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www.gleason.com/laser
A COMPARISON OF AN ANALYTICAL AND FEA APPROACH IN DETERMINING THERMAL LEAD CORRECTION FOR HIGH-SPEED GEARS

A simplified approach for quick and reliable heat analyses for thermal lead correction of single-stage double helical high-speed gears has been developed.

HEAT TREATMENT OF GEARS

The benefits of close interaction between gear designers and heat-treat specialists can lead to total cost and quality optimization.

BUILD RESILIENCE BY MONETIZING VALUE

Uncover the factors, technologies, and financial models that can help make a business more predictable and future-proof.

GIVING FORM TO PROCESS MATERIALS

COMPANY PROFILE  Sinto America, Inc. provides high quality, cost effective, and innovative equipment and solutions to a variety of industries throughout North America.

SOFTWARE THOUGHT BACKWARDS

When using the proper design software, manufacturers are able to go from the desired gear to the perfect skiving tool.

GROWING ROLE OF METROLOGY IN EV

Advanced technologies will be needed to produce complex surface features in gear teeth to enhance efficiency.
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Relationships are built by taking the time to sit down with you, and discovering what keeps you awake at night.

Colonial isn’t typical in the BROACH INDUSTRY—our main focus is to establish customer relationships that are a perfect fit with our decades of service providing broaching systems to international companies looking for experience and reliability.

The solutions we provide delivers the highest quality in the world at a reliable Lowest Cost Per Piece, GUARANTEED! An industry first. What do you take in your coffee?
Energy efficiency is critical to many of today’s end markets. Next-generation gear-system designs and, specifically, new propulsion powertrains, demand performance at the lowest possible cost.

What is the maximum allowable torque of a gear and why does it matter?

The top alloy groups have seen increased growth in application because of corrosion resistance, strength, and low distortion upon precipitation hardening treatment.
A s the world slowly returns to some sense of normalcy, *Gear Solutions* is here to give you some amazing articles and information to help get you through one more month. And has been our tradition, our July issue is offering even more than usual.

For a long time now, the July issue of *Gear Solutions* has been a source of news and information about four important aspects of the gear-manufacturing industry: tooling & workholding and inspection & metrology.

This issue includes articles, product announcements, and listings for these topics that will serve as a valuable resource and a quick guide that can be used throughout the year. It's basically a mini-Buyer's Guide for these gear-manufacturing areas.

Similar to previous years, we have included these topics as bonus sections within our standard issue. It’s an easy, one-stop-shopping way to check out the information, as well as the company listings you’ve come to expect.

By focusing on tooling, we hope to bring you some in-depth knowledge on machine tooling, improving efficiency, performance, and precision in gear manufacturing. Improvements in tooling are happening all the time, so we want you to stay informed of the latest news and developments.

Inspection and metrology markets have been making a lot of strides in automation, data collection, and results analysis. Whether it involves a large OEM, major tier supplier, or a small job shop, these technologies can benefit practically any company.

As important as these topics are, this issue isn’t just about them. The regular part of our July issue also offers several interesting looks at gear manufacturing. Don’t miss some fascinating articles on heat treating and innovative technology to aid in making businesses build resilience by monetizing value. Our regular columnists are also bringing you some can’t-miss info on the mechanics of the industry as well.

I’ve said it before, but it bears repeating: This is why *Gear Solutions* exists. We are here to be a visible and viable tool you can use in order to get your message out to the industry.

Let us be your eyes, ears, and, most importantly, your voice. We are here, first and foremost, to shine a spotlight on your valuable products, services, and know-how to a market that continues to have limited avenues available to discover it.

*Gear Solutions* is here to serve you. With that in mind, if you have any suggestions or would like to contribute, please contact me. I’m always looking for exciting articles to share.

As always, thanks for reading!
We have the world’s largest stock of used late-model Fellows Gear Shapers

WE OWN WHAT WE SELL, AND WE KNOW WHAT WE’RE SELLING!
Schwarze-Robitec gearing up for Fabtech 2021

Fabtech 2021 in Chicago September 13-16 is expected to be one of the first major events where metalworkers from all over the world will meet again after a long pandemic break. Schwarze-Robitec, the tube bending machine manufacturer from Cologne, Germany, is presenting the fully equipped, fully electric CNC 80 E TB MR multi-radius tube bending machine, an absolute all-rounder for tube bending.

Designed for high volumes, short cycle times, and resource-saving material handling, the highly efficient CNC 80 E TB MR is perfectly matched to the requirements of the automotive industry, for example. Production time is reduced by up to 40 percent compared to conventional machines, depending on the component and the desired tube geometry. Material waste is reduced by 90 percent. The contact pressure can always be optimally gauged, while tool costs and changing times are reduced. Overall, the use of the CNC 80 E TB MR increases repeatability and process reliability.

These advantages are possible thanks to numerous features of the machine from Schwarze-Robitec’s high-performance series. It bends and cuts tubes in a single work step thanks to an integrated fully electric cutting device. With extended vertical transport carriage, this is also possible despite the multi-stack bending tool. A vertically adjustable pressure die moves to the different levels for bending synchronously with the tube. The intelligent NxG control checks the interaction of all machine axes for each bending sequence and simultaneously prepares all axes for subsequent steps. In addition, the CNC 80 E TB MR is equipped with the Quick-Tool-Unlock tool changing system in combination with a rapid clamping system for the bend former. This makes it easy to open and close the tension bars for tool changing, while no bolts are required to fasten the bend former to the turntable.

So, after the worldwide pandemic-induced trade fair break, Schwarze-Robitec is now fully gearing up with the fully equipped CNC 80 E TB MR. The tube bending machine manufacturer is looking forward to meeting customers and interested parties from application industries such as automotive and aerospace, plant engineering and shipbuilding, again for direct exchanges at Fabtech. At booth D45954, Schwarze-Robitec will illustrate the competitive advantages that its bundled competence in tube bending brings to its users.

KHK USA Inc. announces extensive line of metric internal ring gears

KHK USA Inc., a factory-owned distributor of the market-leading KHK® brand of metric gears, offers an extensive line of metric internal ring gears. KHK’s large selection of internal ring gears are designed for use in planetary gear trains and are suitable wherever high-speed reduction is required.

Internal gears, also known as ring gears, are cylindrical disks which have involute-shaped teeth cut into their interior face. KHK internal ring gears are offered in carbon
steel, with many configurations of modules and numbers of teeth. All KHK internal ring gears allow for secondary operations such as adding through or tapped holes in the face. KHK’s quick customized products can be ready within five business days.

Two categories of KHK internal gears are available. KHK steel internal gears (SI), typically with 50 to 100 teeth, are a low-cost option that is suitable for many applications. KHK steel ring gears (SIR) are larger in size and number of teeth, typically between 120 and 200 teeth, and can be cut to make segment gears and corner racks.

The production process of KHK cylindrical gears, including internal ring gears, depends on consideration of tooth size expressed in module or DP (diametral pitch), configuration, material, heat treating, method for finishing the tooth surface, precision of the gears, and manufacturing quantity. The typical production sequence involves cutting off material, blank making on a lathe, tooth cutting on a hobbing machine, and deburring. KHK also offers a new method in which a 5-axis machining center is used in combination with gear manufacturing software.

MORE INFO  www.khkgears.us

Gleason sets stage for future virtual shows with successful ‘emotions’

Gleason Corporation’s first-ever virtual show, called ‘emotions’, drew visitors from 39 countries representing manufacturers from all the major gear industries. The 12-day global event will serve as the launch pad for subsequent Gleason virtual events, making it easier for visitors around the world to engage on the most important gear technologies and developments.

‘Emotions’ showcased the latest gear technology innovations for cylindrical and bevel gear design, manufacture, and inspection. Visitors from around the world accessed four showrooms with different themes, ranging from e-drives to industrial gears, closed loop manufacturing, in-process inspection, and detailed gear noise analysis.

Each showroom was accompanied by a special event presentation by an industry expert. After each opening event, participants could browse through the respective showrooms to experience the featured technologies, with or without a guided tour. Gleason’s technology experts and product...
Innovative Grinding Technology Since 1895

Krebs & Riedel offers solutions from continuous generating grinding to single-profile grinding, and bevel gear grinding to power honing applications. (Courtesy: Krebs & Riedel)

The cornerstone of the Krebs & Riedel grinding wheel factory in Bad Karlshafen was laid some 125 years ago. Today, the family-owned company operates worldwide as a manufacturer of individually manufactured precision grinding wheels and innovation and solution-oriented application technology advice. Customers from the automotive, aerospace, mechanical engineering, medical technology, and wind power sectors rely upon the high-precision products manufactured by Krebs & Riedel. In addition to conventional grinding wheels, cutting wheels, cup grinding wheels, and grinding segments with ceramic and synthetic resin bonds, Krebs & Riedel also manufactures CBN and diamond tools with ceramic bonds, as well as honing rings.

At Krebs & Riedel, high-quality products are created with special quality standards and maximum safety. Krebs & Riedel is a member of the VDS (Verband Deutscher Schleifmittelwerke e.V.). As a founding member of the oSa (organization for the safety of abrasives), safety comes first. The production program includes corundum and silicon carbide wheels with a ceramic bond and synthetic resin bond for most industrial grinding applications up to 900 mm outside diameter for round, flat, tool, centerless, gear, and rough grinding applications. Products include cut-off wheels in synthetic resin bond with and without fiber reinforcement up to 800 mm outside diameter for chop cut, pendulum cutting, and rotary cutting; roughing and pendulum grinding with and without fiber reinforcement for the cleaning shop and the foundry industry; grinding wheels for pendulum grinding machines, grinding wheels for bench grinders, and grinding wheels for grinding manipulators; and diamond and CBN grinding media in vitrified bond with a working speed of up to 200 m/s for internal, flat, circular, tool grinding, and special grinding processes.

Krebs & Riedel is a specialist in the field of gear applications and supplies top gear manufacturers around the globe. These grinding wheels are used on many gear-grinding machines, including those from the manufacturers Gleason, Kapp-Niles, Klingelnberg, Liebherr, Mitsubishi, Reishauer, and Samputensili.

Krebs & Riedel’s experience ranges from grinding the smallest gears in the field of medical technology to large planetary gears in wind turbines. From continuous generating grinding to single profile grinding, and bevel gear grinding to power honing, it also offers customized grinding solutions to increase productivity, improve tool life,
Supertec chooses NUM for CNC cylindrical grinding machines

Supertec Machinery Inc., one of Taiwan’s leading machine tool manufacturers, has chosen to base new versions of its renowned Plunge type of CNC cylindrical grinding machines on NUM’s Flexium+ CNC platform.

Founded in 1954, Supertec Machinery Inc. has grown to become one of Taiwan’s top machine tool manufacturers. The company specializes in precision grinding automation and produces a diverse range of centerless, cylindrical and surface grinding machines. Supertec operates sales and support facilities at strategic locations throughout Asia and Europe, as well as in the United States and South America.

Supertec has traditionally used Fanuc CNC systems for most of its machine tools. However, when NUM added non-circular grinding functionality to its popular NUMgrind cylindrical grinding software in June 2020, the company realized that this innovative CNC technology provided exactly what many of its customers needed on their cylindrical grinders.

NUMgrind simplifies the creation of G code programs for CNC grinding machines through the use of a highly intuitive graphical human machine interface (HMI), and unlike conventional CAD/CAM workstation tools, it is designed specifically for use by shop floor personnel in a production environment.

After evaluating the software, Supertec immediately raised a purchase contract with NUM. Betty Chu, Supertec’s assistant general manager, said, “NUM has an excellent reputation in the grinding industry. Much like Supertec, this has been earned over many years. And the latest version of NUMgrind, which accommodates non-circular grinding, is a natural fit for our CNC cylindrical grinding machines. We also now benefit from very responsive local support – NUM’s Taiwan facility is less than 15 kilometers away from our factory.”

Supertec’s Plunge type of CNC cylindrical grinding machines offer a choice of six capacities, covering distances between centers from 500 mm to 2,000 mm. The machines can also accommodate grinding diameters from 300 up to 430 mm (3 sizes), or optimize surface finishes.

The company produces a wide range of dressable grinding worms with a ceramic bond for customers’ gear machining. All specifications guarantee the highest profile accuracy with the lowest thermal loads on the workpieces. The combination of Krebs & Riedel grinding worms with fine-grain or polishing worms creates powerful tools that enable grinding and polishing in one application.

Krebs & Riedel offers a carrier variant for CBN and diamond abrasives. The proportion of carbon fiber guarantees maximum strength with the lowest weight. The body is up to 75 percent lighter than a comparable steel body. In addition to easy handling during assembly, it runs quite smoothly. This means that the load on the grinding spindle is lower. With the new CBN worm grinding wheels, an increase in productivity can be achieved through increased stock removal with an improved service life. The working speeds are up to 100 m/s. Depending on the composition, higher working speeds can also be achieved.

MORE INFO www.krebs-riedel.de
grinding wheel speeds up to 1,390 rpm, and workhead spindle speeds from 30 to 350 rpm.

The new versions of these machines are based on NUM’s Flexium+ 8 CNC platform and use NUM’s high performance MDLUX drives and brushless servo motors for the X, Z and C axes. In addition to the NUMgrind HMI, the software that is being supplied by NUM includes the Flexium 3D simulator, which can be used offline or online, and an application-specific profile editor which enables users to import DXF files.

Johnny Wu, general manager for NUM Taiwan, said, “The ability to use the Flexium 3D simulator both offline and online provides Supertec’s customers with a distinct advantage. CNC programs can obviously be prepared offline and checked for potential problems such as collisions before being transferred to the machine. But the simulator can also be used online. This enables operators to gain vital visibility of the grinding process – which is normally obscured by the flow of oil.”

The new machines will be introduced to the public at the next opportunity, which will likely be TMTS in 2022 due to Covid-19 restrictions.

MORE INFO
www.supertec.com.tw
www.num.com

Exsys expands inventory, speeds delivery at Florida facility

To ensure customers the shortest delivery times possible and cost-effective pricing, Exsys Automation has significantly expanded its inventory capacities at its facility in Florida. The company now has ample room to stock its wide range of product offerings that includes its popular Preci-Flex modular tooling system and associated adaptors along with other tool holding solutions and gear box systems.

In addition to providing tooling repair services and applications expertise, the company will also house in stock its BMT style gear hobs, dual Y-axis live holders, 0-180-degree angle adjustable holders and high-speed live holders along with dual, double static holders, and other special tooling as part of its expanded inventory capacity.

For today’s manufacturers, Exsys Automation offers new high-quality Eppinger products designed to revolutionize chip making, maximize productivity, and reduce per part costs to boost their competitiveness.

EXSYS Automation, Inc. is the exclusive importer of German-made Eppinger automation solutions, high-precision live and
fixed toolholders for CNC turning centers, modular adapter systems for quick lathe tooling changeovers, and gear box solutions for a wide range of applications. With headquarters near Tampa, Florida, and support offices in California, Canada, and Mexico; Exsys Automation offers a variety of different toolholders, gold-standard tooling repair, and applications expertise to manufacturers throughout North America.

MORE INFO  www.exsysautomation.com

Sinumerik One Dynamics offers powerful new 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 free-form 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 free-form 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

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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.

Siemens’ Sinumerik One Dynamics offers three technology packages that increase CNC machine users’ efficiency when programming in the machine shop and executing CAM-generated CNC programs. (Courtesy: Siemens)

The new digital-native CNC from Siemens, Sinumerik One, is setting new productivity benchmarks with its digital twins — the new hardware platform and innovative technology functions.

MORE INFO  www.usa.siemens.com/sinumerik-one

West Ohio Tool announces new production leadership

Custom PCD and carbide cutting-tool maker West Ohio Tool hired production and training expert Chad Mahurin as production manager and a member of the company’s leadership team.

Mahurin brings more than 20 years of experience in tool grinding and cutting, grinding-machine programming, support, training, and service. At West Ohio Tool, Mahurin will contribute to the expansion of the company’s custom product lines and assist in guiding workflow processes as well as efficiency initiatives. His understanding of tools and tool production will benefit West Ohio Tool and its customers with technical insights and an advanced understanding of how to obtain the best results from industry technology.

West Ohio Tool’s hand-selected team of experts in engineering, tooling, innovation, and advanced machining geometry devel-
ops special drills that have been exceeding expectations for more than 30 years, with delivery times up to 75 percent faster than industry standards. The firm’s innovations include the patented edgeX4, the cross-center tipped drill that runs up to three times faster and 10 times longer than carbide. As an experienced PCD and carbide cutting tool maker, West Ohio Tool focuses on building long-term partnerships with customers based on problem solving, technical support and better, faster, longer-running drills.

MORE INFO  www.westohiotool.com

Registration begins for AMB 2022 international trade fair

After the suspension of last year’s event, AMB — the international exhibition for metal working — will get back into its regular cycle and take place again at the Stuttgart trade fair center September 13-17, 2022. All major exhibitors from the metal working and processing industry will present their innovations and further developments to the interested professional visitors over five trade fair days.

“We’re really excited to finally be able to stage trade fairs again,” said Gunnar Mey, department director industry at Landesmesse Stuttgart GmbH.

The Trade Fair Advisory Board supports the project team in its endeavor. At the kickoff meeting in June, all companies pledged their full backing for the trade fair. The companies present in the meeting were DMG MORI, INDEX-Werke, HAHN+KOLB, EMCO, GF Machining Solutions, CHIRON Werke, FFG Europe, KASTO, GÜHRING, CERATIZIT, ISCAR, Hartmetall-Werkzeugfabrik Paul Horn, MAPAL, NAGEL Werkzeug-Maschinen, Ilg + Sulzberger, and Römheld. “The trust placed in us from exhibitors and partners makes us extremely proud and confirms us on our way to a great AMB 2022,” said Mey.

The current market data presented by the promotional supporters of AMB including the VDMA Precision Tools Association, the VDMA Software and Digitalization Association, and the German Machine Tool Builders’ Association (VDW) approve the impressions of the Trade Fair Advisory Board and give a positive outlook on the current economic developments. Increases in incoming orders are good signs for a successful restart of AMB, which gathers momentum with the announced registration phase.

The next important milestone for exhibitors at AMB 2022 is the start of the planning phase in October.

Around 90,000 international trade visitors and 1,500 exhibitors are expected at the twentieth AMB, which will be held at the Stuttgart Trade Fair Centre. On an exhibition area of more than 120,000 square meters (gross), the focal points will be innovations and further developments for metal-cutting machine tools, metal-removing process machine tools, precision tools, measuring systems and quality assurance, robots, workpiece and tool handling technology, industrial software & engineering, components, assemblies and accessories. AMB 2020 will be backed by the promotional supporters, i.e. the VDMA Precision Tools Association, the VDMA Software and Digitalisation Association, and the German Machine Tool Builders’ Association (VDW).

MORE INFO  www.amb-expo.de
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.
Why a trade association might be that missing piece for your company

Is there something missing in your business strategy? Do you find that you have a great product, a strong workforce, and some advertising channels, but you still feel that your name isn’t getting the attention it deserves? Often times, that missing piece is the industry intel and networking that you can only get through being an association member.

AGMA has always been a member-driven trade association. The board of directors, the committee involvement, events, and even the strategic plan is led by member volunteers who work directly in the power transmission supply chain.

AGMA and its members drive power transmission innovation — it’s a bold vision, crafted with care by members, for members, as we collaborate together and shape the future of AGMA and our industry.

Why is this important to your business?

Well, if you are not part of an association, you are not involved with those who are making decisions on behalf of your industry. Additionally, you are not establishing yourself or your team as experts in your sector. Joining a trade association can truly help get your name out there and connect you to the full supply chain. Being a part of an association means you are a part of the big picture, and the investment you make into membership will add great value to your bottom line.

Membership benefits include:

- Direct connection to industry experts and peers.
- Exclusive access to important economic data and reports.
- Opportunity to join active and engaging committees that develop standards, policy, and events for industry.
- Marketing platforms and tradeshows that enhance your company’s abilities to get your products into the right hands.
- Discounted education courses to help train your workforce and develop professionally.
- Establishment of your company as a leader and contributor to the future of your industry.
- A team of people always looking for the best ways to support you and your company.

Membership is an incredible tool, but it isn’t free. It is important to do your research and to set up a meeting with the association before joining. Bring your team members who touch different aspects of your business and find out what resources you will have access to.

Make sure the association gets to know you and your business. If you want to hear testimony, ask for a board or committee member from the association to tell you why they joined. Do not be afraid to ask questions and to fully understand what your investment gets you.

The competition out there is tough, especially for manufacturing. Supply chains are global, the trade laws are changing all the time, hiring economists and getting a real look into the future of technology is not easy, and can be very expensive. But, when you belong to an association, that work is done for you.

For those of you in the gear industry who do not yet belong to AGMA, contact Rebecca Brinkley at brinkley@agma.org. Let us show you how being a member of our association can give you that missing piece to your business and, hopefully, help you grow.
Upcoming Education

Fundamentals of Gear Design & Analysis (In Person)
July 20-22, 2021

Gain a solid and fundamental understanding of gear geometry, types and arrangements, and design principles. Starting with the basic definitions of gears, conjugate motion, and the Laws of Gearing, learn the tools needed to understand the inter-relation and coordinated motion operating within gear pairs and multi-gear trains. Basic gear system design process and gear measurement and inspection techniques will also be explained.

This course is IACET accredited and worth 1.7 CEUs.

This course is taught at Ranken Technical College. A shuttle bus is available each day to transport students to and from the hotel. Class are 8 a.m.-5 p.m. each day.

Basic Inspection for Operators (In Person)
August 10-11, 2021

This course will provide a solid foundation for anyone going into gear inspection. Learn the common, current, and basics of the tools and techniques used to measure and inspect gears. Understand the four main categories by which a gear is evaluated and classified. Gain proficiency in understanding gear quality by learning the numerical scale on which gear design, manufacture, and inspection are based, and more.

This course is taught at Daley College. A shuttle bus is available each day to transport students to and from the hotel. Class are 8 a.m.-5 p.m. each day.

This course is IACET accredited and worth 1.3 CEUs.
Upcoming Webinars

When Discussing Electric Vehicles You Must Talk About the Consumers
August 4, 2021 | 1-2 p.m.
We continue to discuss the paradigm shift in automotive manufacturing. The future is uncertain. In order to have a comprehensive picture, one must include the consumers. Escalent’s EVForward™ is the largest EV study of the next generation of EV buyers. Mike Dvorany and his team talked with 10,000 new vehicle buyers. Come and listen to what they discovered from this research as we work to move forward in this space.

Latest Trends in Trade Secrets Protection and Enforcement for the Bearing and Gear Industries
July 14, 2021 | 1-2 p.m.
This webinar will survey recent developments in trade secrets protection and enforcement and issues affecting the bearing and gear industries. Topics include:
- Corporate best practices for managing and protecting trade secrets.
- Patent vs. trade secret protection.
- Trade secret audits and tracking.
- Restrictive covenants and non-compete, new challenges.
- Employee lifecycle: Tips for employee on-boarding and exit interviews.
- Interplay between cybersecurity and trade secret protection.
- Use of cybersecurity tools to detect external and/or internal threats.
- Managing risk with JV partners, vendors, and independent contractors.

AGMA’s Emerging Technology Efforts — What’s Next?
September 1, 2021 | 1-2 p.m.
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. As we enter our fourth year of work in this space, join us for an overview of what we have accomplished and a roadmap of where we hope to go next.

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WHY ATTEND MOTION + POWER TECHNOLOGY EXPO
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ALL MOTION AND POWER TRANSMISSION INDUSTRY SECTORS
Motion + Power Technology Expo covers the full range of power transmission solutions using mechanical power transmission, pneumatics, hydraulics, electric motors, and drives. Read how professionals from each industry sector will benefit from attending.

MORE INFO motionpowerexpo.com

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

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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.

July
- July 15 — Nomenclature Committee Meeting — WebEx
- July 19 — Materials 7 Metallurgy Committee Meeting — WebEx
- July 20 — Fundamentals of Gear Design & Analysis Course — St. Louis, Missouri

August
- August 4 — Lubrication Committee Meeting — WebEx
- August 4 — Emerging Technology Webinar — WebEx
- August 5 — Gear Accuracy Committee Meeting — WebEx
- August 5 — IIoT Committee Meeting — WebEx
- August 10–11 — Basic Gear Inspection for Operators Course — Chicago, Illinois
- August 12 — Plastics Committee Meeting — WebEx
- August 17 — Powder Metallurgy Committee Meeting — WebEx
- August 18 — AGMA Board of Directors Meeting — Alexandria, Virginia
- August 19 — Nomenclature Committee Meeting — WebEx
- August 20 — 3D Printing Committee Meeting — WebEx
- August 24 — Metallurgy & Materials Committee — WebEx
- August 24–26 — Detailed Gear Design Course — Chicago, Illinois
- August 31 — Robotics & Automation Committee Meeting — WebEx
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Materials matter – and so does total cost of ownership

Energy efficiency is critical to many of today’s end markets. Next-generation gear-system designs and, specifically, new propulsion powertrains, demand performance at the lowest possible cost.

Gear designers have options when exploring cost reductions within a component, from using different material grades and leaner processing to incorporating less-proven offshore suppliers. While individually, these options may provide lower costs, consequently they might drive higher costs in other areas of the supply chain. It’s important to look holistically at the supply chain and focus on total cost of ownership.

Whether you are managing a supply chain or partnering with an experienced company like TimkenSteel to do so, you should recognize that each stopping point in the creation of your gear presents an opportunity for performance and savings. For example, if your application requires a more costly raw material, you may discover savings by customizing that material to your downstream suppliers’ equipment or processing capabilities.

Using integrated systems to improve the flow of information and materials within the supply chain can dramatically reduce inventory costs and investment in working capital.

Remember these points to help control costs within the supply chain:

- **Consider all the capabilities of the supply chain** when making sourcing decisions. Make sure you’re conducting due diligence to select the right suppliers for the right roles. Look at factors such as their physical location, technical and management expertise, demonstrated process capabilities, planned lead times, historical quality performance and warranty claims data, etc.

- **Understand material utilization, projected scrap rates and how much material is needed to manufacture the desired components.** Ask yourself if there are opportunities in the design phase of the project to minimize material requirements.

- **Understand how to communicate well and help facilitate a smooth transition between suppliers.** Know the handoff points and understand how you can automate the communication process and share information electronically between compatible systems.

- **Consider where you can eliminate redundancies.** For example, can you sequence or combine inspections while ensuring quality?

- **Identify opportunities to utilize open capacity** in the supply chain.
versus making investments in new capital equipment.

- Be careful to manage working capital and take advantage of trusted regional or localized supply partners. Evaluate safety stock, required WIP and planned delivery times carefully to manage the inflow inventory and conserve cash.

- Continuously analyze and manage logistics costs for each part of the supply chain and combine freight pick-up and delivery destinations where possible.

- Design raw material thermal treatment for optimal machinability within the supply chain and for customer gear cutting and finishing, which ultimately affects gear performance.

- Review options to combine operations within the supply chain. Suppliers like TimkenSteel offer turnkey processing from melt-to-component manufacturing, which could allow you to focus on core competencies.

The most important part to managing a complex supply chain is having the expertise to know where you can improve. This includes identifying and mitigating problems early in the process, reducing inefficiencies and sources of variation and devoting resources to drive out costs. Open, proactive communication with suppliers and customers is also key to identify and implement comprehensive continuous improvement initiatives and reduce the total cost of ownership.

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This article first appeared in the December 2020 issue of Gear Solutions.
Maximum allowable torque

What is the maximum allowable torque of a gear and why does it matter?

When participating in a competitive sport, there is a strong desire to maximize the physical output of your body. Whether it is running faster or leaping higher, we all strive to push the boundaries of how we were designed. Sometimes these activities result in spectacular imagery, such as when we leap high into the air and catch a football in the end zone, scoring the game winning touchdown. Other times, they result in spectacular failure, such as when we land from that amazing catch and our femur cracks under the pressure. Engineers typically push the physical limits of gearing in a similar way to what athletes do to their bodies.

In order to properly size a gear for a specific application, design life is critical. If a gear needs to operate for a short cycle, perhaps one hour, then the applied torque can be significantly higher than if the same gear needs to operate for six months or more. A common design standard for gearing is 2,600 hours. This benchmark represents a gear being in service for eight hours per day, five days per week, for one full year, with a factor of safety of 1.25. With this time frame established, annual preventative maintenance can be scheduled on the mechanism to check for wear and other issues.

As torque capacity is inversely proportional to the operational speed of a gear train, the maximum allowable torque will vary depending on the speed of the driven gear. When a gear is not rotating, the maximum allowable torque is equal to the static torque. As the gear begins to rotate, the dynamic torque capacity decreases as noted in the Figure 1.

Just as the speed is important to the value of the maximum allowable torque, so is the definition of maximum allowable torque itself. Most engineers only consider the maximum allowable torque due to bending strength. This is the maximum applied torque that will cause an instantaneous failure of the gear. Another torque to consider is the maximum allowable torque due to surface failure. The failure mode, also known as bearing failure, is defined as the allowable applied torque that minimizes surface wear, thus allowing the gear to perform as designed for the desired life span. These two torque capacities are independent and can vary significantly.

Let us consider the following situation:

If we choose a module 2, 20 tooth, carbon steel spur gear, with a 20mm face width, operating at 100 rpm, symmetrically supported by bearings, properly lubricated, driven by a uniform load and a desired life of 107 cycles, then the maximum allowable torque due to bending strength is 46 Nm. However, the maximum allowable torque due to surface failure is only 2.83 Nm. With this gear, the surface torque capacity is only 6 percent of the bending strength torque.

If we choose a module 2, 40 tooth, carbon steel spur gear, with a 20mm face width, operating at 100 rpm, symmetrically supported by bearings, properly lubricated, driven by a uniform load and a desired life of 107 cycles, then the maximum allowable torque due
Just as the speed is important to the value of the maximum allowable torque, so is the definition of maximum allowable torque itself. Most engineers only consider the maximum allowable torque due to bending strength. This is the maximum applied torque that will cause an instantaneous failure of the gear.

to bending strength is 118 Nm. However, the maximum allowable torque due to surface failure is only 12.5 Nm. With this gear, the surface torque capacity is slightly better at 10.5 percent of the bending strength torque.

In order to improve the surface durability, a heat treatment is typically applied to the tooth surfaces. Dependent on the base material, the heat-treatment method could be laser hardening, carburizing, or induction hardening. Each of these processes increases the surface durability of the tooth flank but they also reduce the bending strength.

Using the same gears detailed above and induction hardening the tooth areas, we are able to significantly improve the maximum allowable torque due to surface failure. For the 20-tooth example, although the bending strength torque capacity drops from 46 Nm to 38.3 Nm, the maximum allowable torque due to surface durability increases from 2.83 Nm to 16.6 Nm. For this gear, a 17 percent decrease in bending strength results in a six-fold increase in surface durability. For the 40-tooth example, the bending strength torque capacity drops from 118 Nm to 98.3 Nm, and the maximum allowable torque due to surface durability increases from 12.5 Nm to 72.1 Nm.

As noted earlier in this article, the desired life is shorter, then the maximum allowable torque values will be higher, and if the operating speeds are increased, then these values would be lower. The maximum allowable torque is never one static value. The designer must always consider all of the operating conditions in order to properly calculate the maximum torque values. Athletes, like gears, can suffer from bending strength failures, resulting in broken bones, and they can suffer from surface failures, resulting in hip and knee replacements. When operated properly, the service life of both athletes and gears can exceed their design life.

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Precipitation hardening stainless steels

The top alloy groups have seen increased growth in application because of corrosion resistance, strength, and low distortion upon precipitation hardening treatment.

In this column, we will discuss precipitation hardening steels and their physical metallurgy.

Precipitation hardened stainless steels are a class of stainless steels that can be hardened to significant strength levels by heat treatment. These alloys were first introduced in 1946 [1] to fill the need of high-strength, corrosion-resistant alloys that would be capable of operating at elevated temperatures. Since their initial creation, numerous different alloys have been created. These alloys are now widely used in aerospace, marine, automotive, paper, nuclear, petrochemical, and other applications. These alloys are used whenever a combination of high strength, corrosion resistance, and toughness is required. Precipitation hardening is achieved by the addition of copper, molybdenum, aluminum, and titanium. These alloys are generally solution heat treated at the mill, fabricated at shop (forming and machining), then aged to achieve the desired mechanical properties. The age hardening step then precipitates the hard intermetallics that significantly increase hardness and strength.

Precipitation hardening stainless steels are divided into three main groups of alloys: martensitic; semi-austenitic; and austenitic. Typical chemistries of common alloys in each group are shown in Table 1.

### MARTENSITIC PRECIPITATION HARDENING STAINLESS STEELS

These stainless steels are typically used as bar or forging stock, but can be available as castings, sheet, or plate. Cold forming of these alloys is difficult because of the untampered martensitic structure developed during solution heat treatment. Alloys in this condition have relative low ductility and high strength. Hardening by a single aging treatment will produce yield strengths from 1,170 MPa to 1,376 MPa (170-200 Ksi). These alloys can be used at temperatures up to 482°C (900°F).

### SEMI-AUSTENITIC PRECIPITATION HARDENING STAINLESS STEELS

These alloys are predominantly produced as sheet because the austenitic structure after solution heat treatment provides excellent formability. Mechanical deformation after solution heat treatment transforms the austenite present from solution heat treatment to a martensitic structure. Refrigeration can also drive martensite transformation. Aging at temperature allows the precipitation hardening mechanism to occur.

### AUSTENITIC PRECIPITATION HARDENING STAINLESS STEELS

This group of alloys has lower mechanical properties than the other two groups of precipitation hardenable stainless steels but has good creep resistance and holds their properties to temperatures to as high as 704°C (1,300°F). Precipitation occurs during aging at 650°-750°C.

### PHYSICAL METALLURGY

There are predominantly two different crystal structures for precipitation hardening stainless steels – ferrite and austenite.

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Typical Chemical Analysis %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>Mn</td>
</tr>
<tr>
<td>A 286</td>
<td>0.04</td>
<td>1.45</td>
</tr>
<tr>
<td>17-10PH</td>
<td>Austenitic</td>
<td>0.07</td>
</tr>
<tr>
<td>13-8Mo</td>
<td>Martensitic</td>
<td>0.05</td>
</tr>
<tr>
<td>17-4PH</td>
<td>Martensitic</td>
<td>0.05</td>
</tr>
<tr>
<td>Custom 455</td>
<td>Martensitic</td>
<td>0.05</td>
</tr>
<tr>
<td>17-7PH</td>
<td>Semi-austenitic</td>
<td>0.06</td>
</tr>
<tr>
<td>AM-350</td>
<td>Semi-austenitic</td>
<td>0.09</td>
</tr>
<tr>
<td>PH 15-7 Mo</td>
<td>Semi-austenitic</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 1: Typical compositions of some precipitation hardening stainless steels.
This solution heat treated and quenched thermal treatment is called and quenched at the mill. Product forms are bar, plate, sheet, and billet.

**MARTENSITIC PH STAINLESS STEELS**

This material is typically solution heat treated at 1,037°±13°C (1,900°F) and quenched at the mill. Product forms are bar, plate, sheet, and billet. This solution heat treated and quenched thermal treatment is called “Condition A.” In this condition, the material is readily machined to the desired shape. After machining, the part is aged to the desired properties. One of the advantages of precipitation hardening stainless steel is the ability to readily machine parts in Condition A, and age them at moderate temperatures to the final strength. The typical contraction from hardening this group of alloys during aging is extremely small. Aged from Condition A to 900°F, the resulting contraction is 0.0004-0.0006 inches per inch. The contraction from aging Condition A at 1,150°F is 0.0009-0.0012 inches per inch [2].

**SEMI-AUSTENITIC PRECIPITATION HARDENING STAINLESS STEELS**

These steels are austenitic in the solution-treated condition, transformed to martensite either by mechanical working or by thermal treatment. Additional strengthening occurs during aging. An additional austenite conditioning step is required before aging. Refrigeration at -100°F after rapid cooling from the conditioning step helps to achieve the desired peak strength. These alloys have a much more complex heat-treatment cycle and mechanical working to achieve the very high strengths. Space does not allow a full discussion of the interactions between austenite conditioning, aging, and mechanical deformation.

**AUSTENITIC PRECIPITATION HARDENING STEELS**

In these alloys, sufficient austenite stabilizers are present (such as nickel) to maintain an austenitic structure. The martensite start temperature is lowered, so that it is room temperature or below. This group of alloys contains titanium and aluminum, and hardens by the formation of Ni₃(Al,Ti) during precipitation hardening.

The heat treatment of this group of alloys consists of solution treatment at 982°C (1,800°F), and cooling rapidly (typically an oil or polymer quench) to Condition A. The alloy is then fabricated, and subsequently aged at 704°C (1,300°F) for 16 hours, then air cooled [4]. These alloys have a much lower yield strength (620 MPa) than the martensitic or semi-austenitic grades.

**CONCLUSIONS**

In this column we introduced the different types of precipitation hardening stainless steels, and briefly discussed the thermal treatments and physical metallurgy of the three alloy groups within the broader precipitation hardening grades of stainless steels.

These alloys have seen increased growth in application because of corrosion resistance, strength, and — importantly — low distortion upon precipitation hardening treatment.

**REFERENCES**


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**ABOUT THE AUTHOR**

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A COMPARISON OF AN ANALYTICAL AND FEA APPROACH IN DETERMINING THERMAL LEAD CORRECTION FOR HIGH-SPEED GEARS
A simplified approach for quick and reliable heat analyses for thermal lead correction of single-stage double helical high-speed gears has been developed.

By ANDREAS BEINSTINGEL, BURKHARD PINNEKAMP, MICHAEL HEIDER, DANIEL STIERLI, and STEFFEN MARBURG

For high-speed applications, gears of large dimensions and high-power density are used. Temperature distribution in those rotors is much different in operation as compared to manufacturing. Therefore, the tooth contact as it can be validated by blue ink during assembly is not only affected by distortion and bending under load but also by non-uniform thermal growth. As power density and specific load are continuously increasing over time, for highly sophisticated applications, this influence should be accounted for with suitable lead modification, as it is demanded by the latest version of API 613.

For many years, RENK-MAAG has been using empirical methods for thermal lead corrections based on measurements and experience. Lately, the authors carried out complex finite element calculations to numerically investigate the influence of temperature distribution on tooth contact. This kind of detailed finite element modeling for tooth contact analyses requires a strong effort with respect to the corresponding finite element meshing as well as extended computation time. Therefore, the numerical method was further enhanced. As a result, a simplified approach for quick and reliable heat analyses for thermal lead correction of single-stage double helical high-speed gears was developed. The paper describes the theoretical background and gives a comparison of the results with the different calculation approaches.

INTRODUCTION

Under operation, a part of the transmitted mechanical power is lost as thermal energy. Therefore, heat generation in a gearbox is related to the overall power loss consisting of gear mesh, bearings, seals, and auxiliary losses [1]. The total gear-power loss can be further distinguished in load-dependent losses and load-independent losses. The first category is related to frictional rolling and sliding energy dissipated during power transmission, whereas the latter one considers dissipative effects due to the rotational movements of the wheel bodies; in detail, windage power loss and oil power losses due to oil injection impacts, oil squeezing during gear meshing, and oil acceleration. It is obvious that, especially for high-speed applications with larger dimensions, these power losses and their resulting heat generation can become significantly high. As a result, thermal distortion of the gear blanks needs to be considered in addition to bending and torsional deflections when designing profile modifications for high-speed gears. A schematic draft of the mechanical deflections and the thermal distortion of a pinion shaft is illustrated in Figure 1.

Already in the 1970s, MAAG published its philosophy on how to compensate for thermal deflection by specific lead modification [2]. The determination of the steady-state temperature distribution in a gear blank was investigated experimentally in [3,4] and simulated numerically in [5] and [6]. RENK-MAAG, a subsidiary to RENK AG, adopted these methods and has, for many years, been using thermal modifications, continuously improving the application through experience. The computational approach in [7] also focuses on the radial deformation of the gear teeth. In this article, a simplified calculation strategy is presented to determine the thermal condition of the gear wheel bodies as well as the resulting thermal profile correction along the path of contact in the normal direction relative to their corresponding tooth flanks. The underlying computational model of this technique considers only the pinion and wheel body as a basic cylinder volume without an explicit description of the gear-teeth geometry. The quality of this approach is tested against a detailed finite element analysis of the same gear type and is finally compared to design values of experience.
1 THEORETICAL BACKGROUND OF THERMAL LOAD ANALYSIS

The computational approach to determine an optimum thermal lead correction basically consists of three sequential steps:

- Calculation of temperature distribution in pinion and wheel.
- Calculation of thermal growth due to the temperature change in pinion and wheel.
- Derivation of thermal lead corrections by superimposing the results of pinion and wheel.

In the first step, the thermal situation in the pinion and wheel body is determined by solving the heat equilibrium equation [8] using the thermal boundary conditions defined in the next section

\[ c \cdot \rho \cdot \frac{dT}{dt} = \lambda \cdot \Delta T + \dot{q} \quad \text{Equation 1} \]

where
- \( T \) is the current temperature [K].
- \( t \) is the time [s].
- \( \lambda \) is the material conductivity [W/m/K].
- \( c \) is the specific heat capacity [J/kg/K].
- \( \rho \) is the material density [kg/m³].
- \( \dot{q} \) is an external heat flux [W/m²].

Then, the gained result — in form of a temperature distribution — serves as the boundary condition for the structural analysis in the second step. Here, the thermal expansion \( u_a \) and \( u_r \), in axial and radial direction, respectively, caused in a cylindrical body by a temperature change is given as follows [9]

\[ u_a(r,z) = \alpha_{th} \cdot \int_0^b (T(r,z) - T_0) \, dz \quad \text{Equation 2} \]

\[ u_r(r,z) = \left[ (1 + \nu) \cdot \frac{1}{r} + (1 - \nu) \cdot \frac{r}{r_a} \right] \cdot \alpha_{th} \cdot \int_0^r r \cdot (T(r,z) - T_0) \, dr \quad \text{Equation 3} \]

where
- \( r \) is the radial coordinate [mm].
- \( z \) is the axial coordinate [mm].
- \( \nu \) is the Poisson’s ratio [-].
- \( b \) is the gear width [mm].
- \( r_a \) is the tip radius [mm].
- \( \alpha_{th} \) is the thermal expansion factor [1/K].
- \( T_0 \) is the initial temperature [K].

Finally, the deformations occurring on the active flanks of the pinion and wheel can be determined. As schematically illustrated in Figure 2, a subsequent superposition of these resulting thermal expansions delivers the effect of actual thermal distortion on the total gear meshing. As a result, a two-dimensional thermal lead correction field along the gear flank and the path of contact — from point A to point E — can be derived.

2 DETERMINATION OF BOUNDARY CONDITIONS OF THERMO-MECHANICAL MODEL

As the focus lies on the temperature balance of the pinion and wheel body, only the two corresponding components of the complete gearbox are considered in all computations. Moreover, these subdomains can be further reduced with respect to their axial- and longitudinal-symmetric design, see Figure 3.

Any further effects of thermal growth such as impact on gear backlash, center distance, bearing load distribution, and alignment are not considered in this article.

In this specific area, the main heat generation consists of the power loss of the gear mesh and the power loss of the adjacent bearings. The thermal heat input related to the bearings is here assumed to primarily dissipate through the housing and hence no additional temperature exchange at the shaft surfaces \( F_s \) takes place in the following investigations. As a result, the only heat input into the wheel bodies is the corresponding heat flux acting on the respective surface \( F \) due to the gear power loss \( P_v \), which consists of two parts [1]: a load-dependent power loss \( P_z \) and a load-independent power loss \( P_{z0} \)

\[ P_v = P_z + P_{z0} \quad \text{Equation 4} \]

The load-dependent power loss \( P_z \) is the result of the frictional losses along the path of contact during power transmission, where rolling as well as sliding friction occurs during the gear-meshing process. As sliding friction dominates, the rolling friction is neglected and the power loss \( P_z \) is finally given [10,11]

\[ P_z = \frac{1}{\pi a} \cdot \int_a^b F_N(\eta) \cdot \mu(\eta) \cdot v_s(\eta) \, d\eta \quad \text{Equation 5} \]

where
- \( P_{\text{ef}} \) is the transverse pitch [m].
- \( F_N \) is the normal force [N].
- \( \mu \) is the frictional coefficient [-].
- \( v_s \) is the sliding velocity [m/s].

The frictional coefficient \( \mu \) is determined according to [12,13]. The calculation of the normal load distribution \( F_N \) along the path of contact is based on [14].

The load-independent power loss \( P_{z0} \), related to the rotational movements of the wheel bodies consists of windage-power loss and oil-power losses caused by oil injection impacts, oil squeezing, and oil acceleration. Therefore, the amount of the power loss \( P_{z0} \) increases with the gear dimensions and the rotational speed and can thus move significantly into the foreground for high-speed applications.

![Figure 2: Schematic representation of the thermal expansion of pinion and wheel and its effect on the gear meshing process.](image)

![Figure 3: Computational sub model within its boundary surfaces.](image)
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can be determined by a computational fluid dynamics (CFD) analysis [15] or by an approximation according to [10] and/or [16]. The latter method is the approach of choice in this article.

Finally, the total power loss $P_v$ serves as the basis for the thermal heat input into the surfaces $F$ for the pinion and for the wheel, respectively. Under consideration of the gear ratio $u = \frac{z_2}{z_1}$, the respective portion of the pinion power loss $P_{v,1}$ and of the wheel power loss $P_{v,2}$ can, as an approximation suggested by the authors, be calculated by the following equations:

$$P_{v,1} = \frac{1}{2} \cdot (P_2 + \frac{1}{u_{\text{re}}} \cdot P_{20})$$
$$P_{v,2} = \frac{1}{2} \cdot (P_2 + \frac{u}{u_{\text{re}}} \cdot P_{20}).$$

Equation 6

Besides the heat absorption of the gear cylinder surfaces $F$, both the pinion body and the wheel body are in constant thermal interaction with the surrounding air/oil mixture. In detail, the front side surfaces $F_f$, the gear cylinder surfaces $F$, and the gap surfaces $F_g$ between the helices. All interactions at these particular areas are specifically described by means of forced convection heat-transfer coefficients. While the cylinder surfaces $F$ and $F_g$ are approximated by flat plates with longitudinal flow [17,18], the front side surfaces $F_f$ are interpreted as a rotating disk in a stationary fluid according to [6, 19,20,21]. Therefore, an individual calculation is required for the corresponding Nusselt numbers $N_{uf}$.

$$N_{u\text{plate}} = \begin{cases} 0.664 \cdot \frac{1}{Re} \cdot Pr^{\frac{1}{3}}, & Re \leq 5 \cdot 10^4 \\ \frac{0.637 \cdot Re^{0.86} \cdot Pr^{0.5}}{1 + 2.443 \cdot Re^{-0.1} \cdot (Pr^{0.5} - 1)}, & Re > 5 \cdot 10^4 \end{cases}$$

Equation 7

$$N_{u\text{disk}} = \begin{cases} 0.308 \cdot (k + 2) \cdot Pr^{\frac{2}{3}} \cdot Re^{\frac{2}{3}}, & Re < 1.95 \cdot 10^5 \\ 10 \cdot 10^{-30} \cdot Re^5, & 1.95 \cdot 10^5 \leq Re \leq 2.5 \cdot 10^5 \\ 0.0197 \cdot (k + 2.6) \cdot 0.5 \cdot Pr^{0.6} \cdot Re^{0.8}, & Re > 2.5 \cdot 10^5 \end{cases}$$

Equation 8

where

$Re$ is the Reynolds number [-].

$Pr$ is the Prandtl number [-].

$k$ is an exponent-constant according to [19] [-].

With the definition of the physical properties of the surrounding air/oil mixture, the forced convection process at the two-wheel bodies is initially described. Hereby, a complete atomization of the injected oil is assumed due to the high circumferential velocities in high-speed applications. As a result, the specific fluid properties $\phi_{\text{mix}}$ of the homogenous two-phase flow inside the gear housing are calculated with the following formula

$$\phi_{\text{mix}} = (1 - \xi) \cdot \phi_{\text{air}} + \xi \cdot \phi_{\text{oil}}$$

Equation 9

where

$\phi_{\text{mix}}$ is the fluid property to be determined.

$\phi_{\text{air}}$ is the corresponding property of air.

$\phi_{\text{oil}}$ is the corresponding property of oil.

$\xi$ is the oil/air-ratio [-].

Since the oil-to-steel contact in the gear meshing means a further significant heat transfer for the two-wheel bodies, this cooling process is also considered by an additional forced convection heat-transfer coefficient interacting with 100 percent oil at the top surfaces $F$ and $F_g$ in the mesh sector of the circumference. In addition, a representation of the fling-off effect according to [22] is considered.

As the intermediate surface $F_{\text{sym}}$ represents the symmetric split of the double helical gear, symmetric boundary conditions are applied for all thermal and structural analyses.

Finally, the thermal boundary conditions can be summarized in a basic manner as follows:

Table 1: Gear geometry data and material properties of investigated gearbox.
where

- $n$ is the unit vector normal to its corresponding surface [\].
- $h_{\text{disk}}$ is the convection coefficient according to rotating disk theory [W/(m²K)].
- $h_{\text{plate}}$ is the convection coefficient according to flat plate theory [W/(m²K)].
- $h_{\text{flo}}$ is the convection coefficient according to fling-off theory [W/(m²K)].
- $h_{\text{oil}}$ is the convection coefficient considering thermal output during gear meshing [W/(m²K)].

\[ \frac{\partial T}{\partial n} |_{F_f} = h_{\text{disk}} \cdot (T - T_{\text{amb}}) \]  
\[ \frac{\partial T}{\partial n} |_{F_e} = h_{\text{plate}} \cdot (T - T_{\text{amb}}) + h_{\text{flo}} \cdot (T - T_{\text{oil}}) + h_{\text{oil}} \cdot (T - T_{\text{oil}}) + \dot{q} \]  
\[ \frac{\partial T}{\partial n} |_{F_s} = \frac{\partial T}{\partial n} |_{F_{\text{sym}}} = 0 \]

**Equation 10**

**Equation 11**

**Equation 12**

**Equation 13**

$T_{\text{amb}}$ is the ambient temperature of the air/oil mixture [K].
$T_{\text{oil}}$ is the oil temperature [K].
$\dot{q}$ is the external heat flux due to the gear power losses [W/m²].

### 3 APPLICATION AND RESULTS

The procedure from Section 2 to determine the thermal lead correction, under consideration of the boundary conditions defined in Section 3, is now carried out by means of an example. The computation is done once by applying the finite element method and then again by using a highly simplified analytical approach. The obtained profile modifications of these two methods are finally compared with each other to validate the analytical model on the basis of the finite element calculations. In addition, a reference is made to the results of an empiric formula developed and proven over the years at RENK-MAAG.

In all the investigations covered by this article, only the steady-state temperature distribution of the two wheel bodies is taken into account, and, hence, the time dependency in Equation 1 does not apply. All calculations and results refer to the gear data and the material properties listed in Table 1. While the ambient temperature inside the housing is here assumed by experience, the integral temperature is calculated as suggested in [13].

As indicated in Figure 4, the finite element approach maps the complete wheel body in three-dimensional space, including their exact tooth geometry. Therefore, the boundary conditions of the previous sections can be applied directly to the corresponding surfaces — for example: the heat input due to the gear power losses is directly applied to the active flank surfaces. Accordingly, the thermal expansions of the active tooth flanks, in normal direction, also are determined automatically by the finite element analysis.

In contrast, the analytical approach of the present work computes the temperature distribution and the structural deformations of a wheel body by describing its complete geometry as a simple cylinder without gear teeth. For this reason, the thermal boundary conditions are adjusted to take account of the difference in the surface area. In a subsequent step, the resulting thermal expansions of the cylinder — Equation 2 and Equation 3 — are transferred to the thermal expansions of the active gear flanks in normal direction by basic geometry operations.

Once the thermal expansions of the active flanks are available for pinion and wheel, the thermal lead correction from the superimposed thermal distortion between pinion and wheel is derived identically for both calculation approaches. The results for one half of the double helical gear are shown in Figure 5 for the finite element approach and in Figure 6 for the analytical approach, respectively. The colors in the figures correspond to equivalent scales. For this reason, Figure 5 and Figure 6 can be put directly in relation to each other.

It can clearly be seen that basically the finite element analysis aligns with the analytical approach. Both thermal lead corrections propose their highest peak at about 80 mm in longitudinal direction.

Furthermore, they have their minimum value located in the area of the tooth gap of the double helical gear. However, minor deviations show up along the path of contact at the beginning and at the end of the gear meshing. This can probably be referred to the fact that the exact tooth geometry is not considered with the analytic approach. Figure 7 shows an extract of these results — Figure 5 and Figure 6.
— along the longitudinal axis at pitch radius. In addition, a thermal lead correction design based on the empirical formula as described in Section 1 is depicted in Figure 7.

As it can be expected, the curves are not identical. However, the general shape and amount of modifications align sufficiently well. The first validation of finite element approach and analytic method with the empirical values covered by experience is successful. Applying and continuously improving the calculation methods will even increase the reliability and provide confidence to even extrapolate the results beyond the actual area of experience.

4 CONCLUSION
In addition to mechanical distortion, the temperature distribution in the gears demands for a specific thermal lead correction for high performance high-speed gears. Sophisticated calculations with the finite element method are compared to a much easier-to-apply analytical method developed by the authors. The results not only align satisfactorily with each other but also with empirical formulae that have been used for decades and match well with experience.

Therefore, the newly developed calculation method is considered suitable for actual gear designs even if they extend the scope of coverage of the existing empirical methods. Further research and validation by practical experience will give the basis for further improvement of the calculation approach.

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ABOUT THE AUTHOR
Andreas Beinstingel, Burkhard Pinnekamp, and Michael Heider are with RENK AG. Daniel Stierli is with RENK-MAAG GmbH. Steffen Marburg is with the Technical University of Munich.
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HEAT TREATMENT OF GEARS
The benefits of close interaction between gear designers and heat-treat specialists can lead to total cost and quality optimization.

By BILL DISLER

Often the options of heat treat may feel pre-defined when looked at from a gear designer’s perspective. There are options, but both gear designers and some heat-treat manufacturers are constrained by limited exposure to the fundamental physics that drive the process performed by the equipment available. The heat-treat industry is old and rich with experience, but it moves slowly without the proper incentives to change. It is important to recognize the benefits of early, constructive dialogue between gear and powertrain designers and heat-treatment experts to advance system features and designs to the overall benefit of cost-effective performance of quality powertrain systems.

The objective of this article is to touch on some of the key elements of heat treatment at the fundamental levels to impress upon readers the benefits and limits of commonly discussed methods. In some cases, older methods with newer packaging can be a foundation for progress. The science of our processes has not changed much over the last several decades. The focus of this article is carburized gears, but most of the fundamentals discussed can be applied in other heat-treat processes when the benefit can bring value.

A REAL-WORLD EXAMPLE – LARGE DEEP CASE GEAR OPPORTUNITIES MISSED

In this case we’re talking about wind-turbine gears — gears that can weigh in excess of 1,500 pounds (680 kilograms). The pressure created by surface winds apply extreme force to the turbine nacelle and the structure supporting the gears and rotating gear mass. Gears, no matter the application but especially in wind turbines, are expected to operate with as little noise as possible. To effectively operate in such harsh conditions, most wind-energy gears are carburized and quenched. The most common equipment used is pit furnace systems. The driving force in selecting this technology is the very long carburizing time related to quench utilization. Multiple pit carburizing furnaces can be serviced by one shared quench tank. When carburizing times are measured in days, utilizing multiple carburizing chambers with one quench tank is logical. However, when the overall gear design is taken into consideration to include both heat-treat and hard-grinding processes, opportunities exist to significantly improve manufacturing cost and overall quality.

The fundamentals of this carburizing and quench process are sound, but the physics of the mechanisms are not being considered. Keep in mind that thousands of these systems are being used for large gear processing around the world today. Carburizing en masse for deep-case parts makes sense. Beyond the awkward material handling and the undesirable product-to-fixture load ratios, the quench configuration is the true weakness. These systems use oil to quench the parts, which is a time-tested and proven process. Here is where physics comes in and the problems grow.

The oil quench system used is a vertically elongated quench chamber. It is simply not possible with such massive loads to get uniform high volume oil flow from the bottom to the top of such loads. Since oil boils when it gets too hot, there is an inevitable non-uniform cooling of these gears that leads to dramatic distortion. The more uniform the heat transfer during quench, the lower and more predictable the distortion you will see. Gears can be designed to compensate for predictable distortion.

Oil by nature is a multi-phase quenchant when used in heat-treat quench applications. This means there will always be more than one type of heat transfer occurring in a load, no matter what we do in quench designs: the heat transfer of liquid oil (convection), film boiling heat transfer, and the heat transfer into oil vapor (bubbles) when it all out boils. The differences of these heat transfer rates are dramatic (Figure 1).

For those of a less technical mindset, consider...
thawing something frozen for dinner. Let it thaw in air (vapor) or put it in water (liquid). The same physics principles are involved. All oil quench tanks have agitation — or they should — to minimize the formation of vapors that create non-uniform cooling of the parts. In an optimum situation, you want enough flow to absorb heat into the oil and take the oil away (convection) before it gets to a temperature of phase change. There are also detrimental effects from too much agitation, so we really want a sweet spot of 2-3 feet/second in an optimum world. (See Figure 2)

The quench tank in a pit furnace setup is the worst-case scenario, as the agitation is from the bottom to the top of the elongated tank. There is no way, regardless of how aggressive the agitation may be in the bottom of that tank, to have any uniform, much less laminar, flow through the load. Even with high flow at the bottom, the top of the tank will act closer to still oil. In addition, the mass of the gears creates voids of flow between themselves due to the needed vertical fixture. (See Figure 3)

The way the parts are configured within a load is very important to the uniformity of any quenchant’s flow. By using CFD flow modeling, fixturing can be optimized to improve flow. As an equipment supplier, I can say with experience this technology is seldom used early in a project, but often used to solve problems later in production. Figure 4 shows how CFD modeling can help with progressive quench system designs. Imagine what a flow model would look like if applied to a pit furnace quench tank. (See Figure 4)

During tests done in a conventional sealed quench batch furnace with a much more optimized oil quench configuration, it was found that a decrease in distortion could have a substantial impact in reducing the amount of costly hard grinding needed for these gears. It could also allow a decrease of carburizing time by almost one day — more than 20 hours of furnace time. The reason is the gear could be designed with less planned waste material, as the reduced distortion would minimize that requirement due to the improved quench method applied. Of course, using conventional sealed quench batch furnaces, each with their own quench tank, is not a cost-effective or practical solution for a number of reasons. However, the lessons learned can lead to new designs of equipment applying conventional technology in a new package. These alternatives exist and bring with them improved automation, improved quality of the parts, and much lower overall part costs.

But today, pit furnaces remain the primary solution purchased for heat treating such large, extremely deep case gears as are used for wind energy. Why? To take advantage of this change in heat treatment approach, the actual gear design, upstream of heat treatment, must be changed. In many companies, there is not an optimal channel of communications, and the actual Value Add that
could be seen is not easily conveyed.

**THE HEAT-TREAT BUILDING BLOCKS**

**GEAR DESIGNERS (AND FURNACE ENGINEERS) SHOULD UNDERSTAND**

1. Heating and holding parts at temperature during carburizing and other processes.
   a. Temperature specification for a process chamber may be common, but what the actual part experiences in one system vs. another is not the same — and it can matter.
   b. When comparing a continuous furnace to a batch furnace, regardless of process (atmosphere carburizing, LPC, nitriding, tempering, etc.), parts will experience more uniformity in continuous furnaces.
   c. In addition, in a comparison of a continuous process, parts experience better uniformity with a continuous process vs. a batch process. The reason is that although the chambers may be validated to common uniformity specifications, a part/load moves through a continuous furnace, and, hence, the parts experience an averaging effect of the highs and lows within the acceptable specification band. In a batch chamber, the parts are stationary and one part vs. another in the same load will experience the full variance of the tolerance allowed.

   Consider a ±10°F temperature specification in the typical carburizing furnace. That is a 20°F total spread. Although the significance to the quality results of what the parts see will vary based on case depth and process, consider that a change of 100°F in carburizing temperature either doubles or halves the case depth. If you are striving for higher and higher quality, this might matter.

2. Atmosphere options for carburizing — conventional endothermic gas vs. LPC-based approach — understand the pros and cons of both.
   a. Endothermic carburizing gas, either created by a generator or through a blend of nitrogen and methanol directly in the furnace, is controlled via sensors inside the furnace throughout the cycle, allowing compensation for load size variations.
      i. These processes displace air in the chambers with the gas, but will have trace levels of oxygen remaining.
      ii. Cycles are fairly “text book” with respect to carbon potential and case-depth creation.
   b. LPC uses alternating acetylene and nitrogen throughout the cycle to carburize, with no sensors inside the furnace involved throughout the process.
      i. LPC chambers use vacuum to remove air from the chambers and backfill with carbon-rich gas; hence, virtually no oxygen remains in the chamber.
      ii. Cycles can be simulated, but testing is required to dial in the exact process for each specific load of parts — the results depend on exact load surface area each time, so partial loading is not possible.
      iii. With no trace air, inner granular oxidation (IGO) can be eliminated, and this can be a benefit in some cases.

   Figure 4: Quench flow CFD model through fixtured parts.

   Figure 5: Heat transfer rates of common quench media.

   1. LPC processes come with a price, so be certain the IGO benefit applies to the application; often, it does not due to the failure points of the gear or the post-process grinding requirements.
   1. Acetylene carries about six times more carbon than conventional endo atmosphere and can offer faster cycle times for light-case parts.
   1. After a short carburizing time, the benefit of this surface carbon activity is overridden by carbon diffusion physics within the part. In mid- to deep-case carburizing, it is unlikely that the process times will differ in a significant way.
   1. The same can be expected for case uniformity when measured from the root to the face of a gear — with a shallower case, the benefits are likely to be more pronounced; with a deeper case, it will be less so.
   1. Viable temperature increases to shorten carburizing times, and their adverse effect on microstructure apply to both LPC and conventional atmosphere systems.
   1. Complications are created when using vacuum in continuous furnaces, so LPC is typically constrained to batch only processes.

3. Quench media and load size — key considerations to minimize distortion (a newer way to look at this topic).
a. Quench media, in my opinion, should be grouped into two main categories:
   i. Multi-phase quench media: oil, water, polymer.
      1. Each of these will experience phase changes during quench, which leads to non-uniform heat transfer in the parts, regardless of what is done in machine design.
      2. Although oil is a multi-phase quenchant, when used properly, it remains a high-quality, flexible solution that meets the needs of many gears and other components.
   ii. Single Phase Quench Media: Compressed Gas or Molten Salt
      1. These will not experience a phase change during quench and, therefore, will provide the most uniform heat transfer from the part during quench.
      2. Compressed gas, typically nitrogen or helium (which has a better heat transfer coefficient but is no longer viable), has very limited heat-transfer properties.
      3. Salt has better heat-transfer properties and is often blended with small amounts of water if even higher heat transfer rates are required.
   iii. In all cases, circulation is a major consideration.

b. The smaller the load, the better quench uniformity can be in all cases. This again is the intersection of physics regarding how one can get flow uniformly through the load.

c. Figure 5 shows approximate heat transfer rates for common quench media options.

Some words about using salt as a quench media: It has a stigma from the past of being a nasty media with all kinds of safety and environmental issues. Often, when I mention salt quenching, I get looks from seasoned heat-treat experts like I am crazy. It is very important that people understand salts better to open opportunities for the future. The salts being referred to in this article are 99-plus percent recycled, and what is left can be easily discarded, unlike oil. Salt used in these quench systems is very green and environmentally friendly. Further, with new sensors being developed, the heat-transfer rate of salt with small amounts of water added can be controlled and become an added factor to tailor many processes. Demand for salt quench systems is growing. In some cases, this is because it can do things no other media can, like quench to bainite with a 700°F quench temperature. In other cases, it is being considered for martensitic quench processing to provide better heat-transfer rates for those who have seen the benefits of gas quench systems but do not want to deal with the poor heat-transfer rate limitations. Like everything, it has limitations and aspects to be considered for its application, but due to its mechanical properties, it may be worth considering.

I encourage gear designers to reach out and explore the evolution of heat-treatment processes. Heat-treat systems tend to evolve slowly compared to other technologies such as metal cutting and automation, but they do evolve and can do so in the most efficient way when gear designers engage and explore options together with their suppliers. Much of what can be done is limited by physics, but creative packaging will allow for much more flexible and accommodating systems in the future. Although not explored in this article, changes are coming with other aspects of heat-treatment systems. As an example, consider the modular system shown in Figures 6 and 7.

This system is designed for fast installation on flat floors, is easily re-deployable similar to CNC machines, can process moderate sized loads to balance flexibility and cost per part, has small load quench benefits, and uses salt quench for environmentally friendly, low distortion quenching. Change can happen when gear designers and heat-treat equipment experts work together to develop a vision of their future needs.

Figure 6: Future modular system with salt quench.

Figure 7: Re-deployable heat-treat systems.

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Bill Disler is president and CEO of AFC-Holcroft L.L.C. He also held a previous concurrent title of chairman of the Board of ALD-Holcroft, a joint venture between ALD GmbH and AFC-Holcroft. Previous positions include leading the opening of an induction heat-treatment business unit for a major Japanese company through its Gear Technology Center and an industrial cleaning company serving the metal cutting equipment in gear centers and other powertrain related systems. Since 1916, AFC-Holcroft has been a leading manufacturer of industrial furnace systems used in the heat treatment of ferrous and non-ferrous metals. AFC-Holcroft has been a part of the AICHELIN Group since 2016.
When you need a new vacuum furnace to keep up with growing demands, we've got you covered with our HFL-IQ Series horizontal production furnaces. Standard features set us apart like improved graphite insulation materials, curved graphite heating elements, high velocity gas quench systems, and SolarVac® interactive control systems. Matched with our outstanding customer service and reliable Aftermarket support, we will keep your furnace running year after year.
Business resiliency is vital for protection from unexpected disruptions, market fluctuations, and macroeconomic issues.
(Courtesy: relayr)
Uncover the factors, technologies, and financial models that can help make a business more predictable and future-proof.

By GUNEET BEDI

Unforeseen disruptions, market fluctuations, and macroeconomic issues. The last year alone has exposed the unpredictable nature of the market and supply chains.

Even new competitors popping up from other industries — think Google competing with CNC machine providers, a pump OEM, or a water fixture manufacturing company — can make or break a business. Finding ways to make your business more resilient has become imperative, and those who can do that while creating more value will be even more primed for success.

Improving resiliency is a huge undertaking, and if you’re like many people, you’re probably unsure of where to start.

In this article, I’ll walk you through the different factors that can help build resiliency at your business, how advanced technology can enable it, common hurdles to watch out for, and some of the top advantages you can gain from doing the work.

WHAT MAKES A RESILIENT BUSINESS MODEL?

First, let’s go over what we mean when we talk about business resiliency. Relayr has identified nine different points of resiliency that manufacturers can leverage and capitalize on:

- **Revenue.** Ideally, you’ll want revenue to be recurring, long-term, and predictable to manage through any macroeconomic or market issues effectively.
- **Failure Risk Exposure.** Is your failure risk exposure from you and your customers? Have you either covered some of this risk or monetized the risk? It’s also essential to determine if your accrued risk on your balance sheets is possible to be covered by a partner like a specialty re-insurer.
- **Remote Equipment Visibility.** This is constant monitoring of your equipment. Do you have access to the data outputs? Are you aware of what’s happening with the equipment and how it’s being operated? Can you help your customers operate the equipment better to capture more equipment lifetime?
- **Maintenance Repair Costs.** Ideally, you’ll want any maintenance or repairs to be predictable, proactive, and remote.
- **Operation Cost.** Similar to repairs, can you predict your operation costs?
- **Spare Parts.** How many spare parts do you still have in your inventory, and why? Do you need to have it in your inventory? Instead, can you offer it on demand?
- **Utilization.** An idle machine is a monetization opportunity. How are your machines being used, and can they be deployed elsewhere?
- **Product Improvements.** If you’re gathering data from your gear, your product department can work on a more accurate, real-time basis to provide better machines for your end customers.
- **Remaining Useful Life.** Lastly, what’s the lifetime value of your assets? How often do you interact with customers? When do they come back to purchase a new machine? Can you make the machines remain useful for longer or replace them so that downtime is minimized?
All these factors are opportunities for your business to harness, ensuring you can proactively and predictively harbor any storm.

**HOW ADVANCED TECH PLAYS A ROLE IN MONETIZING**

You’re probably familiar with the Industrial Internet of Things (IIoT), artificial intelligence, machine learning, and big data. While these technologies are more enhanced than ever, they’ve also turned into buzzwords with promises of exponential business growth and prosperity.

IIoT, in particular, has been around for more than three decades, yet the concept still means something different to everyone. Many people define it as the connection of assets to gather data, such as smart home devices. However, the benefits of IIoT go well beyond that to address inefficiencies and other pain points in industrial settings.

But technology is only an element of a monetizing business transformation. In fact, technology investments should come well after you’ve defined your overall business strategy.

In general, people are done with piloting, and they’re finished with failed IIoT projects. They’re looking for business-impacting technology more than anything else. This leads us to the crucial question: How do you get there?

**COMMON HURDLES FOR SUCCESSFUL BUSINESS TRANSFORMATIONS**

Any fundamental shift in how you do business requires a lot of upfront work and planning before you ever flip the switch on any technology. While every manufacturer is different in terms of market, size, etc., there are common factors that can get in the way of your success.

**NOT STARTING WITH THE BUSINESS OUTCOMES**

Remember: This type of transformation is not about technology. It’s not about digitization either. The manufacturers who are getting this process right — the ones with greater resiliency — take a step back and approach their monetization efforts through a business lens.

Determining your desired business outcomes first helps you outline yours and your customers’ challenges and how you will solve them. Starting with the outcome will dictate all the technology architectures to follow.

Additionally, this overarching strategy will allow you to determine micro-goals or the smaller, incremental steps you’ll take throughout the process. Not only do these goals help give your team smaller wins to celebrate along the way, but they also serve as moments to pivot or course correct if needed.

**THE INTERNET OF LEGACY THINGS**

In the industrial world, assets are in the field for 20 to 50 years. Connecting these assets isn’t as easy as installing sensors or replacing them with new machines — especially with price tags of $200,000 to upwards of $1 million.

Therefore, it’s important to solve for the legacy and the existing install base through retrofitting. You need to make sure your technology solution and go-to-market strategy consider older gears you may have.

**THERE ARE NO COOKIE-CUTTER CASE STUDIES OUT THERE**

You could look at other industries for success stories, but digital business transformations are still relatively new in the manufacturing world. If you want to disrupt, you must get comfortable with being the first mover in your market.

If you’re a service provider or manufacturer of equipment and there is nothing for you to look to and copy, you have to start from scratch and develop it. As a first mover, you’ll probably come up against the classic inventor’s dilemma, but don’t worry: some stuff you’ll do wrong, yet others you’ll do right and improve.

This is an area where an expert partner can help guide you through the process, ensuring you have a sound strategy, the right resources in place, and are prepared for the cultural evolution needed for success.

**DISCOUNTING THE CULTURAL MIND SHIFT**

Many businesses get so wrapped up in the business transformation, and they forget to support internal changes. Worse yet, they underestimate how much focus and energy it takes to keep the momentum going.

Ask yourself: Do you have the right team in place who can make sense of the data you’re harvesting? How can you ensure others throughout the organization, especially those who aren’t used to the new processes or metrics, understand and are aligned? How do you set up an organization that embraces failure?

Changing the underlying mindset of your culture and the incen-
tives that follow is a major factor in how well your business can adapt to new ways of working.

**WHAT’S IN IT FOR YOUR BUSINESS**

As long as gear and rotating equipment manufacturers have been around, they’ve been differentiated by their products. Whoever had the best, longest-lasting asset for a competitive price would win the business. All of this is changing with technology.

About 200 CXOs at industrial companies were surveyed by relayr, and this year’s results showed that nearly half of U.S. businesses want to change the way they take products to customers. Even geographies are blurring. Where once German or U.S. companies would serve their respective markets, for example, now your reach can extend well beyond borders.

Today’s manufacturers need to start differentiating by exploring aftermarket services.

In the industrial sector, the interest of operators and their end customers isn’t aligned with manufacturers’ interests. This is because the manufacturer usually sells gears as a capital expense (CAPEX) and then goes away for 15 to 20 years and loses touch. They’re incentivized to build high-quality machines that don’t fail.

But, if the machines don’t fail, the manufacturers aren’t making any aftermarket revenue — and of course, the end customer doesn’t want the machine to go down. So, when we talk about monetizing your value, we’re really talking about aligning these interests.

Vertical integration is one area seen more and more in the industrial ecosystem as businesses look to remove barriers and create more value.

For original equipment manufacturers (OEMs), they’re forward integrating by trying to get into the aftermarket space to continue customer relationships, which will compete with the service providers. At the same time, service providers are backward integrating by being OEM-agnostic. They know how your equipment works, and it doesn’t matter who made it.

**NEW FINANCIAL MODELS**

A digital business transformation can enable numerous efficiencies and outcomes that can all make operations more resilient. One of the more popular strategies for manufacturers is switching to a pay-per-use model. You’ll also see this referred to as equipment-as-a-service (EaaS) or servitization.

Instead of purchasing an asset outright with pay-per-use pricing models, the OEM retains ownership and charges the customer on a subscription basis. Customers benefit by switching from CAPEX to operating expenses (OPEX), while manufacturers get more predictable and recurring revenue streams, additional customer touchpoints, and the flexibility to enter new customer markets.

EaaS is not a new concept but is a model seen more in software and consumer-focused industries. An example in the industrial world is “Power by the Hour,” coined by Rolls Royce, which was packaged as “Total Care” in the early ’90s.

Instead of selling jet engines outright, the company bundles them with a variety of services. Rolls Royce then leverages the data from the equipment to provide more guaranteed outcomes and performance of those assets. It’s committing to asset performance and charging for utilization, then bundling all the services and performance guarantees as well.

This is possible because Rolls Royce is closing the loop (see Figure 1). And by closing the loop to your customer, you can leverage the data from those machines to your benefit and the benefit of your customers.

As a closed-loop system, EaaS helps align the interests between manufacturers and customers. According to Bain & Company, not only does the customer experience a 15-percent reduction in operating costs, but the manufacturer or gear provider can make 50 percent more revenue throughout the lifetime of the asset. Additionally, aftermarket, uptime guarantees, and consumables all come with much more customer intimacy than traditional models.

While subscription models might not make sense for every business, it becomes more appealing when looking at your utilization. For example, suppose the utilization is high with rotating equipment, around 90 percent, or low at less than 15 percent. In that case, an EaaS model with uptime and availability guarantees starts to make a lot of sense.

**FOCUSING ON VALUE OVER PRODUCTS**

Often, we can’t predict issues, natural disasters, and other macro unknowns that may affect your business. What we can do, though, is identify those areas that are key for resiliency and how advanced technology, such as IIoT, AI, and machine learning, can help bring them to life. Whether it’s vertical integration, a pay-per-use subscription model, or machine uptime guarantees, it’s all about how you leverage the data and the value it can bring.

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GIVING FORM AND LIFE TO PROCESS MATERIALS

Peening, particularly for gears, is a critical process.
(Courtesy: Sinto America)
Sinto America, Inc. and its group of operating companies provides high quality, cost-effective, and innovative equipment and solutions to a variety of industries throughout North America.

By KENNETH CARTER, Gear Solutions editor

Every Sinto America employee takes pride in ensuring the best possible outcome for any challenge that comes its way. As a matter of fact, the company’s very name boasts a clue to that philosophy.

In Japanese, Sinto is written as two characters: “new” and “east.” Within those two simple words are the key to how Sinto America approaches its customers: by taking on new challenges while always moving forward with hope — essentially combining its strengths with its passion.

“I would say our overriding philosophy is to help our customers succeed with cost-effective products and services we can provide; we aim for satisfaction across the board with our customers, starting from the first phone call, all the way to supporting them after their equipment has been installed,” said Charlie Gorman, vice president of Sinto Surface Treatment. “But specific to gear manufacturing, we want to develop and provide the latest technologies to our customers in order to participate in the advancement of the transportation industries that use these products that depend on the applications.”

ENHANCING THE VALUE OF GEARS

Particularly for the gear industry, Sinto America provides services that can enhance the value of gears, according to Mike Fredbloom, director of Sales for Sys-T-Mation and new products.

“Sinto provides foundry equipment and services; one of the product lines we provide is blasting equipment for a foundry’s cleaning room to de-sand castings,” he said. “From that, Sintokogio (the parent company of Sinto America) adapted their products for other applications; peening gears for the automotive industry is an example. Sinto has developed several different models of shot peening machines for different applications, including the gear industry. Peening is one of the ways we are becoming involved in the gear manufacturing industry.”

Sinto has a product line called Sightia for nondestructive testing and quality assurance, according to Fredbloom. Sinto will be submitting a technical paper to GEAR Magazine for their fall technical conference concerning non-destructive testing and quality assurance. Using Sinto’s Sightia product line, manufacturers may perform 100 percent in-line, product quality checks. The process is very rapid, as little as 10 seconds, depending on the surface treatment performed on the gear.

“With any type of development, we’re always trying to look ahead in the industry that we’re participating in and see what challenges our customers are facing,” Fredbloom said. “We want to provide a better way to achieve a goal that improves quality, reduces process variation, and ideally lowers costs.”

MAXIMUM CUSTOMER SATISFACTION

With an international engineering support team, Sinto America can tackle a customer’s challenge from both a high level, as well as a lower level of detail, according to Gorman.

“From a high level in order to stay within the scope and budget of the project and then we tackle the details so we can ensure that the product is going to correctly function, be dependable, and be repeatable over the lifetime of the product or service,” Gorman said.
X-ray diffraction. (Courtesy: Sinto America)

A robotic load/unload of individual gears. (Courtesy: Sinto America)
Also, looking for partnerships with other companies is becoming the norm for Sinto America to give its customers more value-added product. Gorman emphasized such arrangements will ultimately strengthen Sinto America’s reputation, as well as its products and services.

“I think in today’s business environment, it’s going to require multiple types of solutions, whether it’s our equipment or not,” he said. “We want to participate primarily with the technology. Sinto has worked very hard to develop non-destructive, quality control products. Sinto’s Sightia product line is designed to perform 100-per-cent part-quality assurance checks within the production process ‘in line.’ Our PSMX-II, an X-ray diffraction device, measures the residual stress to confirm surface treatment is performed to customers’ specifications, while our ECNI eddy current device determines if the treatment covered the entire part.”

INNOVATION GOALS
With a history that covers decades of providing products and services to a variety of industries, Sinto has carved an impressive swath of innovation, particularly when it comes to peening, according to Fredbloom. For example, Dr. Yuji Kobayashi, a development manager at SintoKogio, was named “shot peener of the year” in 2018 and holds several patents on Sinto technology.

“Many of the technologies and processes that Dr. Yuji Kobayashi has developed are now the products that we are trying to promote in the North American gear market,” Fredbloom said. “His development in the area of peening and non-destructive testing have led to multiple products now being sold.”

That approach to peening will be necessary as electric vehicles become more of the norm, according to Gorman.

“With electric vehicles, weight is a huge concern,” he said. “Providing compressive stress adds strength and fatigue resistance to components that allow designers to reduce the weight of those components. We see that as a big driver going forward. The use of more automated processes and controls — non-destructive testing being one of them — reduces costs associated with surface enhancement processes. Sinto is striving to lead the way in the development of several of these different technologies.”

REMOTE MONITORING
As Sinto America continues to evolve and move into the future, the company is developing new Industry 4.0 technologies. Among these technologies are remote monitoring capabilities that are able to monitor processes and provide immediate feedback to the customer, according to Fredbloom.

“We have seen this technology demonstrated,” Fredbloom said. “Sintokogio has an internal video of this process of remote gear surface treatment evaluation, where a customer is at their manufacturing location, peening their gear, and Sinto technicians are located remotely at Sinto’s Surface Technology Center, reading the information on those gears. Then, the Sinto technicians advise the customer on how to calibrate the process to effectively peen the gears better.”

Peening, particularly for gears, is a critical process. Gorman pointed out that process control also remains critically important in the gear industry. Sinto is working to advance peening technologies and developments for future industry requirements.
MHI Machine Tool launches two new hobbing machines

Mitsubishi Heavy Industries Machine Tool Co., Ltd., a part of Mitsubishi Heavy Industries (MHI) Group, recently launched the GE15HS and GE25HS models of hobbing machines. Emphasizing high speed, precision, and efficiency, the new machines produce gears for electric and hybrid cars amid the global trend toward reducing the carbon footprint.

The GE15HS model is for gears with a maximum diameter of 150mm, widely used in automobiles and motorcycles. The high-speed, high-torque main spindles provide optimal machine structure for high-efficiency processing of mass production gears. (Courtesy: Mitsubishi Heavy Industries Machine Tool Co., Ltd.)

The GE15HS, one of two models with enhanced precision and efficiency added to the GE Series. High-speed, high-torque main spindles provide optimal machine structure for high-efficiency processing of mass production gears. (Courtesy: Mitsubishi Heavy Industries Machine Tool Co., Ltd.)

The GE15HS and GE25HS models of hobbing machines. (Courtesy: Mitsubishi Heavy Industries Machine Tool Co., Ltd.)

The Mitsubishi GE15HS, one of two models with enhanced precision and efficiency added to the GE Series. High-speed, high-torque main spindles provide optimal machine structure for high-efficiency processing of mass production gears. (Courtesy: Mitsubishi Heavy Industries Machine Tool Co., Ltd.)

Demand for mass production of high-precision gears is continuing to rise with the shift to electrification of vehicles. With the need for improvements in NVH and fuel efficiency, and the move toward low-cost manufacturing, MHI Machine Tool, with expertise in both gear machine tools and cutting tools, offers a full lineup of gear production machines, including these two new models. By delivering precision cutting tools and processing solutions to achieve high-precision, high-efficiency processing, MHI provides comprehensive support for manufacturing in a wide variety of industries.

MORE INFO www.mhi.com

Helios offers abrasives for gear manufacturers to increase productivity

Demand for ground gears continues to grow, especially in the automotive and truck power transmission industries. Consequently, manufacturers need improved solutions for abrasive tools. Helios Gear Products has launched the latest line of abrasives backed with dedicated application engineers specifically for gear manufacturers. These tools cover all applications for gearing, including form grinding wheels, continuous generating grinding wheels, diamond dressing tools,
honing rings, bevel grinding cups, and traditional solutions for OD and ID grinding.

Gear grinding means quality, so manufacturers require state-of-the-art abrasive tools. The Helios abrasives line includes such tools that use the latest technology for ceramic and aluminum oxide grains and bonds. For example, the Tyrolit Burka-Kosmos Mira Ice series of form (single-profile) grinding wheels uses the latest grains combined with an innovative, high-strength bond system and increased porosity to achieve industry-leading “cool” grinding. Mira Ice enables gear manufacturers to push the envelope on speeds and feeds.

“It is not uncommon for gear manufacturers to decrease cycle times 20–30 percent by switching to an optimized grinding wheel technology, such as Helios’s Mira line. Additionally, manufacturers can extend tool life dramatically by optimizing their processes (engineering their applications) with the Helios team,” said Tim Lee, Helios technical sales manager – hard finishing.

Several solutions comprise the rest of the Helios abrasives line for gear manufacturers. These tools for generating grinding, tool dressing, honing (with the industry’s shortest lead times), and bevel gear grinding meet the Helios standard of globally competitive manufacturing solutions. Many of these tools are manufactured in technically cutting-edge European and U.S. factories, and they equip manufacturers to serve global markets.

By leaning on the Helios team of application engineers, gear manufacturers can reap the benefits offered by contemporary wheel specs.

“Successful manufacturers know that what comes in the box is not just a grinding tool but also the team of engineers to support it. By literally using the Helios team, manufacturers can stay at the top of their game,” said David Harroun, Helios vice president.

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**Heller’s new generation of proven horizontal technology cuts costs**

Heller launched the fourth generation of the H series in early 2021. The 4-axis horizontal machining centers offer numerous benefits over the previous generation and stand out from other machines with shorter idle times, increased milling performance, reduced service times, and more flexible customization to customers’ requirements.

Heller has been known as a specialist for 4-axis machining centers since the 1960s. With the H series (H for horizontal) presented in 2007, the company then launched a machine tool that is considered the benchmark by users from many industries.

In spring 2020, the first machines of the fourth generation were put into field test operation at selected customers. “Our goal was to put the H series through rigorous testing under real-life conditions in order to launch a mature machine to the market at the beginning of 2021,” said Dr. Manuel Gerst, Heller head of development.

Since February, Heller has been offering the horizontal machining centers in the sizes H 2000, H 4000, H 5000, and H 6000, covering a stroke range from 630 mm to 1,000 mm: the first two models for tools with HSK-A 63, the larger ones with HSK-A 100. With a construction in modular design and many standard components, users have a wide range of options to adapt the machine to their individual requirements. In terms of drive technology, there are essentially two equipment packages to choose from: Power and Speed. The Power package has been designed for medium batch sizes and for the machining of steel and difficult-to-machine materials. The Speed package is suited for high-volume machining of cast iron, aluminum, and other light metals.

“With the Speed equipment package for the Gen4 we have succeeded in reducing chip-to-chip times by an average of 10 percent,” Gerst said. “One of the crucial factors are the short positioning times. In field tests, we were also able to demonstrate cycle time improvements of approximately seven percent.”

What has also proved helpful is the new AutoSet technology cycle for weight-dependent dynamics adjustment of the Z-axis and B-axis included in the Speed equipment package. The cycle helps to achieve the optimum axis dynamics in direct correlation to...
the load capacity. Moreover, the developers have optimized the tool change process in order to enable time savings for medium tool weights and have reduced the spindle run-up times. Depending on spindle size, these vary between approximately 1.4 and 2.6 seconds.

The in-house developed spindle for the Gen4 machines is available in three different versions: Power (PC), Speed (SC) and a new Dynamic Cutting (DC) version. All spindles are available with HSK-A 63 or HSK-A 100 tool holder. The DC units in particular offer a perfect combination of high torques and high speeds – with the DC 63 version providing 16,000 rpm and 180 Nm and the DC 100 version delivering 12,000 rpm and 400 Nm.

However, the high spindle power and the extreme axis dynamics alone are not sufficient to increase the machine’s productivity in practical application. To achieve this, the machine also has to provide the necessary stability and a suitable damping behavior. Therefore, the classic machine design with a twin-drive in the Z-axis has been maintained and improved with regard to numerous details.

The machines from the H series already provide high basic accuracy and surface finishes. In combination with the optional High-Accuracy package, a further improvement in these two regards can be achieved.

The integral U-axis of the Heller out-facing head allows users to perform contour turning operations on their components using motion tools. Moreover, maintenance and service work can now be performed even faster. The key to this is good accessibility to all units.

“Our zero spindles can be exchanged within about an hour as only the mechanical parts have to be replaced. The motor remains inside. As a result, our customers are able to save approximately 30 percent of running costs throughout the life cycle of a spindle compared to classic motor spindles. With the reduced downtimes not even counted in,” said Heller head of sales Fabian Mattes.

Not new, but significantly enhanced, and opted for by more than 80 percent of H series buyers, is the wide range of Industry 4.0 features available from HELLER under the product name HELLER4Industry. All these HELLER4Industry features can be visualized directly at the machine, in the company network or online.

MORE INFO  www.heller-us.com

New grinding wheel blends rapid stock removal, operator control

Sigma Z, a high-performance grinding wheel for stainless steel, carbon steel, mild steel, galvanized steel, and alloys, is now available from Rex-Cut Abrasives.

Sigma Z grinds stainless steel welds up to 15 percent faster than other leading wheels. In addition to a high material removal rate, this new wheel features cool grinding, extended wheel life, and a chatter free operation.

“Sigma Z is the hard working and reliable wheel you’d expect from the Sigma Line. Grain and bond advancements allow this wheel to knock down welds in record time,” said Bob Costa, Rex-Cut Abrasive president.

Sigma Z is available now in 4.5-inch, 5-inch, and 7-inch diameters.

Rex-Cut Abrasives provides the metalworking industry with high performance, non-woven cotton fiber and other premium abrasive products, improving the daily grind for a worldwide customer network. Rex-Cut products are specialized for use on stainless steel, aluminum, mild steel, and exotic metals. A 100 percent employee-owned organization, Rex-Cut offers many other specialty products for use on a variety of grinding, deburring, blending, and finishing applications.

MORE INFO  www.rexcut.com
There are already an infinite number of different gear geometries. Nevertheless, engineers are constantly coming up with new variants. For example, gears are becoming smaller, more complex, and lighter. At the same time, the demand for performance — quiet, smooth operation, even under highest load — is always higher. The variety of gears knows no limits, but high-precision manufacturing does.

Today, the desired geometry of a gear is often achieved by skiving. This means the precision of the gear is limited by the precision of the tool. The principle of skiving has been known for more than a hundred years, but the technology in mechanical engineering has only been able to perform skiving reliably for a few years. That is, the previously desired precision of the tools and thus of the skiving process was achieved in elaborate development steps.

"Just a few years ago, the quality of gears in class 4 to 6 was the measure of all things," said Haas Schleifmaschinen software manager Wolfram Hermle. "Today, tolerances of 2μ are not uncommon."

Hermle said the time was ripe to take a fundamental look at this issue in order to search for a groundbreaking solution.

EXACT TIMING

In a high-precision gearbox, exact timing is everything. The cylindrical gears must mesh 100 percent. Flank shape and helix angle do not allow any tolerances, and this applies to both internal and external geometries. The manufacturing of such complex profiles requires highly sophisticated calculations. In the profile accuracy or the pitch accuracy of the gears, the smallest error continues and leads to inaccuracies in the entire gear unit. Often, when the gearbox is prototyped, it is not even apparent where exactly the error is hiding. Therefore, it was time for the engineers at Haas Schleifmaschinen to come up with a solution.

"On the market, there has been no satisfactory calculation model for ever increasing precision requirements." Hermle said, describing the situation two years ago when he initiated the project in the development of the Multigrind® software.

The goal was to create a calculation basis that is able to cope with the unbelievable variety of gears. And this with a precision that opened up new horizons for gear manufacturers. Derived from the perfect geometry of a cylindrical gear, the calculation is based on the geometry of the skiving tool. The motion sequences in production and the relative speed of the flanks define the future geometry of the respective generating skiving tool.

"We calculate with the exact path resulting from the movement of the gear," Hermle said; however, he does not want to be more specific about this because, after all, this calculation model is a new development from Haas Schleifmaschinen that is causing a lot of excitement in the market with its unique position.

The desired grinding paths are created on the calculated surfaces in longitudinal, transverse, and trochoidal paths. The contact point between tool and workpiece can thereby move on the grinding wheel profile. This
Above: The image of a skiving tool does not capture how complex the calculation of its geometry actually is. (Courtesy: Haas Schleifmaschinen)

Left: The GearScan 500. (Courtesy: Haas Schleifmaschinen)
shortens the grinding paths and, thus, the grinding time. Standard grinding wheels are used for this application. This eliminates the need to purchase expensive form grinding wheels.

However, the new calculation model is only one side of the coin. The other is implementation. Because precise software requires equally precise coordination with precise hardware, the exact transfer of the Multigrind® Horizon software to the machine movement does not allow any deviations. To generate this precision, the alignment of the grinding wheel must be accurate to 1/10,000ths of a degree.

MEASURING, DRESSING, GRINDING, MEASURING, DRESSING, GRINDING

The desired grinding performance cannot be achieved without sophisticated measurement technology and frequent dressing of the grinding tools. The desired accuracy of the skiving tool and subsequently of the gear can only be achieved if all production steps are coordinated with each other in a collaborative process. The results of the permanent re-measurement with subsequent compensation of errors are the basis for the fine correction of the grinding path. This automatic process takes place entirely in the sense of a closed loop. In this way, the quality remains constant and error-free — workpiece for workpiece. The Multigrind® Horizon software handles this production sequence reliably and quickly, even in an unmanned operation.

“As far as I know, this level of precision can only be achieved within the Haas Schleifmaschinen Cosmos,” Hermle said. “Only when software and hardware are perfectly matched to each other can the perfect tool be created for manufacturing a perfect gear. At Haas, we specialize in developing from the desired end product. The question ’What properties should the gear have?’ becomes the starting point of our manufacturing strategy for the perfect skiving tool.”

HAAS SCHLEIFMASCHINEN: TURNKEY SOLUTIONS SINCE 1934

Haas Schleifmaschinen opened its doors in the southwest of Germany in 1934. In the beginning, the multi-axis high precision grinding machines served for automotive and watch-manufacturing industries. The third-generation, family-owned company offers in the Multigrind® series several models of 5-axis CNC grinding centers that can grind parts from 3 millimeters up to 3 meters; however, the highly flexible grinding machines of the Multigrind® series become high-tech tools thanks to the smart software solutions. The unique combination of perfectly matched hardware and software offers the customers of Haas Schleifmaschinen maximum added value. Last year, the daughter company Haas Multigrind® LLC moved to Charlotte, North Carolina. For more information, go to multigrind.com.

ABOUT THE AUTHOR

Zita Bader works in the marketing and communication department of Haas Schleifmaschinen GmbH.
“I don’t always buy workholding but when I do, I prefer Königs”

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PATENTED
CONSIDERATIONS
IN HIGH TORQUE
TOOLING

The only retention knob designed to run the gamut on eliminating V-Flange CNC milling problems.

By CRAIG A. FISCHER

It is common knowledge in the CNC manufacturing community that if you use V-Flange tooling, you use retention knobs, which are the critical interface between the spindle and the toolholder and tool. Often considered nothing more than a bolt, the knob is actually a precision tool made to strict specifications and tolerances. While some machine-tool manufacturers have standardized their requirements, others have defined several different knobs as options. The fact is, V-Flange tooling is flawed, and machinists, operators, and owners must be educated about the importance of the retention knob, and the right retention knob, to correct the flaws.

JM Performance Products, Inc., a leading manufacturing innovator of CNC mill spindle optimization products since 2009, recognizes it is of paramount importance to illustrate that retention knobs not uniquely manufactured to JMPP’s patented High Torque© design standards are just standard retention knobs that don’t fully address the gamut of vital and costly V-Flange production issues.

Extensive testing has proven that toolholder expansion is an inherent design flaw of V-Flange tooling.

The following is a deep-dive examination into patented High Torque© retention knob essentials for CNC milling, which correct this flaw:

THE V-FLANGE TOOLING DESIGN DILEMMA

V-Flange tooling should be the most productive and profitable tooling system available. Its precursor, using NMTB holders, employed a 7/24 taper with an extended, internally threaded neck, which accepted the threaded draw bar. This manual change system was replaced by V-Flange to implement automatic tool changes. In order to facilitate this change, the draw bar was modified to include a collet closer (or fingers), and the extended neck was removed from the holder and replaced by the retention knob, which threads directly into the taper.

While these modifications made tool changes occur quickly and automatically, they introduced a variety of issues that were not present with the NMTB system, such as excessive chatter and run-out, resulting in poor finishes and expensive secondary processes. Holding tolerances can be problematic, requiring skilled machinists tweaking speeds and feeds, affecting production in an effort to reduce scrap. Still a good option for heavy milling processes, V-Flange forced the industry to look to HSK, CAPTO, and other precision tooling systems, all significantly more expensive to adopt in a shop.

The modifications caused these problems essentially because steel maintains its elastic properties, even after hardening, and threads create torsional stress. This stress, exerted by the engagement of the threads of the retention knob with the threads of the V-Flange holder at the small end of the holder, often creates a distortion of the holder. Once expanded or distorted, the holder will no longer pull all the way into the spindle, stopping short of full engagement. The small end of the taper makes contact before the large end at the gage line, leaving...
the holder to move randomly within the spindle, much like a bell-clapper.

This random movement translates to vibration and chatter (and the above resultant issues), and negatively affects tool life, especially expensive carbide that is fragile and susceptible to microfracturing (which yield poor surface finishes). If a microfracture occurs, the whole tip may disappear, and the inserts can be rendered useless. Toolholder expansion caused by standard retention knob installation can reduce the toolholder to spindle contact by 70 percent or more. Carbide tool life is diminished by 50 percent for every 0.0005” distance short of full engagement.

THE HIGH TORQUE DESIGN INCEPTION
JMPP became aware of this tooling system design flaw, and designed a gage to measure and study the expansion. Using this gage, JMPP redesigned the standard retention knob into its patented High Torque retention knob, which uses the lowest available threads in the toolholder. Key to the design is a relief beneath the pilot that forces the threads of the knob deeper into the threaded bore of the toolholder, where a thicker cross-section of material resists the expansion and deformation.

Notably, the design can be used in any toolholder as long as it is made to industry specifications. Additionally, we found that most holders, unless improperly hardened, will return to their original form, so even those holders that were expanded by a standard knob could be kept in service.

Figure 1 compares a standard knob without a pilot to a standard knob with a pilot, and finally to the High Torque design knob. Note that, from the top of the knob head to the flange that rests on the holder face, the knobs are dimensionally alike. The additional length of the High Torque design is beneath the flange, inside the toolholder bore.

DIFFERENTIAL DESIGN FEATURES OF HIGH TORQUE RETENTION KNOBS

PRECISION PILOT
The pilot is that portion beneath the knob flange above the threads that stabilizes the knob in the toolholder. The High Torque design includes a precision ground pilot that ensures the perfect alignment of the knob in the holder during installation. It is important to note that some toolholder manufacturers do not adhere to strict tolerancing of the counter bore at the small end of the holder. In cases where this counter bore is uncontrolled — while the pilot...
does add some strength and rigidity to the knob and therefore, the tool — it may not facilitate alignment.

MATERIAL
Today's CNC mills are designed to operate with greater draw bar pressure, faster tool changes, higher feed rates, and greater depths of cuts, which place more demand on retention knobs in V-Flange tooling than ever before. In response to meeting machine manufacturers' future requirements and ever-increasing demands, JMPP has decided to manufacture all 30 and 40 taper retention knobs, including the patented High Torque knobs, from AISI 9310H material, offering 40 percent more tensile strength, instead of the traditional 8620H material.

40 percent added tensile strength is the minimum benefit derived by combination of the steel composition and the effects of heat treating (carburization). JMPP worked closely with metallurgical specialists to define the proper temperatures, processes, depths, and case hardening values to ensure the standards for retention knobs are exceeded. Additionally, proper quenching and cryogenic freezing greatly reduces the possibility of cracks. The processing of JMPP’s knobs is done by highly skilled and certified heat-treat partners.

PRODUCTION PROCESSES
JMPP reviewed the standards and identified a design flaw in regards to the expected cross-sectional strength of the knob. To correct this, the size of the coolant holes in many of the company’s 30 and 40 taper knobs was modified. The knobs will continue to supply more coolant than demanded, but will be sized to increase the cross-sectional strength of the knob.

Of note, JMPP uses a black oxide, non-acid process with strict temperature control to safeguard against hydrogen embrittlement of the AISI 9310H material. This process ensures proper adhesion of the blackening process to the dense chromium molecules present in this material.

The engineering catch phrase for “approximate radius or a series of radii next to each other” is called Blend Radii. This relates to common machining/engineering knowledge that a sharp edge, including those on retention knobs, creates stress points that are easily subject to failure. Therefore, JMPP eliminates the sharp edges and corners using radii in transitional surfaces during the machining or finishing processes.

Finally, a hard-turning machining operation is applied to each lot of knobs manufactured from 9310H material. In this process, all critical and control surfaces are controlled to 50 percent of allowable tolerances. Tolerances under 0.0008 are 100 percent inspected to ensure conformity. All surface to surface runouts are 0.0004 TIR or less, which ensures better uniformity of gripper to retention knob contact in machine tool spindles.
THREADS
JMPP precision cuts its threads, with each thread starting and finishing at 180 degrees to the next thread. Each part is held on the major diameter of the threads to ensure precision runout between threads, and all surfaces being hard-turned are held to 0.001 TIR. Keep in mind that most standards require 0.002 maximum TIR to threads. This thread-making process is designed to provide a precision mating between the toolholder threads and the retention knobs threads.

Notably, the High Torque design takes into account the mechanical functionality of each thread, and the fact the load on each thread diminishes with each step down from the first thread. To that end, JMPP has removed any non-mechanically necessary threads, so the mass of the knob is dynamically balanced by design. Simply adding an additional thread or two will not yield a better installation result and do nothing to resolve toolholder expansion. A review of the load percentage on each thread of a retention knob reveals the maximum number of functional threads is six; any additional threads are unnecessary. Also, the process of forming the threads, whether cutting or roll forming, does not affect the distribution of the thread load.

MAGNETIC PARTICLE TESTING
Magnetic particle testing is a non-destructive test that will reveal faults and cracks in the material. Using only high-quality U.S. made steel that has eddy current testing (ECT) certification, ensures the part’s material is defect-free from surface and sub-surface flaws.

JMPP will conduct magnetic particle inspection tests on purchased knobs, which is useful for detecting minute surface and near-surface cracks down to a depth of about 0.100”. Essentially, a magnetic field is induced in the test specimen, which is then “dusted” with iron particles, either dry or in a liquid suspension. The particles will collect along the edges of any micro cracks or other discontinuities in the structure of the material to provide a readily visible indication of the flaw. Notably, JMPP’s testing typically proves out at a 100 percent flawless rate.

INSTALLATION TORQUE SPECIFICATIONS
JMPP provides an axial force calculation, based on drawbar force and taper size, to define the installation torque that should be used on each knob during installation. This value ensures against over-torquing the knob (resulting in premature fatigue and failure of the knob), eliminates expansion in toolholders made to spec, and ensures the knob is installed with sufficient torque so it does not back out of the holder during cutting operations.

Many competitors will specify torque values well in excess of JMPP’s top-range values, for instance: 76 ft. lbs. for a 40 taper knob. Inasmuch as testing has proven that as little as 13 ft. lbs. of torque can cause toolholder expansion and excessive knob stress, JMPP specifies values less than 40 ft. lbs. for most 40 taper knobs. It is important to recognize that any installation torque values that have been published earlier were based on bolted threads. It is also vital to recognize the V-Flange tooling design flaw and the negative effects of over and under torqueing the retention knobs during installation.

REPLACEMENT SPECIFICATIONS
As they are subjected to more stress than any other tool used in CNC milling, retention knobs are not intended to last forever; therefore, any knobs showing wear should be replaced. It is always better to replace knobs before a catastrophic failure occurs, so if the knobs are exposed to multiple shifts, heavy cuts, or excessive side-pressure, they should be replaced more frequently.

Typically, knobs should be replaced based on their time in service. JMPP recommends replacement after three years if you’re running a single shift, after two years if you’re running two shifts, and after a year if you’re running “lights out” or three shifts. Also, retention knobs should not be removed from a toolholder that has been in service and re-installed in another holder. This process will flatten and distort the threads, allowing for unintentional over-torqueing of the knobs.

PATENTED HIGH TORQUE CONSIDERATIONS/CONCLUSION
While many competitive retention knobs on the market recognize toolholder expansion (or swelling), they have not taken any significant measures to eliminate the inherent V-Flange tooling condition. This continues to cost shops significantly as less than 75 percent taper contact with the spindle results in poor T.I.R. (runout), poor tool life, poor tolerances, vibration and chatter, poor finishes, and excessive spindle wear and tear.

JMPP’s patented High Torque design was intended to eliminate (or vastly reduce) toolholder expansion caused by the torsional stress exerted on the thinner wall of the small end of the holder by the knob threads. Uniquely, it provides for a relief beneath the precision pilot, which forces the threads to engage deeper in the toolholder bore, where a greater material cross-section resists deformation. The difference is crucial in terms of today’s time, tooling, and production results.

ABOUT THE AUTHOR
Craig Fischer is the JMPP plant manager. Established in 1966, JM Performance Products, Inc. (JMPP) has established itself as a leading manufacturer of CNC mill spindle optimization products. Across a myriad of markets, JMPP is dedicated to reshoring with over 500 styles of patented retention knobs for BT, DIN, ISO, and CAT toolholders from 30 taper to 60 taper – all manufactured and material sourced in the United States. All products in the integrated suite are engineered to optimize milling machine performance including: improving finishes, eliminating run-out, reducing chatter and harmonics, decreasing set-up times, extending tool life, and increasing spindle performance. For more detailed information contact: www.jmperformanceproducts.com.
After more than a year of COVID-19 pandemic challenges, gear manufacturers are ready to get back to work. This includes learning about the latest technology available to the industry, so Helios Gear Products will be exhibiting at the 2021 Motion + Power Technology Expo (MPT Expo) September 14–16, 2021. Gear manufacturers of all types can attend the show to see the latest on processes such as hobbing, shaping, thread milling, deburring, grinding, inspection, and more.

“The expo is a critical research tool for manufacturers to stay up-to-date on industry trends and manufacturing disrupters,” said Adam Gimpert, Helios president.

In the Helios show booth, manufacturers will see a Hera 90 CNC gear hobbing and thread (worm) milling machine with unified gantry automation. This machine offers a single platform for automatically hobbing and milling parts up to approximately 3.5” outside diameter. With its 6,000 rpm cutter spindle, the machine productively handles small parts with small hobs by maximizing surface speeds. This high-speed spindle also enables productive milling of worms.

Also in the Hera series of hobbing machines, show attendees will learn about the uncompromising model 350, which empowers manufacturers as a robust vertical hobbing platform for parts up to approximately 15” outside diameter. As with other Hera hobbbers, the 350 is surprisingly affordable and offers several options for an optimized solution, such as 2- or 4-station ring loaders, re-hobbing abilities, automation systems, and more. Similarly, Helios offers the Hera models 500 and 750 for parts up to approximately 30” outside diameter. Additionally, manufacturers of fine- and ultra-fine-pitch gears can learn about the Hera 30, which features dual direct-drive work spindles, and a 10,000 rpm hob spindle for productive hobbing of parts up to approximately 1.6” outside diameter.

For productive manufacturing of internal gears, Helios will feature the Neo Power Skiving (“NEOPS”) line. This series of machines, which includes the models 100, 200, and 400, produces internal or external gears for parts up to approximately 16.5” outside diameter. Compared to traditional shaping, a NEOPS can produce precision gears in a fraction of the time, making it a go-to choice for manufacturers of internal gears.

“Show attendees will really want to stop by and learn about the Neo power skiving machine, which offers this cutting-edge technology at a fraction of the price compared to competitors in the market,” said David Harroun, Helios vice-president.

At the MPT Expo, Helios will also feature the 2021 CNC upgrades to its line of Tecnomacchine (“TM”) gear deburring machines. The TM series now offers manufacturers complete CNC programming of the chamfer-deburring process. This includes tool position (radial, axial, tangential, and inclination), tool pressure, tool rotation speed, tool rotation direction, workpiece rotation direction, and workpiece rotation speed. This allows manufacturers to store a complete application to later be recalled by the CNC with just a few software steps. Consequently, changeover time reduces to a few minutes rather than the traditional 30-45 minutes. Moreover, it significantly lowers the bar for personnel training, altogether making the machine investment more flexible and productive for high-mix gear manufacturing.

Helios also offers manufacturers cutting and abrasive tools, including hobs, milling cutters, shaper cutters, continuous generating grinding wheels, form (single-profile) grinding wheels, bevel gear grinding cups, diamond dressing gears, and more. Manufacturers can establish their communication channel with Helios engineers at the show to empower their manufacturing teams with guidance on tool specifications and machining parameters. Show attendees can ask questions and learn from Helios experts on the spot while viewing machines and tools that enable globally competitive production of gears.

MORE INFO www.heliosgearproducts.com
Dillon diamond-shaped serrations increase pull-down effect for hard jaws

Aggressive diamond-shaped serrations on hard jaws from Dillon Manufacturing increase the pull-down effect that reduces part slippage and push back from using a bar feeder.

Serrations on the gripping surfaces are ideal for cast parts, scaly parts, or parts with imperfections. They are manufactured of 8620 steel and case hardened with precision ground locating surfaces, then black oxide coated for corrosion resistance. The hard jaws are available in one-step or two-step sets and are reversible for OD or ID chucking. One set covers a wide clamping range.

Dillon hard jaws are available in standard sizes from stock and in different mounting configurations including serrated, T&G, Acme, and square serrated key types to fit all brands of chucks. Dillon chuck jaws are versatile, with multiple radiiuses for both inside and outside clamping to make them ideal for any size run. Dillon also offers special or modified hard jaws with industry-best turn-around time, which saves time and money by reducing down time.

MORE INFO www.dillonmfg.com

Suhner adds machining block spindle for high-speed operations

Suhner Industrial Products Corp., automation division introduces the BEX8, a high-speed machining block spindle capable of maintaining rigidity, precision, and reliable performance at extremely high-speed operations — up to 25,000 rpm.

The BEX8 is a smaller version of the popular Suhner BEX15, but weighs only 33 pounds and features the ability to mount directly onto robotic arms for fully automated machining operations in high-speed, high-production departments in automotive, appliance, off-highway, and other industries.

The standard motor supplied is either 0.37kW or 0.75kW and the standard toolholder supplied is ER20.

This new machining spindle from Suhner adapts to the UA15 slide unit via the integral mounting supports. Spindle concentricity is better than 0.01mm.

MORE INFO www.suhner.com

Big Kaiser expands hydraulic chuck offering for Swiss lathes

Big Kaiser has expanded its program for hydraulic chucks for Swiss lathes to include inch-size Standard Type chucks, as well as new F Type and R Type chucks.

Standard Type hydraulic chucks with tool-side clamping are now available in inch sizes with the clamping range of ø1/8", 3/16", and 1/4”.

The new F Type’s single wrench enables easy cutting tool changes on the tool post. The easy-access rear clamping design is ideal for front tool post. Clamping from the opposite side of the cutting tool and optimum-length design improves overall ease of use. The F Type is available in a clamping range of ø3-10mm and coolant delivery is possible with an Rc(PT)1/8” screw.

The new R Type eliminates interference at both the upper or lower tool post positions with a unique block design and tightening at an offset position in the tool side. The R Type is available in a clamping range of ø3-10mm and its oil hole drills can be used for coolant delivery when mounted on the upper section.

To minimize machine downtime and provide operator safety, these hydraulic chucks use a simple hex wrench that requires only two to three turns for both clamping and unclamping. Tightening is complete when the clamping screw hits the bottom; controlling tightening torque is not needed. Once a hydraulic chuck is centered, the runout will not vary, even if a cutting tool is changed repeatedly. Runout of fewer than three microns at four times diameter can be
achieved. Hydraulic chucks have a standard pipe thread for coolant-through connection and are available for most Citizen and Star machines with 3/4” or 22mm straight shank.

Big Kaiser, a global leader in premium high-precision tooling systems and solutions for the metalworking industries, introduced hydraulic chucks for Swiss lathes in 2018, the first improvement to the technology in more than 30 years.

MORE INFO www.us.bigkaiser.com

Schunk gripper has bionically inspired adhesion technology

Imagine gripping smooth surfaces with ease, leaving no trace of residue or imprint. With the ADHESO gripper from Schunk, it’s possible.

The bionically inspired gripper technology ADHESO, based on the principle of adhesion, uses the intermolecularly acting Van der Waals forces for handling components. Made of special polymers, the patented surface architecture is optimized by numerical simulation, creating a structure of extremely finely structured legs that adhere to different materials and objects.

Glass fibers as light as feathers; the smallest SMD components or micro-mechanical parts; sensitive battery components; plastic films; paper and glass — all can be handled by the ADHESO gripper. Gripping of automotive or mechanical engineering components of a weight of 33 pounds and more is also possible. Automated separation of breathable components is also feasible. With the ADHESO gripper, solutions can be tailored to each customer’s individual needs, creating opportunities that are as diverse as the applications themselves.

Using Van der Waals forces, the face of the gripper is gently pressed onto the workpiece during the gripping process, increasing the contact surface and locking the grip into place. This effect can be reversed by applying a slight pressure/rotary movement so that the gripper can be loosened from the object without leaving a residue or any marking.

The alternative use of a wiper ensures that the object is gently put down. The respective adhesive forces and removal of ADHESO depend on the type of material, surface roughness or flatness, and miniaturization, and can be customized to the different requirements of the relevant environment. Therefore, the adhesive structures can be adapted to the required size and the loading condition (horizontal/vertical) of the application, and can be designed transparent, translucent, or opaque. This high degree of individualization ensures that components with dimensions of a few hundred micrometers can be handled as reliably as those measuring several meters.

Installation costs and commissioning efforts are minimal. The adhesive technology is gentle on components, low-noise, and doesn’t require compressed air, vacuum, or current. An external energy supply is not necessary for gripping or for maintaining the gripping force. In case of a power failure in the handling system, the holding forces of the gripper are reliably maintained. Schunk ADHESO allows gripping times of < 100 ms: It can be used in conventional industrial environments, but also in cleanrooms and vacuum environments. In the field of micro handling, repetitive positioning accuracies of < 0.01 mm can be achieved with this technology and it can be also used in collaborative applications. The ADHESO gripper has a bayonet lock and therefore the grippers can be exchanged in just a few simple steps.

Schunk is a leader for gripping systems and clamping technology. With more than 11,000 standard components, Schunk offers the world’s largest assortment of gripping systems and clamping technology from one source.

MORE INFO www.schunk.com

This year, Big Kaiser’s program has expanded to include inch-size Standard Type chucks, as well as new F Type and R Type chucks. (Courtesy: Big Kaiser)
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July 2021 69
It has become abundantly clear that not only are electric vehicles (EVs) becoming more prevalent on the roads but that almost all automotive companies are announcing plans where EVs will eventually dominate their product portfolio. As the shift from internal combustion (IC) to electric continues, the number of drivetrain components will dramatically lessen. And the remaining components found in cars of all types will be more critical to the vehicle’s operation and longevity. One such area is the gear components necessary to convert the high-force torque from electric motors to the RPMs at the wheel.

Two factors of the vehicle’s operation are related to these new gear packs for electric cars—efficiency, or “rangeability,” and gear noise. To appeal to consumers, electric vehicles will need to reach similar mileage as their internal combustion counterparts. Accomplishing this will require gears with lower surface texture, where surface friction is reduced, thereby increasing the vehicle’s overall range. Second, the sound from the IC engine typically masked the noise from the drivetrain. Efforts to dampen sound in the passenger cabin were designed into the vehicle frame and the passenger compartment. Yet, with the shift to electric engines, gear noise could again become prominent if it were not for a change to new manufacturing methods and processes.

With recent processing developments and tighter specifications on EV gears, precision metrology can play a fundamental role. ZYGO’s work with industry partners, such as the Ford Motor Company, has helped advance these processes by establishing a reliable method to measure and monitor these surfaces, allowing for even tighter specifications and stringent quality control.

THE GROWING ROLE OF METROLOGY IN EV PRODUCTION

Advanced finishing and grinding technologies will be needed to produce extremely complex and precise surface features in gear teeth to enhance efficiency and reduce noise, thereby improving customer satisfaction.

By MICHAEL SCHMIDT

The design and manufacture of gears can take many paths, leading product design engineers to evaluate different methods to achieve stringent surface texture and waviness specifications and high-production volume demands. Contingent on the production method, fabricating accurate gear tooth form and flank texture can be a balancing act. But when achieved, specific techniques can produce gears in high quantities while attaining the required form and surface texture demands. One such method is continuous generating grinding. This method uses threaded wheels, which remain in constant contact with the developing gear-tooth structure (see Figure 1). This method, among others, has been proven to produce the essential gear texture and waviness specifications to improve gear tooth interaction while reducing contingent noise.

THE ROLE OF PRECISION METROLOGY

To ensure the surfaces on the gears are optimized, it is essential to use metrology tools to analyze, understand, and characterize. Because these gears are high value means it is highly preferable that non-contact metrology solutions are used, which will not compromise or damage the post-processed gears. As gear surfaces
become smoother, tactile and other analysis methods will become more challenging to use. They may result in surface scoring or simply not reach the critical inspection areas. This is why industry partners, such as Ford, look to ZYGO’s suite of 3D non-contact optical profilers.

At the heart of ZYGO’s optical metrology solutions is its coherence scanning interferometry (CSI), which uses specialized optical microscope objectives that provide the imaging and magnification of a surface and measure the 3D topography of the surface. CSI profiling is entirely non-contact, and, in contrast with other microscope-based 3D topography techniques, CSI has the distinct advantage that the height resolution of the measurement is consistent across all magnifications, whether the magnification is 1x or 100x. This presents a unique opportunity for CSI-based systems as the shape and size of the gear may limit the types of objectives able to gain access to the area of interest.

With other technologies, the use of a long working-distance objective may limit the vertical resolution of the measurement. ZYGO’s internally developed objectives lose neither vertical resolution nor measurement precision. This was one of many determining factors for Ford in selecting the ZYGO Nexview™ product for its EV gear line. Other considerations included the extreme stability of the measurement, ease of gaining access to the measurement area, as well as the assortment of objectives to meet the company’s demanding requirements for on-the-floor production metrology.

**STITCHING**

Another key driver built into ZYGO’s solutions is field stitching. With some similarities to panoramic photography, a user can set up a measurement to capture more area than the installed objective. This creates a matrix of overlapping measurements that, when done acquiring, are “stitched” together to form a larger measurement than a single objective can accomplish. Where this is advantageous in gear metrology is the acquisition of surface texture along a gear flank, from edge to edge, or stitching from the gear root to the tip, traversing over the involute shape. What should be emphasized is the ability to perform these stitched measurements over non-planar surfaces, such as hypoid-shaped surfaces. By programming the start and end positions of the measurement sequence, a user can re-measure a hypoid gear.
with continuous high precision because of ZYGO’s proprietary stitching algorithms.

Combining the stitching and measurement methods with ZYGO’s in-house long- and super-long working distance objectives, software ease-of-use, and internal Python scripting provides customers with a complete solution for measuring many different gear types.

It also explains why ZYGO works alongside an array of global EV manufacturers, allowing for the fast, efficient, accurate, and repeatable measurement of the newer generation of highly polished gears.

### SUMMARY

The growth of the EV market is inevitable. It places significant challenges in front of manufacturers as they wrestle with the need for technological advancements in the real nuts and bolts of vehicle engineering. Top of the list at the moment is the requirement for advanced finishing and grinding technologies that are used to produce extremely complex and precise surface features in gear teeth to enhance efficiency and reduce noise, thereby improving customer satisfaction.

As is so often the case in advanced design and manufacturing, metrology’s role moves from a necessary evil to enabling technology when pursuing innovative technological advancements. In the area of gear manufacturing for EVs, it is vital to be able to accurately, quickly, and easily characterize the precision surface features. ZYGO’s suite of non-contact optical solutions easily meets these challenges.

Optical metrology is an extremely versatile inspection method and has an essential role in verifying gear quality and design intent achievement. Today, it has become the “go-to” metrology solution, benefiting from the fact that it is non-contact, non-destructive, fast, highly sensitive, and has exceptional resolution and accuracy.

### ABOUT THE AUTHOR

Mike Schmidt, market development manager for the Zygo Corporation, has served the precision machining and industrial markets for nearly two decades and has extensive knowledge of non-contact optical metrology technology and application solutions development. Schmidt has helped numerous market-leading and global precision manufacturing companies transition and deploy optical technology and process control solutions to the factory floor. Schmidt also has authored and co-authored several industry articles, white papers, and conference papers and remains active in supporting 3D standards and the advancement and adoption of non-contact optical metrology methods. For more information, go to www.zygo.com.
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Undoubtedly there are many benefits associated with the use of additive manufacturing (AM) as a production technology. Across industries, manufacturers exploit the fact that, through the use of AM, they can not only build complex parts — in one piece — which were previously impossible, but they can also build stronger, lighter-weight parts, reduce material consumption, and benefit from assembly component consolidation across a range of applications.

These advantages have been well documented during the last 10 to 20 years as AM has emerged as a truly disruptive technology for not just prototyping but also production, and are invariably seen as being enabled by the additive hardware that builds the parts. In reality, this is a partial picture, particularly for serial production applications of AM. AM hardware systems are just one part — albeit a vital one — of an extensive ecosystem of technologies that enable AM, both pre- and post-build.

Of unique importance today is the role of post-process metrology to validate the integrity of AM builds. One specific reason for this importance is that many parts produced by AM end up in safety critical applications where end-use functionality is of vital importance. The nature and relative roughness of AM surfaces, whether analyzing individual layers within a build, or the surface of a finished part render conventional metrology solutions somewhat impotent. In this article, we review developments from ZYGO including work alongside Richard Leach that allow for hitherto unattainable metrology results, which are being used to enhance the use of AM as a production technology by making validation protocols more efficient.

METROLOGY AND ADDITIVE MANUFACTURING

ZYGO is delighted to be working with Richard Leach, professor in Metrology at the University of Nottingham, Nottingham, U.K., on various projects related to the use of metrology in AM. It is Leach’s view that the issue of metrology is crucial to the success of AM as it begins to establish itself as a true production technology.

“There is absolutely no doubt that inadequate metrology solutions able to cope with the specific characteristic of an AM-produced part are a huge obstacle to overcome if AM is to be used as a viable production technology across industry,” Leach said. “Basically, as we stand today, there is a lack of clarity as to the precise nature of defects that you get when undertaking an AM build, and you also have little idea how they may cause problems in...
terms of part functionality. We don’t have a detailed enough map of how the topography of the defects and the anomalies that you get during the AM process propagate through to the part in an end-use scenario.”

“Imagine you are making a turbine blade in an AM layering process, and you see that there was a blip in the topography in layer four,” he said. “This layer will, in time, be covered up, so its characteristics will be fundamentally different by the time the finished part is complete, and it is at this moment impossible to know — without the clarity that good metrology provides — whether the blip is in fact still there when the build is complete, and if so, if it was actually significant in the first place. Essentially, we are working on — but still haven’t completely solved — the problem of understanding what issues you get on the surface and under the surface when using AM, and how these relate to product functionality. Therefore, it is difficult to predict the mechanical properties, the thermal processes, the fatigue properties, etc., from the types of structures we are seeing post-process.

Defect-function analysis may allow us to move toward controlled AM by just stopping the process when things go wrong, as right now, we spend hours building a part that may in fact have a problem in layer one.”

Despite these challenges, many companies are already using advanced AM successfully for the production of critical parts and components, often in aerospace applications where part failure is not an option. To ensure these AM-produced parts conform fully with design intent, part suppliers undertake far more mechanical testing and metrology verification than they would normally employ for conventional manufacturing processes.

Necessarily, manufacturers are forced to focus on process development and throw all the validation resources they can to “prove” the integrity of the finished AM part. This latter is effectively a belt-and-braces approach, relying on Gage R&R reproducibility and repeatability as a stand-in for a more rigorous measurement uncertainty approach when evaluating the integ-
The current solution is what could be termed “extreme-testing.” "Everyone blames the confusion on a lack of standards for measuring AM parts, but this is not where attention should be focused,” Leach said. “You cannot develop standards if you don’t have the correct measurement technology in place to start with. Standards being developed without the technology solution ready to use are actually worse than no standards at all. That is why the emphasis with ZYGO and other metrology instrument suppliers is on adapting metrology solutions to make them better aligned with the unique characteristics of the AM process and AM end-use parts. In the respect of standards, our focus today is on producing a good practice guide along with ASTAM, showing OEMs what metrology solutions are in place today, and how to get the best results from these when applied to AM surfaces, and setting the instrument up in the best way to understand the data.”

ZYGO CSI FOR AM METROLOGY

So, the focus in the area of metrology for AM is to reduce the time and cost inefficiencies inherent today of relying on a vast range of duplicate and often inadequate metrology steps to validate that an end-use part is fit for purpose.

As Leach works on this vital area, he is involved with a number of metrology instrument suppliers, using a variety of measurement technologies, but among them, ZYGO is perceived to be the most trusted supplier, thanks to its pedigree and near 50-year history in the ultra-precise metrology regime.

“For post-process metrology, a number of alternatives exist including confocal and focus variation, and ZYGO’s coherence scanning interferometry (CSI),” Leach said. “Initially, it was thought that CSI was not suitable to the vagaries of post-process AM parts (with their unusual surface roughness), but ZYGO enhanced its CSI instruments by introducing new ways of playing with the optical light source, illumination conditions, and also the company played with the detection conditions that led to the attainment of high-quality results with extremely rough and complex AM surfaces. I have to admit that before looking in depth at the ZYGO CSI solutions, even I thought that they probably wouldn’t be able to be applied to AM parts, but it actually works extremely well.”

Leach’s initial work with CSI that informed his early view of the inappropriateness of the technology for AM super-rough surface metrology was based on CSI from an alternative supplier other than ZYGO. The CSI instrument his work was initially focused on was a CSI instrument in terms of its basic measurement principle, but it differed from the ZYGO system in terms of hardware, firmware, and data analysis.

Using data from the alternative CSI solution provider, Leach and his team at Nottingham concluded that interferometry was fundamentally not suitable for AM metrology, because the example instrument failed to capture most of the highly irregular topographic features. However, ZYGO had already solved this problem with the introduction of its Nexview™ instrument in 2014. It is the Nexview™ technology that Leach and ZYGO work on together now, and which is now accepted to be a strong and viable AM metrology tool.

The Nexview™ instrument and its sister product, the NewView™, included innovative hardware and software
upgrades, the package of improvements being referred to internally at ZYGO as “More Data Technology,” and this made the instrument much better suited to AM parts.

“We installed a NewView™ 8300 instrument at Nottingham in October, 2016,” Leach said. “Measurements made at Nottingham as well as at ZYGO’s headquarters in Middlefield, Connecticut, USA, on AM surfaces conclusively demonstrated that ZYGO’s CSI implementation was well suited to the task. The ZYGO system is arguably a reference standard today for AM metrology, and other research groups have confirmed its superior capabilities. Today, we work with ZYGO’s Nexview™ optical surface profiler.”

The “More Data” capability has been part of ZYGO’s complete product line (ZeGage™ and NewView™ optical profilers, and Nexview™ system) for several years now and has been shown to be one of the most successful technology developments for the product line.

“More Data” significantly improves the baseline sensitivity of CSI and enables high-dynamic range (HDR) operation making it valuable for a wide range of parts, from steeply-sloped smooth parts to exceptionally rough textures with poor reflectivity. Additionally, HDR is able to measure parts with a wide range of reflectance, often a struggle for other CSI instruments. HDR is unique to ZYGO, meaning an alternative implementation of CSI may not be able to achieve the performance on AM parts that ZYGO can provide.

Today, the focus is on using the ZYGO HDR CSI technology to undertake surface texture analysis and to attempt to better understand its links with the AM production process.

“My work with ZYGO is centered around understanding precisely how the CSI instrument works, and accurately modeling it for AM applications,” Leach said. “At the moment, the issue is that AM surfaces are so different from what we are used to in terms of the raw surface and the post-processed surface that there is no standardized way of measuring and characterizing these surfaces. We are working with ZYGO to ensure that we continue to optimize metrology solutions for the increasingly important area of AM for production scenarios.”

ABOUT THE AUTHOR

Eric Felkel is the product manager for 3D optical profilers at Zygo Corporation in Middlefield, Connecticut. He can be contacted at eric.felkel@ametek.com. ZYGO is a worldwide supplier of optical metrology instruments, high-precision optical components, and complex electro-optical systems, and its products employ various optical phase and analysis techniques for measuring displacement, surface shape and texture, and film thickness. For more information, go to www.zygo.com.
Exact Metrology adds AI-powered, HD mode for 3D scanners

Exact Metrology, a comprehensive 3D metrology service provider and hardware sales company, has increased the capability of its Artec 3D handheld scanners with the new HD mode. This Artificial Intelligence-powered scanning technology provides ultra-sharp, clean, and detail-rich scans for Artec Leo and Artec Eva.

Powered by Artec 3D’s AI neural engine, users can obtain sharp 3D scans with a resolution of up to 0.2 mm. Trained on hundreds of thousands of carefully selected samples, the engine’s neural network detects familiar patterns, surface details, and shapes. This allows the 3D scanner to reconstruct a higher number of polygons per frame, resulting in 3D data that’s both denser and higher quality. Now, the desired HD density can be selected from a standard 1X density up to 36X for Eva (~3 mln polygons per frame) and 64X for Leo (~5 mln polygons per frame). HD mode makes it possible to capture smaller, thinner elements with the 3D scanner while also considerably reducing noise. With these Artec scanners, fine edges can be captured in high definition, faithful to their original shape. It’s easy to capture hard-to-reach areas as the scans are reconstructed with every detail, giving users complete surface geometry.

Handheld Eva and Leo scanners can easily scan dark or shiny surfaces in high resolution and capture the full range of their geometries, without additional steps. Using the Artec AI engine, little to no noise in the raw scan data results in cleaner processed data and also saves time when producing the final 3D model. Once difficult to capture, now short hair, even separate strands, is fully within reach when scanning with HD mode. Furthermore, these scanners can capture a broad range of objects flawlessly and in high detail: from smaller, intricate parts such as thin pipes or valve handles, to larger objects with multiple high-detail sections, including car engines and skeletons. A perfect fit for reverse engineering and quality control due to clean, comprehensive data, scans can be easily fitted with primitive shapes and exported to the most popular CAD solutions for development.

Exact Metrology is ISO, AS9100 Certified as well as FFL and ITAR Registered. Exact Metrology, with facilities in Cincinnati, Ohio; Moline, Illinois; and Milwaukee, Wisconsin, plus affiliated offices throughout the country, is a comprehensive metrology services provider, offering customers 3D and CT scanning, reverse engineering, quality inspection, product development, and 2D drawings. The company also provides turnkey metrology solutions, including equipment sales.

MORE INFO  www.exactmetrology.com

Collect residual stress data with Sightia in 10 seconds

Sinto America launched Sightia™, a new surface evaluation technology that provides real time, non-destructive quality assurance checks for pre and post blasting or peening processes.

Sightia is a class of technology encompassing a group of non-destructive testing equipment and services suitable for harsh industrial environment developed by Sinto America to evaluate surface properties of parts undergoing surface treatment processes delivering accurate and repeatable results.

Sinto, a global turnkey industrial solutions provider, wants customers who are currently facing surface defects in their parts at different stages of manufacturing, such as casting, machining, heat treatment, and surface treatment processes to overcome the challenges with the help of Sightia devices. Sightia is applicable for evaluating gears, springs, pins, fasteners, and other cylindrical parts used within the automotive, aerospace, railway, infrastructure, construction, and die-casting industries.

“This technology makes accurate, fast, and consistent x-ray diffraction measurement possible. Sightia products are now proven in both the laboratory and in the
field. Sightia allows for 100 percent quality check on every part produced affordably and implementation is simple with Sinto’s PSMX-II,” said Charlie Gorman, VP Sinto surface treatment.

Sightia’s ECNI-I non-destructive peening inspection instrument is used for detecting variation in machining, peening coverage, and heat treatment. ECNI can detect defects on the surface of parts in just three seconds ensuring 100 percent inspection without slowing down the production flow at all.

Sightia’s PSMX-II x-ray residual stress measurement device measures each product’s surface residual stress without destroying it. With the PSMX-II, users can collect residual stress data after they have been peened in 10 seconds. It is possible to inspect in-line by integration the technology into existing processes, making in-process quality control possible and minimizes distribution of defective products.

**MORE INFO**  www.sintoamerica.com

**Q&A-style ‘The Surface Texture Answer Book’ now available**

A new resource makes it easier to find answers to surface texture related concepts and applications. The Surface Texture Answer Book answers more than 100 commonly-asked questions regarding surface texture measurement, analysis, interpretation, specification, and application.

“Surface texture is more than just a number from a measurement device,” said Carl Musolf, co-author. “It’s a microscopic world with huge implications for many industries and applications. Our goal with this book is to help technicians and engineers quickly address their questions, regardless of their level of experience with surface analysis. But more than that, we want this book to be a learning resource that will benefit readers far beyond their immediate need.”

“Every day in my work I answer questions like, ‘What is filtering?’ and ‘What is waviness?’” said Dr. Mark Malburg, co-author and president of Digital Metrology Solutions. “These are important questions about measuring and specifying surfaces, most of which are not taught in schools. We found there was a real need for a resource to directly address these kinds of questions in a user-friendly, non-academic way. This book includes hun-

**The Surface Texture Answer Book** answers commonly-asked questions regarding surface texture measurement, analysis, interpretation, specification, and application. (Courtesy: Digital Metrology)

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To showcase Exact Metrology’s CT scanning services, powered by the Metrotom 6 scout, a scan was done on a medical stent. This medical stent, with a diameter of only 1 millimeter, was measured within a 5-micron resolution. (Courtesy: Exact Metrology)

Zeiss Metrotom 6 scout digitizes complex parts in finest detail

Exact Metrology, a comprehensive 3D metrology service provider and hardware sales company, installed a Zeiss Metrotom 6 scout, formally known as a GOM CT, scanner at its facility in Brookfield, Wisconsin.

Considered the powerhouse of resolution for CT inspection and metrology, the Metrotom 6 scout digitizes complex parts including the internal geometries at the finest level of detail. Users obtain a complete 3D image for GD&T analysis or nominal-actual comparisons. The metrology CT excels in digitizing small plastic parts.

The combination of a 3k detector and 225 kV X-ray enables Zeiss Metrotom 6 scout to provide high contrast, high-resolution measurement results and exceptional sharpness of detail. As a result, even the smallest defects in the part become visible and can be analyzed to the last detail.

To showcase the ability of Exact Metrology’s CT scanning services, powered by the Metrotom 6 scout, a scan was done on a medical stent. This medical stent, with a diameter of only 1 millimeter, was measured within a 5-micron resolution. Thus, Exact Metrology inspectors were able to evaluate critical features with amazing precision.

CT scanning provides several benefits including being the only way to get 3D views inside a part and the only way to obtain accurate dimensional data without cutting up and destroying an object. In addition, CT scanning requires very little time to capture data and troubleshoot parts and also offers multiple uses with one scan (void analysis, inspection, volume, porosity, reverse engineering, etc.). In contrast to conventional tactile coordinate measurement techniques, a CT acquires all surface points simultaneously — on even the most complex objects. This includes all hidden features such as undercuts, which are not accessible using other non-destructive measurement methods.

Due to its ability to see data layer by layer, CT scanning permitted Exact Metrology inspectors the ability to see any possible defects/details on the stent. This is crucial for any medical device, especially something as small and essential as a stent that goes into the human body.

Exact Metrology is ISO, AS9100 certified as well as FFL and ITAR registered.
### Gear Solutions' Online Media Portal

Gear Solutions’ online portal is your gateway to social media news and information resources from manufacturers and service providers in the gear industry. You'll find links to social media as well as webinars, blogs and videos.

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The Metrotom 6 was designed and built from Day 1 from the ground up to work like a CMM.

What makes CT inspection and metrology important, particularly for the gear industry?
The key to CT scanning is the ability to see 100 percent of the part. A typical inspection device is a single-point tactile system. With structured light scanning, it’s all line of sight. CT scanning allows us to see 100 percent of the parts, inside and out. When looking at plastic gears, you might have what we call voids or little air bubbles inside the gear. The capabilities of CT scanning allow the user to see all these variables without destructing the part. It’s non-destructive. You can quantify the size and the location of those just like you would measure a feature on the part. And if it’s close to another air bubble, another surface, or close to any other feature, it will warn me. So, I have a lot of analytical capability knowing that I have 100 percent of the part information.

Having 100 percent of the information gives you many other advantages. You may be looking at the root, crest diameter, or radius today, but tomorrow, there might be an issue with something else that you never noticed in the previous scan. There is an incredible advantage in this because you don’t need to rescan the part. The data from the previous scan is still saved.

Exact Metrology recently installed the Zeiss Metrotom 6 Scout scanner in its Brookfield, Wisconsin facility. What makes the Metrotom 6 scanner superior to previous equipment?
Most CT scanners were kind of carry-overs from the medical industry, where accuracy was not a big deal. If they’re within a millimeter, that’s good enough, and you’re usually not measuring something from a medical CT. You’re just trying to see: Is it there? Is it not there?

When you bring CT into the metrology world, obviously we want certifications. We want accuracy statements, uncertainty statements. We want all that information, and CT scanners never had it. They were trying to take the medical CT scanners and qualify them so there would be an accuracy or uncertainty statement. The Metrotom 6 was designed and built from Day 1 from the ground up to work like a CMM and be a metrology tool. It’s calibrated, and you do get a factor of uncertainty. And the accuracy on the machine is 3 microns +L/100, which is very impressive for a CT scanner.

And the second advantage is it has a 3K detector in it, and that gives us down to a 2-micron resolution.

Why was it important to add the scanner to the facility?
It provides a capability that very few people have. It’s not a low-cost investment. The scanners are somewhat expensive, so not everyone has them. Not only can we provide that as a service to people, but we can also educate people on the capabilities of CT scanning.

How does the Metrotom 6 scanner offer an advantage over conventional tactile techniques?
The advantage is seeing 100 percent of the part. Assuming, of course, we can get through the part. Density can be an issue. You need enough power to get through the material, but assuming you are through the material, you are seeing 100 percent of the part, and that’s the key.

The Metrotom 6 does have greater accuracy than traditional CT scanning, but it does not typically have greater accuracy than your conventional tactile measurements.

But I’m not controlling the temperature and humidity like you do on those machines. They have to be in very special environments. You’re also measuring one point at a time, so if you didn’t touch the area that had the defect, you wouldn’t know there was a defect there.

How were similar inspections handled before this new technology was available?
This is so new that what we consider the conventional way is still being done by the mass majority, and that’s putting the part on a conventional CMM, and a CMM would tactilely go around and inspect it. If you needed to see something that was not visible, you would have to destroy the part. You would have to cut it, and you’d have to look at it in a 2D sense on a vision machine. Now, you destroyed the part; you had to pod it and polish it and then put it on a vision machine. After that, you had to put it on the CMM to get the three-dimensional information. It’s quite possible that it could take you an hour, hour and a half, to check one part, whereas on a CT scanner, I can put it in there, scan it for 10 minutes, and I’m done.

Can you give me an example of how the scanner will help with the inspection of gears?
Obviously, there’s a gear, and then there’s another gear that it’s mating to. We can scan those two gears independently, even if they were made at separate manufacturing locations. I can scan those two, and I can virtually put them together, seeing if there’s any interference, if there’s any rubbing, any tight spots where, maybe it passed the inspection, but both parts were a little plus, it causes a situation when you put the two together. We call it virtual assembly. I can start doing that virtual assembly on those parts and understand that interference or potential wear points before I ever find it as a warranty claim from a customer.
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