>$\alpha_{h}$</td>
<td>Proportion of heat entering body 1</td>
</tr>
<tr>
<td>$\dot{\gamma}$</td>
<td>Shear rate</td>
</tr>
<tr>
<td>$\Delta T$</td>
<td>Lubricant temperature rise at the contact</td>
</tr>
<tr>
<td>$\Delta U$</td>
<td>Sliding speed</td>
</tr>
<tr>
<td>$\ddot{\varepsilon}$</td>
<td>Simplified elliptical integral</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Lubricant dynamic viscosity</td>
</tr>
<tr>
<td>$\eta_0$</td>
<td>Lubricant dynamic viscosity at the contact inlet temperature and pressure</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Specific film thickness ratio</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Effective mean coefficient of friction</td>
</tr>
<tr>
<td>$\mu_b$</td>
<td>Coefficient of friction at $\lambda=0$</td>
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<tr>
<td>$\mu_f$</td>
<td>Traction coefficient</td>
</tr>
<tr>
<td>$\nu_{1,2}$</td>
<td>Poisson's ratio (body1, body2)</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Density of contacting bodies</td>
</tr>
<tr>
<td>$\sigma_x$</td>
<td>Composite surface roughness for filter cutoff wavelength, $L_x$</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Shear stress</td>
</tr>
<tr>
<td>$\tau_E$</td>
<td>Eyring stress</td>
</tr>
</tbody>
</table>
were used as input to the calculation of sliding losses at each segment of the mesh cycle, and processed to predict the sliding losses for the gear set at each of these conditions.

**COMPARISON OF THE PREDICTED TRACTION COEFFICIENT WITH MINI TRACTION MACHINE (MTM) RESULTS**

Initial comparisons are conducted for simple contacts, i.e., ball on a disk and barrel on a disk of the MTM tests shown in Figure 1. For this machine, at a constant slide to roll ratio, the reduction in speed results in thinner EHL film. The thinner film may lead to the transition from full film to mixed and then boundary lubrication regimes. For contact pressures up to 1.25 GPa, a ball on a disk with a circular contact area is used. For contact pressures between 1.25 GPa and 3 GPa, a barrel on a disk with an elliptical contact area is used. These comparisons are focused on the region of the Strubeck curve corresponding to large values of $\lambda$, defined as film thickness to contact roughness ratio. In this region, the contact occurs in the thick lubricating film region, where there is no asperity contact between the two surfaces.

For tests in large values of $\lambda$ region, smooth surfaces with an average roughness of $\alpha_x = 20$ nm are used. To calculate this average, the following equation is used:

$$\sigma_x = \frac{(Ra_{1x} + Ra_{2x})}{2}$$  

Equation 1

In the above equation, $Ra_{1x}$ and $Ra_{2x}$, are measured average surface roughness for surfaces 1 and 2, respectively. For calculating the average surface surfaces, the filter cutoff wavelength $L_x$, comparable to the width of the Hertzian contact band was used. The value of specific film ratio $\lambda$, is defined by

$$\lambda = \frac{h}{\sigma_x}$$  

Equation 2

where $h$ is the central film thickness. For all the comparisons presented using the models in this section, $\lambda$ is larger than 8, representing thick film lubrication conditions.

The traction coefficient $\mu_f(p_m, T)$ at the mean contact pressure $p_m$ and the contact temperature $T$ is calculated by the following simple relationship:

$$\mu_f(p_m, T) = \frac{\tau}{p_m}$$  

Equation 3

The Ree-Eyring [3] formula is used to compute the shear stress $\tau$:

$$\tau = \tau_E \sinh^{-1} \left[ \frac{\eta(p_m, T)}{\tau_E} \right]$$  

Equation 4

Where:
- $\tau_E$ is the Eyring stress.
- $\eta(p_m, T)$ is the dynamic low-shear viscosity at the mean contact pressure and the temperature.
- $\gamma$ is the shear rate.

A viscosity relationship describing the variation of viscosity values $\eta(p, T)$ with pressure and temperature was developed by Bair [1] using experimental results of a high-pressure viscometer. This model was generated for a lubricant that is used in all of the tests and calculations presented here.

The shear rate $\gamma$ is determined by the following formula:

$$\gamma = \frac{\Delta U}{h}$$  

Equation 5

Where $\Delta U$ is the contact sliding speed, and is defined by:

$$\Delta U = |U_1 - U_2|$$  

Equation 6

For maximum contact pressures between 1.25 GPa and 3.0 GPa in the MTM tests, where the barrel and disk are employed, the mean contact pressure is determined by the Hertzian formula:

$$p_{max} = 0.364 \left( \frac{WR^2}{E^2} \right)^{\frac{1}{3}}$$  

Equation 7

Where:
- $W$ is the applied load.
- $E'$ is reduced Young's modulus.
- $R$ is the radius of the ball.

The reduced Young's modulus is defined as:

$$\frac{1}{E'} = \frac{1}{2} \left[ \frac{1 - v_1^2}{E_1} + \frac{1 - v_2^2}{E_2} \right]$$  

Equation 8

Where:
- $v_1$ and $v_2$ are Poisson’s ratios of the contacting bodies “1” and “2”, respectively.
- $E_1$ and $E_2$ are Young’s moduli of the contacting bodies “1” and “2”, respectively.

For up to maximum contact pressures of 1.25 GPa, in the MTM tests, where a ball on disk is employed, the maximum pressure is obtained by the Hertzian formula:

$$p_{max} = 2 \left( \frac{3}{\pi a_e b_e} \right)$$  

Equation 9

Where $a_e = 1.14 \left( \frac{WR}{E'} \right)^{\frac{1}{3}}$  

Equation 10

For maximum contact pressures between 1.25 GPa and 3.0 GPa in the MTM tests, where the barrel and disk are employed, the mean contact pressure is determined by the Hertzian formula:

$$p_m = \frac{W}{\pi a_e b_e}$$  

Equation 11

Where $a_e = \left( \frac{6 \pi E^2 WR}{\pi E'} \right)^{\frac{1}{3}}$  

Equation 12

And $b_e = \left( \frac{6 \pi E^2 WR}{\pi k E'} \right)^{\frac{1}{3}}$  

Equation 13

Figure 1: Mini Traction Machine (MTM) used for simple contact tests.

Where $U_1$ and $U_2$ are the rolling speeds of body “1” and “2” at the contact region, respectively.
Where:

- \( a_e \) is the major half-width of the contact ellipse;
- \( b_e \) is the minor half-width of the contact ellipse;

\[ \bar{a} = 1.0003 + \frac{0.5968 R_x}{R_y} \]  
Equation 14

\[ \bar{k} = 1.0339 \left( \frac{R_y}{R_x} \right)^{0.639} \]  
Equation 15

- \( R_x \) and \( R_y \) are the equivalent radii;

\[ \frac{1}{R_x} = \frac{1}{R_{x1}} + \frac{1}{R_{x2}} \]  
Equation 16

\[ \frac{1}{R_y} = \frac{1}{R_{y1}} + \frac{1}{R_{y2}} \]  
Equation 17

and \( R^* \) is defined, \[ \frac{1}{R^*} = \frac{1}{R_x} + \frac{1}{R_y} \]  
Equation 18

Where:

- \( R_{x1} \) and \( R_{x2} \) are radii of curvature for body “1”, and “2” in the \( x \)-direction, respectively;
- \( R_{y1} \) and \( R_{y2} \) are radii of curvature for body “1”, and “2” in the \( y \)-direction, respectively.

Hamrock and Dowson [4], [5], and [6] were among the first investigators to present numerical results for circular contacts. Based on their numerical results, they derived a formula to predict the central film thickness \( h \) as a function of operating conditions shown below. Chittenden, et al. [7] used a similar approach to derive the film thickness for elliptical contacts.

The Hamrock-Dowson equation for circular contact is given by:

\[ h = 2.69 \left( \frac{U_{10}}{E' R_x} \right)^{0.67} (\alpha E')^{0.5} \left( \frac{W}{E'R_x^2} \right)^{-3.067} \left( 1 - 0.61 e^{-0.75} \right) \]  
Equation 19

and Chittenden for elliptical contact, long ellipse axis is along rolling/entrainment direction, \( R_x \geq R_y \) is:

\[ h = 3.06 \left( \frac{U_{10}}{E' R_x} \right)^{0.68} (\alpha E')^{0.49} \left( \frac{W}{E'R_x^2} \right)^{-0.071} \left( 1 - e^{-3.36(R_y/R_x)} \right) \]  
Equation 20

Where:

- \( U \) is the rolling or entrainment speed defined by surface or rolling speeds of body “1”, i.e., \( U_1 \) and body “2”, i.e., \( U_2 \) and is given by:

\[ U = U_1 + U_2 \]  
Equation 21

- \( \eta_0 \) is the dynamic viscosity at the temperature and pressure of the contact inlet;
- \( \alpha \) is the measured pressure viscosity coefficient of the oil.

The following relationship for the lubricant temperature rise at the contact \( \Delta T \), due to sliding relative to the inlet lubricant temperature \( T_0 \) is derived by Olver, et. al. [3].

\[ \Delta T = T - T_0 \]  
Equation 22

\[ \Delta T = \left[ \frac{1.06\alpha h}{(K\rho c)^{0.5} \left( \frac{a}{U_1} \right)} \right]^{0.5} + \frac{h}{8K_{oil}} \tau \Delta U \]  
Equation 23

Where \( \alpha_h \) is the proportion of heat entering body 1 and is given by the following equation:

\[ \alpha_h = \frac{1.06 B_2 + \frac{h}{2K_{oil} A}}{1.06(B_1 + B_2) + \frac{h}{K_{oil} A}} \]  
Equation 24

\( B_1 \) and \( B_2 \) are transient thermal resistance due to the hot spot for bodies 1 and 2, respectively, and are given by:

\[ B_{1,2} = \frac{1}{A (K\rho c)^{0.5} \left( \frac{a}{U_{1,2}} \right)^{0.5}} \]  
Equation 25

Where:

- \( A \) is the area of the contact.
- \( K_{oil} \) is the thermal conductivity of the lubricant.
- \( K \) is the thermal conductivity of steel bodies in contact.
- \( \rho \) is the density of steel bodies in contact.
- \( c \) is the specific heat of the steel bodies in contact.

For the calculations presented in this paper, the thermal responsibility of the surfaces of the two bodies defined by Olver [8], which is a function of the geometry of the bodies, their thermal conductivity, and the convective heat-transfer coefficient between the surface of each body and the lubricant is assumed to be negligible. This assumption was made as a first approximation for the prediction of the lubricant temperature at the contact. Although the temperature predictions for the cases presented in this paper provide a reasonable comparison with the test results, the thermal responsibility of the gear and shaft surfaces must be included in temperature predictions as described by Olver, et. al. [3]. The values of constants are given:

- \( K_{oil} = 0.14 \text{ W/K-m} \)
- \( K = 59 \text{ W/K-m} \)
- \( \rho = 7,600 \text{ kg/m}^3 \)
- \( c = 452 \text{ J/kgK} \)
- \( \alpha = 0.0132667 \text{ mm}^2/N, \text{ for a nominal viscosity of 28 mPa-sec at 80°C} \)

The viscosity of the lubricant and its behavior with pressure and temperature is the prime determinant of the fluid-traction coefficient. The preceding equations for calculations of shear stress, mean contact pressure, central film thickness, shear rate, the temperature rise of the lubricant due to sliding losses, and the empirically derived equation between viscosity and pressure and temperature are used to calculate the lubricant traction coefficient \( \mu_0 (T_{in}, T) \) at values of specific film ratios \( \lambda \) corresponding to the full fluid EHL regime.

The comparison of these predictions with those measured using a mini traction machine is presented in Figures 2 through 4. A comparison of the measured traction coefficient values at a maximum contact pressure of 0.9 GPa and rolling speeds of 0.88 m/sec, 2.62 m/sec, and 3.2 m/sec is shown in Figure 2. For these comparisons, the value of Eyring stress is calculated to be 7 MPa. A comparison of the measured traction coefficient with predictions at maximum contact pressure 1.25 GPa and rolling speeds 0.88 m/sec, 2.62 m/ sec, and 3.2 m/sec is shown in Figure 3. For these comparisons, the value of Eyring stress is calculated to be 7.8 MPa. A comparison of the measured traction coefficient with predictions at maximum contact pressure 2, 2.5, and 3 GPa and rolling speed 2.5 m/sec is shown in Figure 4. For these comparisons, the value of Eyring stress is calculated to be 8.8 to 9.5 MPa. For large values of specific film ratios \( \lambda \), in the range of the calculated shear rates, and different rolling speeds, and loads, there is an excellent agreement between measurement and predicted results as shown in Figures 2 through 4.

**ROUGH SURFACE MEAN COEFFICIENT OF FRICTION PREDICTIONS**

Experiments by Smeeth and Spikes [9] suggested that an effective mean coefficient of friction \( \mu \) may be estimated from fluid generated traction using the following universal empirical relation with
dependency on $\lambda$ in the EHL region:

$$\mu = \mu_f + \frac{\mu_b - \mu_f}{(1 + \lambda)^m}$$

Where:
- $\mu$ is effective mean friction coefficient.
- $\mu_f$ is traction coefficient at high lambda.
- $\mu_b$ is friction coefficient at $\lambda=0$.
- $m$ is exponent parameter.

Once $\mu_f$ was calculated and verified experimentally using the results of the tests obtained by MTM on the test lubricant for large values of specific film ratio, i.e., for values of $\lambda$ in the full film EHD regime, the above relationship was curve fitted to the MTM friction coefficient test results obtained for rough surfaces at a wide range of $\lambda$ values, i.e., $0.06 < \lambda < 1.5$ at maximum contact pressures of 1.25 GPa, and 2.5 GPa, separately.

The exponent $m$ is a constant that determines the value of $\lambda$ where $\mu$ approaches the value of $\mu_b$, and is found to be $m = 2$ for the current MTM test results. This exponent is normally found to be between 2 and 3, depending on the value of $\lambda$ being between 5 and 3 in the full fluid lubrication region, i.e., for larger magnitudes of $m$, lift-up is achieved at smaller values of $\lambda$.

The value of the friction coefficient for boundary lubrication, $\mu_b$, corresponding to $\lambda = 0$ was found to be $0.116$. This value was obtained by extrapolating the graph of traction coefficients, measured by MTM, versus calculated $\lambda$ values to $\lambda = 0$. The value of 0.116 for friction coefficient at boundary lubrication was not obtained experimentally, i.e., it was not measured under pure sliding contact.

Because the above curve fitted equation with $m = 2$ provided a reasonable relationship describing the behavior of mean coefficient of friction for the loads and entrainment speeds used in the MTM tests, this relationship is used to predict the mean coefficient of friction for the FZG tests presented in the next section and the comparison of these predictions with test results.

### COMPARISON OF THE PREDICTED AND MEASURED SLIDING POWER LOSS FOR FZG TYPE-C GEAR SET

The sliding power loss comparisons between the predictions and the actual measured values for an FZG Type-C gear set at three applied torques of 100, 200, and 300 Nm are presented here. For each applied torque values, the tests were conducted using the Ohio State University's FZG test facility, at four driver speeds of 595, 1,785, 2,975, and 5,000 rpm. This test facility is described in detail by Moss, et.al. [10]. The parameters for this gear set are presented in the following table. The gears had no lead crown and mean surface roughness for the gear set was 220 nm. The contact ratio or average number of teeth in contact was calculated to be 1.427.

For each of the 12 tests, the gear mesh cycle was broken into 25

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Driver Gear</th>
<th>Driven Gear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>Module normal</td>
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<td></td>
</tr>
<tr>
<td>Pressure angle</td>
<td>20 degree</td>
<td></td>
</tr>
<tr>
<td>Helix angle</td>
<td>0 degree</td>
<td></td>
</tr>
<tr>
<td>Operating center distance</td>
<td>91.5 mm</td>
<td>91.5 mm</td>
</tr>
<tr>
<td>Effective outside radius</td>
<td>41.1925 mm</td>
<td>59.1425 mm</td>
</tr>
<tr>
<td>Face width</td>
<td>14 mm</td>
<td>14 mm</td>
</tr>
</tbody>
</table>

Table 1: FZG type-C gear set.

![Figure 2: Comparison of the measured traction coefficient values using a mini traction machine with predictions at large values of $\lambda$; maximum contact pressure 0.9 GPa; rolling speed 0.88 m/sec, 2.62 m/sec, and 3.2 m/sec; Eyring Stress = 7.0 MPa.](image)

![Figure 3: Comparison of the measured traction coefficient values using a mini traction machine with predictions at large values of $\lambda$; maximum contact pressure 1.25 GPa; rolling speed 0.88 m/sec, 2.62 m/sec, and 3.2 m/sec; Eyring Stress = 7.8 MPa.](image)

![Figure 4: Comparison of the measured traction coefficient values using a mini traction machine with predictions at large values of $\lambda$; maximum contact pressures 2, 2.5, and 3 GPa; rolling speed 2.5 m/sec; Eyring Stress = 8.8 to 9.5 MPa.](image)
segments. The gear parameters of Table 1 and appropriate equations in AGMA 925-A03 [2] are used to calculate the normal force, rolling speed, sliding speed, and reduced radius of curvature at each segment in the mesh cycle. Hertzian contact pressure for contact parameters between two parallel cylinders provided by Stachowiak, et.al. [11] was used. Using the following formulas, the maximum contact pressure \( p_{\text{max}} \), mean contact pressure \( p_m \), and semi-width of the Hertzian contact rectangle \( \alpha \) were calculated, assuming the load was distributed uniformly along the tooth face width in the mesh cycle,

\[
p_{\text{max}} = \left( \frac{WE'}{2\pi lR'} \right)^{1/2}
\]

\[
p_m = \frac{\pi}{4} p_{\text{max}}
\]

\[
\alpha = \left( \frac{4WR'}{\pi E'l} \right)^{1/2}
\]

where \( l \) is half length of the contact rectangle, which, for this case, is half of the face-width of 14 mm.

Once these were known, the film thickness and the resulting film temperature were calculated for each point in the mesh cycle.

Grubin’s equation [10] for film thickness was used for the line contact generated by these gears:

\[
\frac{h}{R_x} = 1.95 \left( \frac{U\eta_0}{E'R_x} \right)^{\frac{3/11}{\lambda}} \left( \alpha\epsilon \right)^{\frac{3/11}{\lambda}} \left( \frac{W}{E'R_x^2} \right)^{-1/11}
\]

Equation 30

The temperature rise for the lubricant in each of the 25 segments of the mesh cycle was calculated similarly to what was described in the previous section. The surface finish input used for these gear calculations was the average of the measured surface roughness.

Finally, knowing the contact pressure and the temperature of the lubricant film, its viscosity for each segment was calculated, and the resulting traction coefficient was found, as per the same procedure as the MTM calculation, which involved iterating to a successful simultaneous calculation of temperature and heat flow. From there, using the calculated \( \lambda \), a \( \eta_0 \) value of 0.116 and \( m \) value of 2, the power loss for each segment was calculated by obtaining \( \mu \) from the rough surface mean coefficient of friction predictions, multiplying \( \mu \) by the mean contact pressure at the segment to find the shear stress and multiplying it by the corresponding segment sliding speed and the contact area.

After the power loss for each segment of the mesh cycle was calculated, the average power loss was found by adding all the power losses for all the segments for a given running condition and dividing by 25. This average was multiplied by the contact ratio 1.427 for this gear set, to determine the total power loss. This is because for each
42.7 percent of the time, there are two pairs of teeth in the mesh that are engaged. This was compared to the experimental power lost for each test. Figures 5 through 8 show the normalized results comparing predicted- with measured-sliding losses. The normalization value for all of these figures is arbitrary chosen as a constant number. In the primary operating range of commercial gearing shown by the 1,785 and 2,975 rpm results, the predictions are within 15 percent. At high speed and high torque, there is an anomaly with a 26-percent difference between predicted results and measurements. There are also significant differences between calculations and measurements at low speed, although the absolute differences are not significant. To determine the sliding losses due to gears, the FZG test-stand losses were first measured with a torque cell, under a known test load and speed, and then at no load at the same speed. The no-load losses were then subtracted from the total losses to determine the net-loaded gear and bearing losses for each test condition. The loaded bearing losses were then calculated and subtracted from that loss to determine the gear sliding loss. The loaded bearing loss calculation was not verified and may be a source of error in the results.

CONCLUSIONS
The gear sliding loss prediction technique discussed in this article relies on the use of existing appropriate parametric relationships for contact pressure, shear stress, heat conduction, and, most importantly, the use of experimentally determined dynamic low-shear viscosity at high pressure and temperature. This methodology yields comparable accuracy to the best methodology analyzed in Reference 12 – ISO-14179-2 (Hohn's Modification). In addition, this prediction approach accounts for all relevant gear-design parameters, lubrication properties, and operating conditions. This technique eliminates the need for FZG gear testing as in ISO-14179-2, from which a lubrication factor XL is derived. The prediction algorithm can be extended to helical gearing by separately analyzing the individual lines of contact. Based on its effectiveness, it can serve as a basis for advancement in the accuracy and efficacy of calculation of gear-surface degradation, including scuffing and pitting, as all are significantly affected by the tribological factors used in this analysis.

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BIBLIOGRAPHY

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The ability to rebuild machines is a large part of Machine Tooling Technology’s arsenal. (Courtesy: Machine Tooling Technology)
With more than 30 years of experience, Machine Tooling Technology offers compatible parts and tooling for the keyseater industry.

By KENNETH CARTER, Gear Solutions editor

As machine shops have modernized, many of them still rely on keyseater machines that are used to cut internal shapes and forms for large gears.

Some keyseater machines still in operation are decades old, and, since a new one can cost upwards of $1 million, it’s essential to keep these used machines running.

Although Machine Tooling Technology has been branching out in what it can offer the gear manufacturing industry, it still works hard to maintain those older, but reliable, keyseater machines.

“We have a lot of very modern machines here, but the keyseating industry hasn’t changed a lot,” said Scott Thielman, president and owner of Machine Tooling Technology. “I mean, literally, we are selling parts for keyseaters that are 100 years old. And the problem is, the gear industry is really relying on these keyseater machines. Especially the Mitts & Merrill™ ones that we supply for that cut the really big keyways for large gears and large shafts for ocean liners and those kinds of sizes — the really big stuff. Most of your gear shops are relying on these older keyseater machines, because they’re very reliable. They’ve lasted for 100 years, and, actually, there really is no replacement.”

HELPING SHOPS, BOTH LARGE AND SMALL

By keeping these machines operational, Machine Tooling Technology is helping small shops and even some of the bigger shops, according to Thielman.

“The manufacturer does supply them, but it usually involves long lead times and are more expensive,” he said. “We have a cost-effective way of getting an equivalent supply of tooling to the gear shops.”

Thielman learned how to keep these older machines functioning properly from an excellent teacher — his father.

“That’s what my father did for 40 years; he would buy some of these machines that were very, very old, and they would literally strip them down and replace all of the parts,” he said. “They would grind those down or replace them and basically restore them back to new condition.”

Once the keyseaters advanced from mechanical to hydraulic, then Machine Tooling Technology began rebuilding those as well, according to Thielman.

“We rebuilt a lot of the hydraulic ones,” he said. “We even rebuilt a lot of the mechanical ones with these big flywheel belts. We upgraded a lot of them over the years.”

Machine Tooling Technology supplies compatible parts and tooling manufactured in Canada by Keyway Tooling Company, which has been supplying the keyseater industry for 30 years. The company also carries new compatible insert cutters for Mitts & Merrill™ and Morrison™ and stocks most tooling including post feed wedges, cutter bars, clamps, step bushings and more. It also carries an extensive inventory of used cutters, cutter bars, feed wedges, clamps, step bushings, and posts.

CONTINUED EXPANSION

With rebuilding machines a large part of Machine Tooling Technology’s history, Thielman said that his company has been expanding beyond that.

“We’ve kind of gotten out of rebuilding machines,” he said. “We are now focusing on supplying new parts and helping people out with new re-expendable tooling, and we’re helping them out with our vast inventory of used parts. We sell parts that you can’t even buy new anymore. So, we’ve begun to move out of the restoration business. That was more of my father’s love, rebuilding these machines. But this is a good thing we’re doing for everybody by supplying these tools and cutters.”

A rebuilt Davis machine. (Courtesy: Machine Tooling Technology)
Supplying parts for these machines is essential because it's often difficult to find a used Mitts & Merrill™ machine that someone is willing to sell, according to office manager Rose Brown.

“Because, for the people that have them, they’re just gold,” she said.

It’s not just business for Thielman and his team to make sure a customer has the parts he needs to get the job done, it’s personal, too.

“What makes me the proudest is when we can help somebody when their shop is literally shut down and they can’t supply a huge order because they don’t have the right part or they can’t find the part; that’s when these keyseaters become critical,” he said. “You can make a half-million-dollar gear, but if you can’t cut the keyway in it, then you can’t ship it. We’ve had customers over the last decade that come to us and go, ‘I’m panicking. I’ve got to get this out, and I need the right cutter, or this toolbar is broken. I need it immediately.’ And we’ve either been able to actually get some of our parts from our used machines that we’ve had out here, or we’ve been able to get a part made very quickly for them, and get their order out on time so they can stay in business.”

Brown put an exclamation point on that directive.

“My motto is, here in Chicago, if I get your order by 3 o’clock, I can ship it today,” she said.

HUGE INVENTORY

That rapid turnaround time can be partly credited to Machine Tooling Technology’s huge inventory, according to Thielman.

“We stock a huge inventory of brand-new cutters to common sizes and especially cutter bars and things like that,” he said. “We’ve been serving this industry for 40 years, so we’ve got a lot of good established customers. They really like us, and we try and service them the best we can.”

Thielman said he owns several other companies that can often assist in solving a challenge for a potential customer.

“I'm a mechanical engineer with a lot of history,” he said. “When a customer comes to us with something that’s worn out or some-
thing's not cutting right, we involve one of my companies, Material Testing Technology. We have a lot of experience in materials and failure analysis. We can do chemical analyses. So, when customers come to us, we can literally help them solve problems in the cutting of their gears or whatever they happen to be making. We give out technical advice on how to get things cutting better and making better parts. That's our way of helping out the shops."

Another of Thielman's companies supplies components for test machines, which translates into huge inventories.

"That's what our customers really like," he said. "They need a part; they need it quickly, and we try and have them in stock and get them out of here quickly. We hope to do that in the future and continue to inventory even more and have more available."

GOOD COSTS; QUALITY PRODUCTS
As varied as the company's directives have been throughout its history, including looking at the actual manufacturing of machines to doing more restorations, Thielman said his goal is ultimately a straightforward one.

"My goal is just basically to supply the gear industry with good costs and good quality products that we can deliver in a timely manner," he said.

Those good quality parts Machine Tooling Technology can provide include some for the bigger machine names, including Davis, Morrison™, and Mitts & Merrill™, according to Thielman.

A FATHER'S BRAINCHILD
Machine Tooling Technology goes back two generations and was started by Thielman's father, Les, when he began a company called Wings Machinery.

"He was a machinery dealer, and he bought up used machinery around the country," Thielman said. "He ran auctions, and he found out about these machines called keyseaters. Nobody really knew what they were or why they were used at the time, but he actually figured it was a good way to make money. Basically, he cornered the market on used keyseater machines. And he bought up all of the Mitts & Merrills™ and Davises and the different types of keyseating machines that were out there."

Thielman's father would restore these machines and supply parts for them, and that helped spawn the business model of manufacturing and selling new tooling such as cutters and drill bits for regular drill machines. Thielman's father passed away earlier this year, but Thielman said he has been running the business for about 11 years.

"I took over the business 11 years ago, and we primarily have been selling the new tooling for the aftermarket keyseater machines," he said. "We do sell some replacement parts, and we still have 40 years of history sitting out in the warehouse. But, since taking over the business, we've been selling used and mostly new parts for keyseater machines."

KEEPING GEAR MAKERS GOING
Supplying cutters and replacement parts for the keyseater machines has helped a lot of the gear industry stay in business, Thielman emphasized, referring to the enormous cost considerations of buying a new machine.

And that mindset boils down to a simple concept: helping the gear shops as much as possible by supplying them good quality parts, according to Thielman.

"We've got a lot of history and a lot of know-how on keeping these types of machines running, and people are constantly calling us saying this broke, or this happened," he said. "And we go out in our files, and we pull up files on the old machines, and we'll send them drawings, or we'll help them in any way we can in order to keep their machines running, keep making good parts, and keep them tooled."
GF launches MILL P 500 vertical milling machine for processing reliability

GF Machining Solutions has launched the new MILL P 500 3-axis vertical milling machine in North America targeting mold and die makers in the ICT/EC segments and medical device manufacturers as well as others. The MILL P 500 delivers unparalleled levels of precision, reliability over extended machining periods, and exceptional productivity.

Thanks to its robust and thermostabilized polymer granite base platform, the MILL P 500 holds part tolerances to ±4 microns and maintains positioning accuracy over extended machining times, deviating no more than 5 microns during a 24-hour span. Paired with this machine positioning accuracy, an advanced 42,000-rpm, HSK-E40 Step-Tec spindle, as standard, gives shops a competitive advantage in terms of shorter time to market by reducing time-consuming, secondary manual polishing operations.

High-performance Step-Tec spindles are built for all milling operations from roughing to fine surface finishing. With advanced hybrid ball bearings and thermally robust hybrid cylindrical roller bearings, the spindles enable milling with extra-long tools while delivering aggressive material removal rates at high feed rates. GF Machining Solutions will also offer, as optional, the Step-Tec spindle in 24,000 and 36,000-rpm versions.

For maximum ROI, the MILL P 500 features fully integrated workpiece pallet changers, tool magazine expansions, and more for extended uninterrupted production. To ease the integration of automation, the machine allows for automation from the back for seamlessly coupling with a System 3R WorkPartner 1+ (WPT1+) compact pallet changing robot or System 3R Transformer/ Fanuc Automation Solutions.

With either disc or automatic tool tower, the MILL P 500 offers capacities of up to 60 tools via disk and up to 210 tools with the tower. (Courtesy: GF Machining)

is ideal for the ICT/EC and medical manufacturing environments, its large axis ratio makes the machine equally well suited for mold and die makers supplying the packaging, automotive, and consumer appliance industries, among others. Within these industries, die casting, high-temperature forging molds and dies, cold forging dies, and extrusion dies are all perfect applications for the MILL P 500. The machine delivers superior part surface finishes as well as extreme contour and position accuracies along with dimensional precision critical for the production of injection molding and stamping dies and sinker EDM electrodes.

Initially introduced with a Fanuc 35iB CNC, the MILL P 500 will soon come with a Heidenhain TCN640 control. This state-of-the-art hardware combined with diverse software packages allows for greater unattended operations with the MILL P 500, freeing operators to take on other tasks for added production value. Key control functions on the MILL P 500 include Econowatt, Intelligent Spindle Monitoring, Intelligent Thermal Control, Power Failure Protection, Intelligent Tool Measurement, and Operator Support System. Econowatt, for example, can save up to 50 percent on machine energy consumption, while Intelligent Spindle Monitoring and Intelligent Thermal Control contribute significantly to the machine’s high precision.

Power Failure Protection coupled with Intelligent Tool Measurement ensures further process security while protecting tools and extending their working lives. To enhance overall machine productivity, the MILL P 500’s Operator Support System works in tandem with several software tools, including GF Machining Solutions’ rConnect.

rConnect is a digital services platform available for all GF Machining Solutions technologies. It is a modular system that includes a range of available services all backed by T.ViT-certified cybersecurity. rConnect Live Remote Assistance (LRA) makes it easy for shops to achieve the highest possible machine uptime by allowing GF’s expert engineers to rapidly respond to service requests via audio, video chat and other tools.

MORE INFO www.gfms.com/us
Big Kaiser adds chip blower for milling chucks to automate cleaning

Big Kaiser Precision Tooling, a global leader in high-performance metalworking equipment, has updated its offering of chip blowers, which are designed to make removing chips and coolant from parts and machine tables fast, easy, and safe. The new chip blower has an extended steel shank, from 1.77” to 2.5”, for added compatibility with hydraulic and milling chucks.

The chip blower automates in-machine cleaning of coolant and chips by delivering high-volume air flow with spindle rotation. When not in use, the chip blower fits easily into any automatic tool change system for vertical, horizontal, or multi-tasking machining centers. The chip blower can be used with automatic tool changers and programmed into a machining cycle, helping to improve machine utilization and increase productivity. The chip blower complements the solid construction, fixed blade ChipFan.

Glebar offers high-precision centerless grinder

Glebar’s GT-610 CNC outperforms larger competing grinders, which require a much larger footprint and grinding wheels so large and heavy, a crane is required to change them. It offers high horsepower, high rigidity, and superior slide positioning. Through intelligent control and design, the G-ratios (part volume removed divided by wheel volume used) can exceed machines twice its size, all while maintaining better roundness, diameter, and taper tolerances.

The GT-610 CNC is the complete “lights-out” centerless grinding solution for applications where a high degree of automation, data gathering, and gauging feedback is required. Built on a mineral cast base for rigidity, vibration, and thermal stability, the GT-610 CNC weighs more than 8,000 pounds.

Glebar’s vast experience and unique infeed centerless grinding technology shine in this higher precision machine tool, able to process challenging components such as titanium aerospace fasteners, arthroscopic shavers, bone drill blanks, and small powdered hard metal components.

This fully automated system is capable of grinding and gauging multiple components to a high degree of precision. Configurable with pick/place gantries or 6-axis robots, this machine ensures a hands-off, high production, or frequent changeover operation with the assurance of automatic size compensation and 100 percent inspection.

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The GT-610 CNC’s two independent slides (upper and lower), which control the regulating wheel and the work rest blade position, holding the part being ground in place, provide significantly easier and quicker set up than competing systems. The multi-axis controller can position both grinding wheel slides to a resolution of 0.1 micron (0.000004”).

The machine comes standard with a 10-inch work wheel with super precision twin grip spindle. Glebar is now offering an ABEC 7 twin-grip work wheel spindle design (with 12-inch work wheel option) on the GT-610 CNC for increased rigidity, faster component processing speed and larger diameter parts.

Glebar’s patented programmable motorized work rest blade option adjusts the lateral position of the parts (when grinding), which is ideal when controlling a radius behind a fastener head or when grinding the tip of an arthroscopic shaver, for example.

The CNC work wheel dresser incorporates 0.1 micron linear scales on both axis and a high-speed roll dress spindle, single point dressing also available. The CNC regulating wheel dresser allows for the dressing of complex shapes to achieve optimal diameter and roundness accuracy. It’s available with a variable frequency drive on the work wheel spindle for increased wheel surface feet when running super abrasives such as vitrified CBN. Spindle RPM can be varied depending on the wheel type and wheel dressing parameters.

The control software is entirely developed at Glebar and is fully customizable to address customers’ applications and processes. The intuitive touch screen interface allows for ease of use and flexibility. The machine software interface was developed to allow an unskilled operator to run many high precision machines simultaneously.

A built-in automatic wheel balancing system dynamically adjusts and eliminates wheel vibration, producing superior surface finishes and improved wheel life.

As with other high performance Glebar machines, the GT-610 CNC can be fitted with robots, pick-and-place gantries, cleaning and drying stations, laser inspection systems, and more to provide a truly hands-off turn-key solution for high production grinding applications that demand ultimate precision. OPC interfacing to supervisory plant controls is also available to gather production data and track maintenance and critical operational statistics.

This is done by using EtherCAT® by and large the fastest industrial Ethernet technology. This machine can also interface with Glebar Advanced Analytics, Glebar’s new cloud-based solution that allows operators and managers to remotely receive actionable real-time analytics on easy-to-read dashboards; reduce downtime. Boost capacity, increase your availability and more.

**MORE INFO**  www.glebar.com

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Mazak unveils newly enhanced 5-axis machine with powerful CNC

Mazak’s new VARIAXIS i-800 NEO Vertical Machining Center offers shops an enhanced version of a popular 5-axis machine, with a powerful CNC, faster machining cycle times, expanded workpiece capacities, and more automation options. Mazak showcased the new machine during the company’s recent All Axes LIVE event.

Among the primary enhancements on the VARIAXIS i-800 NEO is the MAZATROL SmoothAi CNC. It features such functions as Smooth Machining Configuration (SMC) for process optimization with real-time operator control of a wide range of cutting parameters and Ai thermal shield for stable machining accuracy through smart compensation for heat displacement. Also, with the launch of the MAZATROL SmoothAi, Mazak introduced its Smooth project manager gateway software as an available option.

Working with external CAM software such as Autodesk’s Fusion 360, Smooth Project Manager Gateway allows access to internal machine data, which enables the Fusion 360 programmer to query the machine to download machine models, current tooling configuration, offset data, stroke limits, and many other configuration parameters. This information can then be used at the CAM workstation to create more accurate machine programs configured to the limits and capabilities of the actual machine.

Additionally, highly realistic program simulations with current, real-time setup information can be achieved giving even less experienced operators the confidence they need to run highly complex part programs. The machine’s tooling configuration can be modified and updated at the Fusion 360 workstation and sent back to the machine for operators to complete the setup more accurately than ever before.

In terms of speed, the VARIAXIS i-800 makes popular VMC even faster, more versatile, and easier to automate. (Courtesy: Mazak Corporation)
NEO now achieves rapid traverse rates of 1,890 ipm (48 m/m) in the X, Y, and Z axes that contribute significantly to reduced cycle times. To accommodate larger workpieces, axis strokes increased to 29.52” in X, 35.03” in Y, and 23.62” in Z (750 mm/890 mm/600 mm). Maximum workpiece weight capacities are 2,204.62 pounds (1,000 kg) on the single-table version of the VARIAXIS i-800 NEO, and up to 1,543.24 pounds (700 kg) with a two-pallet changer.

The machine now handles maximum tool lengths up to 16.33 inches (415 mm) in available magazine capacities of 30, 40, 80, and 120 tools. A new servo drive shortens tool wait times by up to 58 percent, and a 4.3 second chip-to-chip tool change time helps further reduce noncut time.

For additional flexibility, automation options include a two-pallet changer, along with the Mazak Multi-Pallet Pool (MPP) compact multiple pallet stocker system and the modular Mazak PALLETECH System. The VARIAXIS i-800 NEO can work within the same PALletech cell alongside other popular Mazak machines, including the HCN 5000 and HCn 5000/50. To support hydraulic and pneumatic fixturing, the machine provides nine ports with a single table configuration and four ports inside plus eight outside the machine for two-pallet changing.

New live tooling available for specific Heimatec turning centers

Heimatec, a world leader in live tools and multi-spindle drill heads, has available live tooling for all popular models in the Hyundai, Miyano, and Nakamura turning center lines.

MMaster North American importer for Heimatec Preben Hansen, Platinum Tooling Technologies, Inc. president, said, “We’re carrying a substantial inventory of live tools for our customers’ machines now and it represents a substantial financial and warehouse space commitment we’ve made to support them in the North American market.”

Hansen said the company will be announcing its in-stock arrangement for many other lines of machine tools moving forward, as the company commits a major investment to the market. Platinum Tooling Technologies, Inc. serves its North American customers with a full team of manufacturers’ rep firms, plus its Chicagoland facility offers stocking, repair, application engineering, and service for the company’s line of live tools, multi-spindle tool, adapters, UTEC® right angle heads, and other items offered.

Heimatec offers a full one-year warranty on all parts and labor for its tooling.

Suhner offers POLYdrill range of multi-spindle drills

Suhner features several options in its popular multi-spindle lines. Among them is the POLYdrill family, offering a huge selection of multi-spindle heads from the standard range. Fixed and adjustable hole pitches and compact models allow the tool to be used in a variety of situations. In addition, Suhner can supply tool holders from all stock for all popular brands of machining centers.

Drilling capacity is available standard between 0.06-1” (1.5-25 mm). Minimum hole spacing is 0.27” (7 mm), while maximum hole spacing is virtually limitless. Optional tool holders include ER, ST, JT33, Weldon, and customized styles. Additional options are axial and radial compensation and custom layout and spacing.

The POLYdrill range includes various multi-spindle heads such as MH 20/5, MH 20/7, MH 20/10, and MH 20/13 plus multiple spindle heads with two adjustable spindles for the utmost in flexibility. The MH 20/5,
20/7, MH 20/10 have maximum speed of 4,000 RPM. Maximum drilling capacities are 5 mm, 7 mm and 10 mm, respectively. MH 20/13 has a maximum drilling capacity of 13 mm and a maximum permissible speed of 3,000 RPM.

The MHF has up to 10 spindles, a custom-made pattern and a fixed spindle distance. Maximum drilling capacity is between 5-13 mm and the speed range is 2,500-4,000 rpm. MHFP is equipped with eight spindles with preloaded angular contact bearings for use of carbide tools and fixed spindle distance. Maximum drilling capacity is between 7-20 mm and the speed range is 0-8,000 rpm. The drive system VG 4-8 allows the user to power up to eight machining units with a single motor with flex shaft power delivery. The speed range for this drive system is between 46-9,320 rpm. Flexible drive shafts NA 7/10/12 have a speed range between 12,000-20,000 RPM.

Heimatec offers new line of standard, custom angle heads

Heimatec, a world leader in live tools and multi-spindle drill heads, has its newest development, a line of standard and custom angle heads, available in all popular sizes and styles to accommodate today’s machine tools and CNC machining center builders, available in stock.

Designed for heavy milling, deep drilling, and tapping operations often found in the off-highway, energy, rail, and other heavy-duty industries, this new Heimatec line of angle heads features twin or double twin sets of matched angular contact bearings plus a rear radial support bearing, ensuring maximum stability in use.

All the gears on these angle heads have inclined teeth made from high-resistance gear steel and have been specially hardened, ground, and lapped in sets to provide the smoothest transmission output possible.

Heimatec angle heads are made from high-tensile strength aluminum. High-precision spindle bearings maintain the highest possible spindle concentricity.

Full 360º body rotation with positive compression locking, 90º incremental repositioning without indicating, maximum torque to 150 Nm, gear ratio 1:1 standard with others available, spindle speeds to 18,000 rpm, and interchangeable torque arms are other standard features of this line from Heimatec.

CAT 40, BT 40, BT 30, HSK 63A, CAT 50, BT 50 and HSK 100A taper styles are available, as well as custom modifications such as 18-inch extension shafts. Heimatec offers a full one-year warranty on all parts and labor. Heimatec tools are offered in North America by master importer Platinum Tooling Technologies, Inc.

MORE INFO www.platinumtooling.com

TwistSFeed drills feature three-flute replaceable tips for quick changes

Ingersoll’s new TwistSFeed drill family features a three-flute quick-change tip with an upgraded clamping mechanism designed to maximize productivity. Unlike conventional three-flute solid carbide drills, TwistSFeed uses a unique, self-centering point to ensure optimal performance, precision, and stability for all applications.

TwistSFeed reduces costs by improving tool life as well as achieving higher productivity due to multiple flutes along with a new IN2205 coating designed for steel and cast-iron applications. The clamping mechanism allows for the simple replacement of drill tips as well as accommodating multiple tip diameters per drill body facilitating economical stock management for end users.

MORE INFO www.ingersoll-imc.com
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Describe for our readers what the Raytech Measuring System is.
It’s a simple solution for shop floor measurement. When you start looking at measurement systems, a lot of the options are getting more tactical, higher end, and more expensive. The Raytech Measuring System is just a grassroots, simple, shop-floor, easy-to-train type system.

They are one-op machines, so they’re custom built. Most of them are on casters, so they’re portable. And it’s basically built to the customer’s needs.

As far as what I like about it, it is the simplicity of the whole thing. You have a hand measurement on a table. You’ve got a table that is squared with just a digital readout that is driven by a handler, if you will.

As far as training, you don’t have all the software issues, and the learning curve with this is very simplistic in its approach.

When did Exact Metrology see the need to add the Raytech Measuring System to its inventory?
It’s one of those gap fillers. It’s better than a caliper because of the size and things that you can get. It falls between that and a portable CMM or a full-blown CMM with the software and the reporting.

It’ll give you basically just straight dimensioning, linear-type measurements. If you don’t need all the bells and whistles of going for portable metrology equipment, this can fill that gap.

What specifically do you feel makes the system unique?
Again, it’s being total customizable to what a customer needs. And I guess that’s kind of where I’m at. When we go to a customer and they say “Hey, I need to measure this, but I don’t need a million-dollar machine or a hundred-thousand-dollar machine to grab this measurement. I need it very quick. I need it very easy.” And then some of these guys, they’ll have maybe a little higher turnover. And the appeal is, I don’t have to spend two or three weeks training a guy on how to run it. I can literally show you how to run it in 10 minutes.

The Raytech Measuring system can use a single-axis or 3-axis configuration. What kinds of jobs are ideal for those two modes?
It can be used with barstock and sheet metal. That’s kind of where I’ve been seeing it used. They can do plastics, window frames, doors. It’s pretty versatile in what you’re looking for.

What’s been the market response so far to the system?
Fairly positive, but so far, most people don’t realize that the system is even out there just yet. It’s one of those where you walk into the customer base, and they’re looking for a simple solution. And the reaction is, “What are you talking about?”

In addition to articles like this, what ways are you getting the word out?
A lot of it is word of mouth and going to visit customers. Obviously, we’re doing some marketing pushes here. Before COVID, we did a trade show with the right type of people, so we’re getting the word out through just the normal channels. A lot of it, it’s revisiting old customers and just letting them be aware that we’re out here.

Do you expect to display it at some trade shows this year when that becomes a viable option?
Let’s hope so. But until then, we’ve updated our website, and there are some things on our website on there for Raytech as well.

Since our audience is mainly made up of the gear manufacturing industry, could you give me a real-world example of how the system could be used for gears?
You could use it to measure your blanks and if you’re looking at quick OD/IDs on the linear hub type stuff. Any linear dimension you’re looking for is really what they’re doing.

“Describe for our readers what the Raytech Measuring System is. It’s a simple solution for shop floor measurement. When you start looking at measurement systems, a lot of the options are getting more tactical, higher end, and more expensive. The Raytech Measuring System is just a grassroots, simple, shop-floor, easy-to-train type system.”

The Barstock Table is designed for checking bar stock materials. (Courtesy: Raytech Measuring Systems)
Fellows Model 10-4 CNC 3-axis Gear Shaper with Fanuc Controls, Motors & Drives

Gleason Phoenix Model 275HC II CNC Bevel Gear Cutting Machine

2007 Kapp Model KX-300P CNC Generating-Style Gear Grinder with Loading

2003 Bourn & Koch model 200H Series II 6-Axis CNC Horizontal Gear Hobbing machine, excellent condition

Gleason Model 250 GMM CNC Gear testers, updated software in 2016 & renishaw probes

2004 Gleason Model 600 HTL CNC Turbo Lapper Fanuc 160i-M Controller

2006 Mitsubishi Model SE25A CNC Gear Shaper with Autoloading

2005 Gleason Pfauter Model GP-150S CNC Gear Shaper

2007 Liebherr Model LC-180

2013 Gleason Model 210H 6-Axis CNC Hobber, Siemens 840D Control

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