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TOOTH ROOT TESTING OF STEELS WITH HIGH CLEANLINESS

For applications with a high manufacturing and surface quality, high quality steels show a high potential for increasing the load carrying capacity as well as power density.

By MORITZ TRIPPE, CHRISTOPH LÖPENHAUS, CHRISTIAN BRECHER, LILY KAMJOU, AND ELIAS LÖTHMAN

WHY SELECTIVE PLATING STOPS GEARS FROM GRINDING TO A HALT

Worn or damaged gears can be costly to replace. Brush plating can help prevent gears from being damaged, and the process can be used to restore worn or corroded gear components.

By MARK MEYER

AIR FILTRATION AND SEPARATION EXPERTS

COMPANY PROFILE Solberg Manufacturing creates quality filtration solutions in most industrial market segments that can improve the performance and longevity of critical machinery.

By KENNETH CARTER

TOOLING & WORKHOLDING

IMPROVING TOOL HOLDER PERFORMANCE

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UNDERSTANDING THE UNDERLYING THEORY BEHIND FRACTURE TOUGHNESS TESTING, AND HOW THE TEST IS CONDUCTED.
The COVID-19 pandemic has forced the industry to shift gears and radically rethink much of how it operates.

Important trade shows have either been postponed or canceled altogether. IMTS, which was scheduled for September, has been canceled for the first time since World War II. That’s unprecedented. But the organizers feel it is necessary.

AGMA also sees the industry feeling some painful adjustments in the near future, but it expects the industry to bounce back and make a full recovery.

*Gear Solutions* is also adjusting to the new normal. Our September and October issues were to be devoted to IMTS, but its cancellation means we have had to rework those Focus topics. Check out our revised Media Kit and Editorial Calendar on our website to discover what we will be highlighting in the coming months.

In the meantime, *Gear Solutions* is here to give you some amazing articles and information to help get you through one more month of the crisis. And our July issue is offering even more than usual.

For a long time now, *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 last year, 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, it seems, 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. 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.

Stay safe and healthy out there, and, as always, thanks for reading!
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WE OWN WHAT WE SELL, AND WE KNOW WHAT WE’RE SELLING!
IMTS event canceled for first time since WWII due to coronavirus concerns

Because of health and safety requirements imposed by the State of Illinois for holding conventions, which include the availability of a vaccine for COVID-19 or a highly effective treatment protocol, IMTS — The International Manufacturing Technology Show has canceled IMTS 2020.

IMTS will offer two comprehensive digital programs, IMTS Network, and IMTS Spark, over the next several months to assist exhibitors and the manufacturing community. IMTS is fully committed to returning to McCormick Place as scheduled for its normal rotation, September 13-18, 2022.

“The show has been held uninterrupted for 73 years, but now the global coronavirus health crisis requires the cancellation of what would have been the 34th edition of IMTS for the health and safety of our exhibitors, audiences and local business community,” said Peter R. Eelman, Vice President & CXO at AMT — The Association For Manufacturing Technology, which owns and produces IMTS. “Our organization and its members take immense pride in presenting one of the world’s largest manufacturing technology events, one that dates back to 1927. The cancellation is especially poignant because the show was poised to offer an unmatched breadth and depth of resources to help industry rethink, reestablish, and reengage with supply chains disrupted by COVID-19.”

Visitors who have registered for IMTS 2020 have the choice to receive a refund on registration or transfer their registration to a tax-deductible donation to Miles For Manufacturing, where every dollar is given to programs that prepare students for careers in manufacturing technology. Exhibitors will receive direct communications from IMTS.

While acknowledging that an in-person show can never be replaced with a digital event, Eelman says IMTS feels a responsibility to provide exhibitors and visitors a way to connect. “In the near future, we will launch the IMTS Network and IMTS Spark to provide the IMTS exhibitors and visitors with connections, networking opportunities and technical knowledge,” said Eelman.

The IMTS Network will live-stream a wide variety of features and human-interest stories from the manufacturing technology sector. IMTS Spark, a new program, will be a comprehensive digital platform that connects IMTS exhibitors and visitors, provides educational and networking opportunities, and offers first rate experiences. The program will launch in the near future.

IMTS had already taken action to help manufacturers address supply chain issues created by COVID-19. The IMTS.com/supplychain microsite — ReBuilding the Supply Chain — shows OEMs how to rethink their current operations, how they can reengage with suppliers and secure trading partners, and how they can reestablish connections for a more localized industrial base. It includes a brief history of why the supply chain disruption occurred, and IMTS has mapped out future content to show steps that can be taken to secure the supply chain moving forward. IMTS will continue to offer digital experiences to foster connections, networking, and technical learning opportunities.

IMTS, the largest and longest running manufacturing technology trade show in the United States, is held every other year at McCormick Place in Chicago, Illinois. IMTS is ranked among the largest trade shows in the world. IMTS is owned and managed by AMT — The Association For Manufacturing Technology.

MORE INFO www.imts.com
Additive manufacturing, or 3D printing, is becoming a widely popular form of production. Although it comes with its own set of challenges, the adoption of the process is accelerating. However, the finishing process (otherwise known as post processing) for 3D printed parts remains a challenging and arduous task for most producers of 3D parts. The medical, automotive, aerospace, and fire arms industries are having difficulty developing finishing processes for their parts. Bel Air has created a series of steps to help manufacturers create or improve the finishing of 3D parts.

In most cases, working with an experienced company such as Bel Air is the best way to design a finishing process for a part. In order to get the most out of the experience, it is best to understand how the process works.

First, a 3D model of the part should be made available to provide valuable information on how the part’s structure and size will affect the post process. A 3D model will help narrow down the machines, compounds, and media that can be used on the part. The 3D model, the size, and the geometry of the part will all affect the finishing process. For example, consider a large part with a complex geometry sent to Bel Air Finishing; since there are many aspects associated with this geometry, it is best to have a conference with the customer to discuss background information related to the part and its function. This will help decide which specific technologies to consider it can also provide vital information for creating a feedback loop that will help improve post processing.

A feedback loop is how Bel Air works with companies in order to produce a more effective post processing operation. The part may not be fully optimized for post processing and by suggesting alternative print layouts; post processing can be more expedient and productive. This step also aims to preserve/improve the cosmetic and functional components of the part. Once the suggestions have been made and the design of the part has been decided, it is time to consider the finishing needs of the part.

The purpose of the parts is an important thing to consider and it directly affects the details of the finishing process. Deciding whether or not a part’s finish should be for cosmetic and/or functional purposes is important. Parts can be made to be shiny, matte, or coarse along with a number of other surface qualities. The part can be processed to a certain Ra value, too. Ra is a measure of the surface’s roughness. Manufacturers also need to know how many parts they want to process a day and how consistent they want the process to be. In the mass finishing world, no two parts have the same exact finish, there are always slight variations. There are bound to be a small number of defects in the processing of parts whether they come from printing or accidental wear and tear in post processing. Consider the margin for error, what are the acceptable values for this number? Furthermore, additional processes can be considered. Dyeing, coating, and electroplating can be done to improve the look and feel of finished parts. After all the criteria have been set, the parts are ready to be processed.

Sending a sample of acceptably finished parts can help create a more effective post process. Bel Air is able to take sample parts and analyze them to determine the exact cosmetic and metric details of the part using ZYGOT metrology data. This means that the surface data is recorded using a contactless method and a 3D image of the surface is created.
ated as well. These provide an in-depth look into how surfaces can be improved.

After the part has been analyzed thoroughly, it is time to decide what technologies to incorporate into the sample process. A sample process is determined based on the manufacturers’ needs, whether they are finish quality, price, and/or pure throughput. Machines, media, and compounds are recommended and then selected for the sample processes. Then, the processes are done and metrology is taken to determine the exact effects of each one. After all of this is completed, it is best to discuss the results and determine how to move forward. Additional equipment should also be considered in order to preserve the life of machinery and media, in order to lower maintenance costs. More sample processes can be made and manufacturer specifications can be changed in order to further improve or create a more realistic finish.

MORE INFO  www.3dpostprocessing.com

Jumat cylindrical grinding machine offers speed, versatility

Using a Junker Jumat 3000 cylindrical grinding machine, Kratzer GmbH & Co. KG is able to manufacture highly complex workpieces for dual-clutch gearboxes in less time.

The grinding machine concept from Junker, which has been precisely tailored to the customer’s requirements, carries out flexible grinding operations with extreme precision.

On a Junker Jumat 3000, Kratzer GmbH & Co. KG manufactures gear parts for complex high-performance gearboxes for sports cars. To produce small batches of different dual-clutch components, Kratzer required flexibility with minimized tooling time and extreme precision. The three-spindle Jumat 3000/60 cylindrical grinding machine works as the ideal basis for providing Kratzer with the latest technology and advanced tools for the production of sophisticated components.

The gear components are ground in batch sizes of about 3,000 pieces. From the outset, the retooing required between the different workpieces was included in the development of the process and, in the end, reduced to a minimum.

“The old machine has to be retooled several times a week; with the Jumat, we have found a flexible cylindrical grinding machine that covers these many different grinding operations with reduced tooling time,” said Florian Kratzer, managing director of Kratzer GmbH & Co. KG.

The dual-clutch gearboxes for sports cars must meet the highest standards and therefore require extremely tight tolerances. The Jumat combines precision and process stability with flexibility and speed. The project and process planning carried out by Junker’s grinding experts was also an important selling point. “We were extremely satisfied with all of the project planning because Junker always found a suitable and constructive solution for us. Choosing Junker and the Jumat 3000/60 was absolutely the right decision,” said Florian Kratzer.

For the family business, seamless, quick decision-making is just as important as precision and service. Kratzer and Junker united in their commitment to precision, quality, and customer proximity.

With 390 employees in Offenburg, Germany, and 70 employees in Jaroměř, Czech Republic, Kratzer develops and manufactures precision components and assemblies from a variety of materials for an extremely wide range of sectors, such as analytical engineering, the automotive and aviation industry, medical engineering, electricity, and the optical industry, as well as machinery and equipment manufacturing.

The Junker Group, based in Nordrach, Germany, is a global market leader in the manufacture of CBN high-speed grinding machines.

MORE INFO  www.junker-group.com

G-Technologies brings Hamai distributor agreement to MTB

Machine Tool Builders Inc. (MTB) of Machesney Park, Illinois, and Hans Grass, president of G-Technologies, recently announced the transfer of G-Technologies North American representation agreement
for Hamai Machines to Machine Tool Builders Inc. Following the appointment of Hans Grass as CEO of Machine Tool Builders Inc., MTB has assumed the exclusive rights as North American distributor of Hamai’s hobbing solutions line.

Established in 1921, Hamai Co., LTD., Tokyo, Japan, designs, manufactures, and services state-of-the-art N-series CNC horizontal hobbing machines and a GN150 hob sharpener. Having built a solid reputation in the small/medium gear manufacturing industries by supplying fine to medium pitch horizontal hobbing machines for nearly 100 years, Hamai has also earned a solid reputation for its high accuracy, impeccable quality, and highly productive machine tools.

This was an ideal fit for Machine Tool Builders Inc., which was looking to expand its new product offerings. It was pleased Grass and G-technologies allowed it to take on the rights to this line. The transfer of this agreement appoints Machine Tool Builders (MTB) as the exclusive sales, marketing, and support arm for all Hamai’s gear hobbing solutions in North America.

When Grass was appointed CEO of Machine Tool Builders Inc. (MTB), he brought with him more than 40 years of expertise in the machine tool industry. His company also held an exclusive representation agreement for North America representing Hamai.

“We are delighted to bring the Hamai line to MTB and offer comprehensive gear manufacturing solutions to our customers,” said Grass, president of G-Technologies and CEO of Machine Tool Builders Inc. “MTB’s representation agreement with Hamai is a perfect fit; this partnership will allow us to further improve our rapidly growing position in the market by offering high-value products and services that meet our customers’ ever-changing needs.”

MTB issued a statement which read, “We thank Hans Grass and G-technologies for laying the groundwork of Hamai’s presence in North America. This provides our customers with another world-class product backed by the MTB name.”

MTB is a leading machine tool solutions provider specializing in world-class gear cutting and grinding technologies, sales and support, machine rebuilding, repair and re-control services customized to the customers’ needs.

Seco Tools acquires cutting tool division of QCT in Mexico

Seco recently completed the acquisition of the cutting tool division of Quimmco Centro Tecnológico (QCT), a subsidiary of the Quimmco Group. The cutting tool division acquired from QCT has three locations...
in Mexico to support customers, and is a leading solid carbide tooling manufacturer, specializing in custom products and reconditioning.

“With this acquisition we build an even stronger foundation in North America for our round tools business, giving us additional capabilities within the fast-growing area of round tools,” said Fredrik Vejgården, president of Seco Tools, AB.

The cutting tool division acquired from QCT will continue to serve its customers and begin serving Seco customers directly after closing. As of June 1, they become a wholly-owned part of Seco Tools de Mexico and will discontinue use of the QCT name.

“This is a great compliment to our product and service portfolio in North America and enables Seco to serve the growing demand for solid carbide tools in Mexico,” said Rob Keenan, president, Seco North America. “The demand for high performance tooling solutions in Mexico is increasing, especially in the aerospace and automotive segments and the QCT acquisition positions us to meet that demand by being close to customers with engineering and production capabilities,” he said.

In 2019, the business had revenues of about $9 million USD and 130 employees. Headquartered in Fagersta, Sweden, and present in more than 75 countries, Seco Tools is a leading global provider of metal cutting solutions for milling, turning, holemaking, and toolholding. For more than 80 years, the company has provided the technologies, processes, and support manufacturers depend on for maximum productivity.

MORE INFO  www.secotools.com

Bourn & Koch, Inc. names Blake Consdorf as its new president

New president Blake Consdorf, who was most recently president & CEO of Felsomat USA, Inc., brings more than 20 years of relevant industry and leadership experience in machine tools and automation to Bourn & Koch. Prior to Felsomat, Consdorf was divisional president of Acieta, LLC, a leading provider of automation solutions. During his tenure with Acieta, he also served as engineering manager. Before Acieta, Consdorf served as vice president of manufacturing and engineering at Wes-Tech Automation Solutions.

Consdorf will work with a talented team at Bourn & Koch to grow the company’s key products in machine tools and related services while expanding Bourn & Koch’s core competence to the global manufacturing market.

Prior President & CEO of Bourn & Koch Terry V. Derrico, will now serve as president and CEO of Precision Cutting Technologies (PCT). PCT is a holding company of Alleghany Capital Corporation with three operating segments: precision automated machine tool solutions through Bourn & Koch, Inc; diamond orifices and nozzles for the waterjet industry through Diamond Technology Innovations, Inc., and high-performance solid carbide tooling and solutions through CID Performance Tooling.

Bourn & Koch, Inc. names Blake Consdorf as its new president

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Inc. and Supermill LLC.

In this new role, Derrico will work to expand the reach of PCT to include additional interests in the machine tool and consumable cutting tool sectors. He will work to further the growth of all Precision Cutting Technologies companies.

MORE INFO www.precision-cutting.com

Glebar acquires Everite Machine Products, ECG technology leader

Glebar Company, a precision grinding solutions organization, recently acquired Everite Machine Products, Inc. Everite is a leader in Electrochemical Grinding (ECG) technology. For more than seven decades, they have specialized in ECG machines to meet complex and precise manufacturing requirements in many industries including the medical and aerospace markets.

“We are excited by this opportunity and welcome the Everite team to Glebar,” said Robert Baker, CEO of Glebar Company. “Combining the capabilities of Tridex and Everite will increase our ability to provide ECG solutions to our expanded customer base. Additionally, we will bring Glebar’s service and aftermarket capabilities to the Everite customer install base strengthening our existing partnerships through improved service and support.”

“We look forward to joining the Glebar team and furthering our mission to provide customers with an ECG solution for their complex and precision manufacturing requirements,” said Bill Clipsham, global business development at Everite.

With more than 70 years of experience, and hundreds of machines installed globally, Everite, offers Burr-Free Cutoff, Surface Grinding, Point Grinding, and Vertical Grinding solutions utilizing ECG.

“We will be focused on building upon existing machine features, bringing both the Everite and Tridex technologies together to the benefit of our customers, while leveraging our expertise in integrated control and automated solutions to drive value for our customers,” said John Bannayan, Chief Technology Officer at Glebar.

Glebar Company is an innovative solutions provider that designs and configures its standard platform of modular precision centerless grinding, micro grinding, and electrochemical grinding machine systems to provide turnkey, custom solutions for its customers. The company focuses on providing solutions in partnership with its customers, maximizing safety, productivity, return on investment, and provides full-service aftermarket support for the entire life of the solution.

Glebar is an ISO 9001:2015 Certified Company and is ITAR Registered.

MORE INFO www.everite.com
www.glebar.com

Partnership gives iGAM customers peace of mind on used equipment

iGAM, an NRTC Alabama, Inc. brand, known as a leading online marketplace for used robots and manufacturing equipment, recently announced a strategic partnership with Manufacturing Repair & Overstock, Inc. (MRO, Inc.) of Chattanooga, Tennessee,

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offer a 20-month warranty on used robots and manufacturing equipment sold on iGAM. MRO, Inc. brings 10 years of manufacturing and industrial equipment repair experience and a global reputation for delivering premier repair services to the partnership. iGAM items covered by the MRO Warranty Coverage are inspected and thoroughly tested and now give customers peace of mind that in the event of a malfunction, the equipment can be repaired quickly to minimize downtime and reduce the impact on production lines.

Additionally, iGAM is offering customers a new industrial repair service, backed by MRO, Inc., as an option for customers who own equipment and recognize a repair is a better alternative to a new or used capital investment.

“When we launched iGAM in October 2019 we knew we were disrupting the supply chain for robotics and manufacturing equipment by adding the convenience of an online marketplace. Now our customers have a powerful warranty behind their purchase to give them peace of mind to confidently invest in the building and expansion of their automation and production facilities,” said Greg Owens, CEO of NRTC Alabama, Inc.

“We built MRO as a technology company modeling world-class customer service and solutions for manufacturing plants. Our partnership with iGAM perfectly blends our repair and warranty experience with their vast inventory and supply chain to offer customers high-quality products, peace of mind, and unparalleled customer experience,” said MRO, Inc.’s founders Justin Wilson and Russell Looper.

Look for the new MRO Warranty Coverage badge on robots and manufacturing equipment sold on iGAM. Customers will find the MRO warranty on circuit boards, controls, and drives to monitors, motors, power supplies, and robots from popular brands including ABB, Allen Bradley, Baldor, Bosch Rexroth, FANUC, General Electric, Indramat, Mitsubishi, Schneider, Siemens, and Yaskawa Motoman.

MORE INFO www.igam.com

Machine Tool Builders, Inc. appoints Hans Grass as new CEO

Machine Tool Builders, Inc. (MTB) recently appointed Hans Grass as the company’s CEO. Grass brings a wealth of knowledge and experience backed by 48 years in the machine tool industry, including 44 years in management roles — most recently as vice president of engineering (managing both engineering and product development) for Bourn & Koch in Rockford. Prior positions included various management and sales/service positions with Pfauter, Gleason, and Index Corporation.

Grass has gained in-depth expertise of gear manufacturing machine tools as well as milling, turning, grinding, and other machine tools. He was educated in Germany with a Pfauter machine tool apprenticeship program, complemented by three years of engineering studies.

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Partnering with QualityReducer to provide Gearbox repair, rebuilding and reverse-engineering.

Hans Grass
MTB is a customized machine tool solutions provider specializing in gear cutting and grinding technologies. That includes rebuilding, retrofitting, CNC re-controls, repairs, and software development as well as new and used machine tool sales.

MORE INFO  www.machinetoolbuilders.com

Prototek names John Cleary to manage Wisconsin operations

Prototek, a national leader in rapid prototyping and one-stop production of precision sheet metal fabrication and CNC machining, recently appointed John Cleary as operations manager for its Grafton, Wisconsin, facility. Prototek’s midwestern location provides full sheet metal, CNC, machining manufacturing of prototypes, and short-run part production, including wire EDM, waterjet cutting, finishing, and assembly for many industries, including aerospace, defense/military, education/research, electronics, healthcare, robotics, and transportation.

“We are very pleased to welcome John Cleary to our management team,” said Prototek President Brian Francoeur. “Our Wisconsin facility strategically connects our East-Coast and West-Coast operations to serve our national customer base. John brings vast experience in all facets of operations management specific to our manufacturing niche.”

“Prototek has a long-standing reputation for turning around challenging parts in record time,” Cleary said. “I am very pleased to join Prototek and I look forward to leading the Wisconsin division for this fast-growing company.”

Before joining Prototek, Cleary led many organizational and operational improvements with several firms, including developing Six Sigma and DMAIC culture and other quality and safety programs, upgrading sales and marketing, introducing new technologies, and overseeing expansions. Cleary served as division president/operations manager for Pace Industries. Earlier, he held operations manager positions with Mumford Metal Casting; LMI Manufacturing; ALLCAST, INC.; and Craft Cast Co., Inc. Cleary earned a B.S. in manufacturing engineering from Silver Lake College.

Founded in 1987, Prototek has grown to become a national leader in rapid prototyping and one-stop production of precision sheet metal fabrication and CNC machining across four manufacturing facilities: two located in Contoocook, New Hampshire; Grafton, Wisconsin; and Sunnyvale, California. With nearly 175,000 square feet of manufacturing workspace, Prototek is known for turning around difficult and fast-turn jobs that other shops turn away. Quick quotes and rapid throughput are a specialty on high-precision sheet metal fabrication and machining of various metals and plastics, electro-mechanical assembly and short-run continuous manufacturing. Prototek serves a broad mix of end markets, including medical, robotics, electronics, aerospace, logistics, and technology.

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Thomas Lord, Sales Director
United States ALD Port Huron
ALD Thermal Treatment Inc.
2656 24th Street
Port Huron, MI, USA 48040
Cell Number +1 (810) 300-1437
Email: tlord@aldtt.net

Christopher Totten, Sales – Canada / USA,
Office Phone +1 810 357 0634
Cell Phone +1 810 300 3601
e-mail: sales@aldtt.net

Mexico ALD Tratamientos Térmicos S.A. de C.V.

Edwin Orozco, Sales Director – Mexico
Office Phone +52 844 866 9791
Cell Phone +52 1 844 277 2257
ventas@aldtt-mexico.com
eorozco@aldtt-mexico.com

Moises Garcia – Sales Director - Bajio
Cell Phone +521 (844) 277 2254
ventas@aldtt-mexico.com
There is no question that the economic conditions throughout the world have changed radically since January — between the pandemic, government shutdowns, international trade wars, and tariff restrictions, the U.S. economy finds itself in the worst position since the Great Depression. However, that does not mean there aren’t positive signs that show the economic recovery is starting. But after looking at the data compiled in AGMA’s Gear Market Report — put together by world-renowned experts at IHS Markit — we are all bracing, because we know it will get worse before it gets a little better for our members.

According to the Gear Market Report, U.S. manufacturing saw zero growth during 2019, and it is expected to plunge 15 percent this year based on a number of issues that include: supply chain disruptions from China, COVID-19 safety issues in U.S. manufacturing facilities, and the “Pandemic Economic Hangover” — investment hesitation during a time of uncertainty leading to a decline in demand.

Let us dive in a little deeper to look at only a couple of the sectors that our gear manufacturers and suppliers sell to. As expected, The Gear Market Report numbers show declines in all 11 of the end-user markets covered for 2020, but some are direr than others.

- **Material Handling Equipment (elevator and moving stairways, conveyor and conveying equipment, overhead crane and hoists, industrial truck, tractor, trainer and stacker machinery, etc.):** Goods consumption is expected to decline 5 percent in 2020, then increase 4 percent in both 2021 and 2022. Durable goods consumption should collapse 14 percent in 2020, then see growth of 9 percent in 2021 and 8 percent in 2022.

- **Industrial Machinery (sawmill and woodworking machinery, food processing machinery, plastics and rubber industry, textile machinery, printing machinery, petroleum refining machinery, and more):** Production is projected to decline 14 percent during 2020 then increase 2 percent in 2021 and 8 percent in 2022. Business confidence must be restored before investment in equipment takes hold.

- **Agriculture Machinery (tractors, planters, food processing equipment, mowers and more):** Farm equipment production is likely to decline only 4 percent during 2020 as farmers’ incomes are hit minimally compared to the rest of the economy.

- **Construction Machinery (backhoes, bulldozers, off-highway trucks, construction tractors, road graders, logging equipment and more):** A $45.5 billion industry, demand was up 9 percent in 2019, much of it supplied by imports. In early 2020, demand turned sharply negative, minus 13 percent. Total construction should be weak over the next three years, especially if there is no further discussion of an infrastructure stimulus.

- **Aerospace (aircraft manufacturing, aircraft-engine and engine-parts manufacturing, and more):** The whole aerospace industry from production to service is likely to take years to recover. We now feel we may have been too optimistic on original expectations. Boeing just announced it is laying off 7,000 workers, and, with air carriers in distress, canceled orders are now a major worry. So far, 150 737 Max orders have been cancelled.

- **Oil and Gas Field Machinery (oil and gas field equipment, derricks, water well drilling machinery, and more):** Exports represent more than 30 percent of shipments, and they collapsed during early 2020. Average oil prices are expected to decline by 45 percent during 2020. Bankruptcies in oil drilling may be widespread.

The Gear Market Report covers more than 10 different sectors and is the type of tool all manufacturing companies and their suppliers can rely on to provide the latest economic data affecting their businesses. The IHS Markit economists use AGMA’s Monthly Market Trend data, which aggregates company shipment and booking data to specifically forecast the gear industry as accurately as possible. With the report coming out every quarter, the data is consistently updated, which takes the guess work out of why you need to shift your strategic plan. After all, in the 100 years many of our members have been in business, it is the understanding of the long game that is critical.

“Manufacturing is several degrees removed from the consumer and is appreciably less sensitive to small dips in the economy ... Manufacturers should smooth forecasts into moving averages. They should not react to small, short-term changes. Instead, they must focus on underlying trends — they must understand their position in the business cycle, and they must separate key indicators from those that impact more changeable industries,” according to the Forbes article, “Three Keys For U.S. Manufacturers To Build Accurate Forecasts.”

The good news story? The forecasts do show the inevitable recovery, but it just might take more time than we would like.

“The full thrust of the recovery for gears will likely be felt in 2022 when end-markets have shaken off the effects of the pandemic. However, it will likely take more time for business to return to pre-pandemic levels,” according to the Q2 Gear Market Report.

For now, it is imperative that manufacturers and suppliers use AGMA and its resources to stay ahead of the numbers. There is a reason many of our members have been around for more than a century, and using reports like the Gear Market Report can provide the insight you need to be around for a long time.

For more information regarding the Gear Market Report or questions on how to sign up, email doran@agma.org.
Upcoming Webinars

National Security Reviews of Foreign Investments in the United States: What U.S. Companies and Overseas Investors in the Bearing, Gear, and Related Industries Need to Know
August 5, 2020 | 1-2 p.m. EST | Free

Under legislation passed by Congress in 2018 and implemented in February 2020, the U.S. government’s Committee on Foreign Investment in the United States is increasingly scrutinizing a wide range of investments by foreign persons — most notably from China — in U.S. businesses, infrastructure, and real estate. Companies and investors in the bearing and gear industries are among those likely to be most affected by the new CFIUS rules and may see their planned investments blocked or penalties levied where the requisite CFIUS review is not performed. This webinar will pull back the curtain on the new CFIUS process and tell you what you need to know to identify CFIUS issues and successfully complete planned investments.

September 2, 2020 1-2 p.m. EST | Free

Behind the headlines about a Chinese company, Huawei’s alleged violations of U.S. export control and sanctions laws are a range of U.S. government initiatives designed to address concerns over Chinese technological and market dominance of emerging technologies such as 5G and “Internet of Things” (IoT). The Trump Administration has been taking a whole of government approach to these issues, engaging in new rulemaking and working closely with Congress and independent agencies such as the Federal Communications Commission to craft a set of rules that will shape the direction of investment in these technologies for years to come. This webinar will explore these
issues and highlight the many pitfalls and opportunities for bearing and gear companies that rely on these technologies or plan to make them part of new projects and products.

Options and Approaches to Addressing the Continuing Problem of Counterfeit Imports: U.S. Government Initiatives and Next Steps for Industry to Consider

October 7, 2020 | 1-2 p.m. EST | Free

Imports of counterfeit bearing and gear products continue to present challenges for our industries, raising real safety risks, undercutting consumer confidence, and harming the bottom line. This webinar will examine a range of new initiatives designed to stem the flow of counterfeit products into this country and provide practical advice on how to fight back and enlist U.S. government resources in that fight.

NFPA’s 2020 Industry & Economic Outlook Conference

August 11-13, 2020 | 9 a.m.-12:30 p.m. CST | Virtual Delivery

The Industry & Economic Outlook Conference (IEOC) is NFPA’s premier economic event that offers hard data and expert analysis for everyone in the fluid power supply chain. Both members and non-members alike are able to attend. Taking place in a series of three half-day sessions, the 2020 IEOC will offer the same exclusive economic content NFPA members have come to expect as well as exclusive opportunities to network with speakers and other attendees.

For more information, please visit: nfpahub.com/events/conferences/the-ieoc

Online Gear Education from the Basics to the Engineering

AGMA offers video training and an online workforce training series for members and non-members. These courses are a convenient way to keep your employees learning from the computer. Visit: www.agma.org/education/online/video-training/detailed-gear-design-beyond-simple-service-factors/ to see the course descriptions.

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- Online Workforce Training: Hobbing.

The AGMA Fall Technical Meeting is Going Virtual!

For 2020, AGMA has decided to make the FTM an online event so people all over the world can experience the quality presentations from the gearing experts without having to travel. FTM Virtual will be in October and will consist of 10 pre-recorded presentations and one live Q&A session with the speakers. More details will be coming out soon, so make sure to check in at www.agma.org/2020-fall-technical-meeting/
CALENDAR OF EVENTS

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

**JULY**

- July 15 — Aerospace Committee Meeting — WebEx
- July 16 — Lubrication Committee Meeting — WebEx
- July 17 — Sound and Vibration Committee Meeting — WebEx
- July 23 — Nomenclature Committee Meeting — WebEx
- July 30 — Metallurgy and Materials Committee Meeting — WebEx

**AUGUST**

- August 5 — National Security Reviews of Foreign Investments Webinar — www.agma.org/education/online (FREE)
- August 12 — Powder Metallurgy Committee Meeting — WebEx
- August 13 — Metallurgy and Materials Committee Meeting — WebEx
- August 18 — Plastics Committee Meeting — WebEx
- August 18–19 — AGMA Board of Directors Meeting — Alexandria, Virginia
- August 20–21 — TDEC Meeting — Alexandria, Virginia
- August 25 — Gear Accuracy Committee — WebEx
- August 26 — Lubrication Committee Meeting — WebEx
- August 27 — Bevel Gearing Committee Meeting — WebEx

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Choosing the best gear finishing method often comes down to production volume, processing cycle times, and gear profiles.

A recent Materials Matter article compared generic deburring versus CAVF (chemically accelerated vibratory finishing.) Both techniques are conducted in a vibratory unit. The main advantage of CAVF processing is its ability to use HDNA, high-density non-abrasive media, to generate an isotropic superfinish, a surface with a non-directional texture and roughness values of ≤ 4 μin (0.1μm). In the gearing world, many applications where an isotropic superfinish is required are vehicular or aerospace related. In such applications, the predominant base gear alloys are SAE 8620, SAE 9310, Pyrowear® 53 (AMS 6308), and for many new applications, Ferrium® C64 (AMS 6509). Parts are typically heat-treated to HRC 58-65 and post heat-treat ground to remove quench distortion and/or apply tooth crown. This is especially true of the higher AGMA class number gears.

CAVF chemistries are available to support the isotropic superfinishing of typical carbon steels (as referenced above), bearing steels, 300/400 series stainless alloys, precipitation hardened stainless alloys such as 17-4PH and 18-8PH, titanium alloys, nickel-chrome superalloys, as well as copper/copper alloys. Mechanical paste polishing is also capable of refining the surface of these materials and can be considered as an alternative to CAVF for surface finish improvement of hardened gear applications. This article will compare the two processes in a quick overview.

A QUICK REVIEW OF CAVF PROCESSING

In CAVF, an HDNA media fills the vibratory unit. The high-density, non-abrasive media is commonly 100 percent aluminum oxide in composition but has been kiln-fired at such a high temperature, the aluminum oxide is vitrified and loses all mechanical cutting characteristics. The CAVF chemistry reacts with and forms a monomolecular layer of a soft conversion coating on the tooth flank. HDNA media is used as a wiping tool during CAVF refinement. The media’s density, typically 125 lbs/ft³, generates superior downward force as parts roll in the mass and efficiently wipes off the soft conversion coating. On a microscopic scale, the coating reforms and is again wiped away, as the part continues to move in the vibratory unit. Each coating formation and wiping cycle reduces the height of gear tooth grinding asperities. As a function of time, depending on the starting Ra value of the gear, asperities are gently planarized, achieving the improved surface quality.

Being high-temperature kiln vitrified, HDNA media has a negligible attrition rate of 0.008 percent. An attrition rate of 0.35 percent is typical for a 20-bond, abrasive-ceramic media. There is an approximate 44-to-1 attrition rate difference between the two. Looking at this in another way, HDNA media must run 44 hours to achieve the same amount of attrition and media swarf generation that a 20-bond media will generate in one hour of run time. Without mechanical-abrasive cutting characteristics, there is a lower propensity to over-radius critical dimensions when HDNA media is used. Additionally, the reduced mechanical force required to affect surface material removal created by the conversion coating further allows for the maintenance of existing gear tooth profile and avoids differential material removal rates between the addendum and dedendum of a gear tooth. Finally, HDNA maintains size and shape for a longer period of time, thereby extending the functional life of the media before attrition shrinks the media such that it becomes a lodging concern.

MECHANICAL PASTE POLISHING

Mechanical paste polishing has been seen as an alternative to CAVF technologies. However, the technology for hardened carbon steel applications may not be a preferred option. Mechanical paste polishing is also conducted in a vibratory unit and can use HDNA media, porcelain media, or other media compositions. However, instead of using a CAVF chemistry to form a soft conversion coating, a mechanical paste is added to the machine.

Even with a metal removal rate of just 0.00001” per hour, edge locations and the addendum of the gear flanks are preferentially contacted in the vibratory unit leading to biasing of gear profiles. Conversely, little to no material removal may occur in the dedendum of the gear teeth. CAVF processing cycles, if properly applied, do not suffer from this issue.
ing holds the fine abrasive on the surface to the gear tooth. As the parts roll in the media mass, the media forcefully presses the abrasive against the gear tooth. This abrasive rubbing scours the tooth flank to improve surface quality but at a slow refinement rate and only in areas where adequate force can be achieved.

Over time, the abrasive breaks down to form 2,000 grit, which eventually becomes a 4,000 grit, then an 8,000 grit, etc. Since the grit is exceptionally fine, the metal removal depth per hour is minuscule. In CAVF applications, metal refinement typically proceeds at a rate of 0.0001” per hour in well-contacted locations (although this speed can be increased if desired).

With mechanical abrasive paste polishing, the metal refinement rate is reduced to 0.00001” per hour in a well-contacted location. As a result, mechanical paste polishing is not an appropriate match for the high-volume production scenarios as seen in the vehicular transmission industry, for example. CAVF processing is favored where high volumes of parts are required on a daily basis and/or where single shift cycle times are required. For ultra-short cycle times, REM’s Rapid ISF® Process combines CAVF processing principles with mechanically accelerated mass finishing equipment (such as a drag finisher) to generate isotropic superfinishes on matched, lapped spiral bevel gearsets in a matter of minutes.

A typical mechanical paste polishing processing run will require multiple shifts. The processing run may be started shortly after lunch and continue through the night, concluding the next morning when personnel return to the building. At that time, a soap cleaning step flushes the residual paste from the gears and generates the final clean part with the desired surface quality. The final processing cycle however is in the 20-hour realm.

Since long processing times and abrasive-only processes have a negative impact on sharp edge locations, such as the interface between a gear face and a tooth flank, such locations are likely to become overly radiused. Even with a metal removal rate of just 0.00001” per hour, edge locations and the addendum of the gear flanks are preferentially contacted in the vibratory unit leading to biasing of gear profiles. Conversely, little-to-no material removal may occur in the dedendum of the gear teeth. CAVF processing cycles, if properly applied, do not suffer from this issue.

**ABOUT THE AUTHOR**

William (Bill) P. Nebiolo received a B.A. from The University of Connecticut and an M.S. in environmental sciences from Long Island University. He has been with REM Surface Engineering since 1989 and currently serves as a sales engineer and as REM’s product manager. Since 1978, Nebiolo has been an active member in the National Association for Surface Finishing (NASF) where he has represented the Connecticut chapter as an NASF national delegate and is the 2010, 2014, and 2015 recipient of the NASF National Award of Merit. From 1996 to 2000, he served as one of SME’s Mass Finishing technical training program instructors. He has published and presented dozens of technical papers and is the author of the “SME Mass Finishing Training Book.” Nebiolo can be reached at bnebiolo@remchem.com.
Precision gearing: Accuracy and tolerances

Understanding the meaning of precision and the real requirements of your application.

When I was a child, one of the great joys of going on the family vacation was to pull out a paper map and review the details of the trip. What highways would we take? What bridges would we cross? What roadside sights would we see along the way? Mom was in charge of making certain that the directions to our vacation hideaway were both accurate and precise. After we packed up the station wagon and headed on our journey, we would inevitably ask, “where are we?” and “when are we going to get there?” This of course was countered with, “Look it up on the map and you can see precisely where we are.” This required us to have an accurate understanding of where we were currently driving through. However, the concepts of accuracy and precision were not something we were considering as we traveled to our summer getaway.

When it comes to precision gearing, there is a misnomer that in order to design the best gear system you must use the most precise gears. In reality, the precision quality of the gearing that you should choose is directly dependent on the operating conditions of the application, and overdesigning the gears for the application will result in higher costs and no added benefits.

In order to properly begin this discussion, we first need to better define what precision is. Precision is the ability to perform an action, then repeat the same action, and see the exact same results. For example, if you were to aim at a target and you hit the same area of the target five times consecutively, it would be said that your actions were precise.

Some would argue that if you were able to hit the same area of a target five consecutive times, that your actions would be considered accurate. This is not the case! Accuracy is the ability to perform an
action and have the action strike a desired value. It is independent of precision.

As noted in Figure 1, a relationship between accuracy and precision does not exist.

In the manufacture of gearing, we aim to be both accurate and precise. Accuracy is related to the tolerances assigned to a dimension, and precision is related to the repeatability in manufacturing. In our production facilities, we grade our spur and helical gears using the JIS B1702-1:1998 precision standards. These standards actually assign values for the accuracy of particular parameters of the gear including: Single Pitch deviation $f_{pt}$, Total Cumulative Pitch deviation $F_P$, Total Profile deviation $F_a$, Total Helix deviation $F_b$, Total Radial Composite deviation $F_i$ , and Runout $F_r$.

In order to see how these standards apply, let us consider these parameters of a spur gear to determine the accuracy of the runout under different grades:

- a spur gear which is module 2 and has 30 teeth

If the gear grade desired is N5, which is a ground finished tooth, the runout value would be 15 microns. If the gear grade desired is N12, which is an injection molded tooth, the runout value is 171 microns. A hobbed gear would have an accuracy grade of N7, and the runout would be 30 microns.

For a handed cranked application, the N12 gear would be adequate for the application as the motion of the crank is not uniform and geartrain does not need to be precise. For an ordinary motor-driven application that is transmitting simple motion, the N7 gear would be more than adequate. However, if the application requires exact positioning and repeatability then the N5 gear would be the appropriate choice, as this gear is the most accurate.

However, all of this precision would be lost if the tolerancing of the bore is not suitable for the application. For our products, we supply our spur and helical gears with an H7 bore tolerance for our metal products and an H8 bore tolerance for our plastic products. These are both zero plus tolerances meaning that the bore is, at a minimum, the nominal size, and, at a maximum, it is slightly oversized in order to fit a precision shaft. This tolerance range accounts for the deviations in both the accuracy and precision of the bore manufacturing process. It also permits the gear tooth to meet the standards of the gear quality grade for which the gear is being produced.

It is important when designing a gear system to thoughtfully consider the application. Will the environment introduce conditions that negate the precision inherent to the gears you chose? The key points to remember when selecting the quality grade of the gears for your design are:

- The precision does not guarantee accuracy, and
- Tolerances are designed to mitigate deviations in accuracy.

ABOUT THE AUTHOR
Brian Dengel is general manager of KHK-USA, which is based in Mineola, New York. Go online to www.khkgears.us
Back to basics — Fracture toughness testing

Understanding the underlying theory behind fracture toughness testing, and how the test is conducted.

In previous articles, we have discussed the many different types of mechanical testing methods and requirements. While some of the test methods have application to the design process (tensile testing), many of the methods are not related to the design of the part. In this article, we will discuss fracture mechanics and fracture toughness testing. These methods are directly applicable to design, as well as can establish non-destructive testing (NDT) criteria for in-use parts. This method is powerful, and is used predominantly in aerospace, but is finding more applications in automotive and other fields.

FRACTURE MECHANICS

In 1920, Griffith [1] proposed the concept that all materials contained flaws. It is these flaws that result in materials that have substantially lower strength than their theoretical maximum. These small flaws in the material reduce the fracture strength of the material by stress concentrations [2]. These stress concentrations cause the theoretical cohesive strength to be achieved in local regions. Griffith created the criterion that "a crack will propagate when the decrease in strain energy is at least equal to the energy required to create a new crack surface [3]." This criterion is used to establish when a flaw of a specific size will initiate cracking and propagate in a brittle manner.

Metals that fail in a brittle fashion will experience plastic deformation before failure [4] [5]. Because of the plastic deformation prior to brittle fracture, the Griffith Microcrack Theory does not apply to metals. However, Irwin [6] proposed that the stress at the crack tip was a function of the applied stress and the crack size:

$$ K = \sigma \sqrt{\pi c} $$

where $K$ is the stress intensity factor and $c$ is the half-length of a flaw. $K$ is completely defined by the crack geometry, applied stress, and specimen geometry. The value of the stress intensity factor when unstable crack growth occurs is the critical stress intensity factor, $K_c$ (for mode I – cracking opening under tensile forces), where the value of $K_c$ is a material property. While the above is for an elliptical flaw, other flaw shapes have also been calculated [7] [8]. This assumes that plane strain conditions have been realized. If plane stress conditions are present, then the stress is relaxed by the increased plastic zone at the crack tip. Further, the state of stress is no longer triaxial and is diminished.

Toughness is a measure of the energy required to resist fracture in a material. Often this property is more important than the actual tensile properties, particularly if the part is to be used in a dynamic environment. The term impact strength is used to denote the toughness of the material. This term is a misnomer; it should really be impact energy. However, impact strength is so established that it makes little sense to change it. Toughness is strongly dependent on the rate of loading, temperature, and the presence of stress concentrations. Several standardized tests have been developed since World War II to measure the resistance to brittle fracture, notably the Charpy V-Notch test [9] discussed in the previous article. These tests are attempts to quantify the behavior of the material in service.

FRACTURE TOUGHNESS TESTING

As indicated earlier, the use of fracture mechanics is important in determining the maximum flaw size that a material can withstand before failing catastrophically. As has been noted, cracking in a thick plate is worse than in a thin plate. This is because...
of plane strain conditions. At the crack tip, the plastic zone is small, with a high-stress gradient across the plastic zone (Figure 1). High tri-axial stresses are present at the crack tip. The fracture appearance changes with specimen thickness because of the amount of triaxial stresses. (Figure 2).

In thin plates, the fracture is characterized by a mixed mode ductile and brittle fracture, with the presence of shear lips. Under plane strain conditions, when the plate is thick enough the fracture is flat, and the fracture stress is a constant with increasing thickness. The minimum thickness for plane strain conditions to occur is given by:

\[ B = 2.5 \left( \frac{K_{IC}}{\sigma_{YS}} \right)^2 \]

Different configurations of test specimens are used to determine the plane-strain fracture toughness, \( K_{IC} \) [11]. Typical specimens are shown in Figure 3. For most applications, the compact specimen is used because less material is used.

The notch is machined in the specimen and made sharper by fatiguing at low cycle, high strain until the crack is about the width of the test specimen. The initial crack length is measured by including the length of the fatigue crack and the notch. Testing of the specimen is accomplished by loading the specimen in tension, with the load and crack opening displacement continuously recorded until failure. A conditional value of fracture toughness, \( K_Q \) is calculated. The methodology of calculating \( K_Q \) is dependent on the type of specimen used. Refer to ASTM E399 for details.

To determine the fracture toughness, \( K_{IC} \), the crack length, \( a \), is measured, and \( B \) is calculated:

\[ B = 2.5 \left( \frac{K_{IC}}{\sigma_{YS}} \right)^2 \]

If both \( B \) and \( a \) are less than the width \( b \) of the specimen, then \( K_Q = K_{IC} \). If not, then a thicker specimen is required, and \( K_Q \) is used to determine the new thickness. Typical \( K_{IC} \) values for steels are shown in Table 1.

**CONCLUSIONS**

In this short article, we have described the underlying theory behind fracture toughness testing, and how the test is conducted. In the next set of articles, we will describe fatigue and how fracture toughness testing can be used to calculate fatigue life.

Should there be any questions regarding this article, or suggestions for future articles, please contact the editor or myself.

**REFERENCES**


**ABOUT THE AUTHOR**

D. Scott MacKenzie, Ph.D., FASM, is senior research scientist-metallurgy at Quaker Houghton Inc. For more information, go to https://home.quakerhoughton.com/
TOOTH ROOT TESTING OF STEELS WITH HIGH CLEANLINESS
For applications with a high manufacturing and surface quality, high quality steels show a high potential for increasing the load carrying capacity as well as power density.

By MORITZ TRIPPE, CHRISTOPH LÖPENHAUS, CHRISTIAN BRECHER, LILY KAMJOU, and ELIAS LÖTHMAN

The power density of gearboxes is continuously increased through different research activities. Besides new material developments, steel cleanliness comes to the forefront in order to meet future requirements regarding load carrying capacity of gears. The experimental quantification of load carrying potentials for high quality steels is the basis for introducing cleanliness as a design parameter.

In this article, investigations on the tooth root load carrying capacity of steels with different cleanliness levels are presented. The investigations are carried out on a pulsator test rig with a standardized FZG-C gear geometry. To determine and compare the different behaviors of the tested steels, correct force application in the test rig needs to be ensured. By this, it is possible to clearly separate the endurance strength for different cleanliness levels within the same steel grade composition.

For the pulsator testing, an approach for checking and ensuring correct clamping of the gears is presented. Using this procedure, endurance tests on conventionally manufactured gears with different cleanliness levels are carried out. Resulting mean values of the tooth root strength as well as scattering of test results are evaluated, and the influence of higher cleanliness on an increasing mean value and decreasing scattering is proved. The confidence level of the mean value is discussed regarding the overall number of tests.

As a conclusion, the impact of steel cleanliness on increasing endurance strength and decreasing scattering is separated from manufacturing and testing influences. A higher level of cleanliness takes into account the influence of the occurring failure mechanisms. Especially for applications with a high manufacturing and surface quality, high quality steels show a high potential for increasing the load carrying capacity and thereby the power density.

1 INTRODUCTION AND MOTIVATION

For many years, demanding applications such as bearings and diesel injection systems have been driving the development of air-melt, high-volume production, clean steels. Through environmental legislation and a continuously ongoing strive to improve power density in many applications, the gear industry is now showing an increased interest for clean steels as well. This is due to steel cleanliness impact on endurance strength, relevant to many high-cycle fatigue gear applications. Also, with more frequent use of sophisticated after-processing techniques, such as superfinishing and shot peening, the importance of the material quality is increasing. This in itself is a driver for the use of cleaner steels, since previously, other factors such as surface quality has been the weakest link.

2 AIM AND APPROACH

The increasing demands on gears with regard to power density require new approaches to the design of gear geometry as well as an increase in material load carrying capacity. Steels with a high cleanliness are already being used in applications with extremely high material demands. In this paper, the influence of the cleanliness of a material on the tooth root load carrying capacity and the test scatter will be investigated.

The aim is to determine the increase in load carrying capacity taking into account the test scatter and to separate it from influences from the test itself and the test geometry. For this purpose, three variants with different degrees of cleanliness for the same steel grade are investigated.

The tests are carried out on a pulsator test rig using a standardized gear geometry. In order to guarantee correct load application in the test and to reduce the influence of the test setup on the scatter, a procedure for checking the pressure distribution in the pulsator test is presented. The tests in the area of fatigue strength are analyzed with regard to mean values and scattering. Taking into account the confidence intervals, the load carrying capacities of the investigated variants are compared, and the influence of the degree of cleanliness on the load carrying capacity is highlighted.

3 THEORETICAL INFLUENCE OF THE CLEANLINESS ON THE ENDURANCE STRENGTH

Previous investigations on the influence of material defects on the load carrying capacity show that the size and distribution of defects are important parameters. The material cleanliness characterizes the number of defects and their frequency of occurrence.
Murakami investigates the influence of inclusions in the material on the load carrying capacity. Especially for hard steels with HV > 400, the size of defects or inclusions has a significant influence on the load carrying capacity [11]. Henser states in his work that a higher cleanliness leads to an increased tooth root load carrying capacity of beveloid gears [4]. Konowalczuk analyzes the influence of the defect size on the tooth flank fracture load capacity. The size of defects has a decisive influence on the load carrying capacity, independent of the core hardness and case depth. A reduction of the defect size leads to a significant increase of the load carrying capacity regarding tooth flank fracture [9].

On the basis of the existing work on the influence of material cleanliness on the load carrying capacity, it can be expected that the load carrying capacity will increase with higher cleanliness. The defect size has a primary influence on the fatigue strength. The number of defects, on the other hand, influences the scatter of the test results around the fatigue strength.

4 INVESTIGATED MATERIALS AND TEST GEARS

For the investigations, three different degrees of cleanliness of a 20MnCr5 material were considered. The investigations were carried out using the standardized FZG-C gear geometry in a pulsator test to determine the tooth root load carrying capacity. The conventional gear manufacturing chain includes the process steps turning, soft machining, heat treatment and gear grinding. All variants were heat treated in the same batch. During the grinding process, only the tooth flank was machined. In the following, the properties of the examined materials as well as the gear geometry and manufacturing quality of the examined components are presented.

4.1 MATERIAL CHARACTERISTICS

Three different 20MnCr5 materials were tested, with assumed different cleanliness levels, a conventional 20MnCr5 as a reference, a bearing quality 20MnCr5 (236F; steel 1), and an ultraclean isotropic quality 20MnCr5 (236Q; steel 2). Table 1 shows the chemical composition of the steels.

<table>
<thead>
<tr>
<th>20MnCr5</th>
<th>IC/CC</th>
<th>Area reduction</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>S</th>
<th>Mo</th>
<th>Cr</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>CC</td>
<td>-10</td>
<td>0.20</td>
<td>0.12</td>
<td>1.25</td>
<td>0.025</td>
<td>0.04</td>
<td>1.17</td>
<td>0.11</td>
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<tr>
<td>Steel 1</td>
<td>IC</td>
<td>-20</td>
<td>0.19</td>
<td>0.24</td>
<td>1.13</td>
<td>0.019</td>
<td>0.04</td>
<td>1.18</td>
<td>0.15</td>
</tr>
<tr>
<td>Steel 2</td>
<td>IC</td>
<td>-35</td>
<td>0.20</td>
<td>0.14</td>
<td>1.15</td>
<td>0.001</td>
<td>0.06</td>
<td>1.15</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Table 1: Chemical composition of materials, casting format and area reduction.

Number of defects > 10 μm (average) Max stringer length (μm)

| 20MnCr5 (reference) | 235 | 330 |
| Steel 1             | 22  | < 75 |
| Steel 2             | 0   | 0   |

Table 2: Results from SEM evaluation.

In addition to the quality of the tooth flank, the geometry and roughness of the tooth root have a decisive influence on the tooth root load carrying capacity. The maximum tooth root stress usually occurs at the 30°-tangent in the tooth root [8, 12, 14]. A small root radius at this point leads to a higher stress at the same load and thus to a reduced load carrying capacity. For this reason, the radius of the tooth root fillet in this area is considered in order to exclude any influence on the test results. Since the gears were manufac-
tured conventionally, the tooth root was not machined after the heat treatment. All gears were blast cleaned after heat treatment to remove the surface oxidation. The root fillet was measured on a Klingelnberg P16 gear-measuring center. The radius \( \rho_{F,30°} \) in the range of the 30°-tangent was then determined on the basis of the measured point cloud. The root fillet radii were determined for each investigated pinion at four gaps.

In Figure 2 the mean tooth root radii at the 30°-tangent of the three considered variants are shown on the left side. Furthermore, the maximum and minimum measured radii are shown as deviation bars. The mean tooth root radii are \( \rho_{F,30°,\text{Ref,mean}} = 2.22 \text{ mm} \), \( \rho_{F,30°,\text{steel 1,mean}} = 2.24 \text{ mm} \) and \( \rho_{F,30°,\text{steel 2,mean}} = 2.22 \text{ mm} \). The tooth root geometry of the three variants therefore shows no significant deviations. Since the mean values of the root radii correspond, the deviations only have an influence on the scatter determined in the pulsator tests. Due to the similar scatter of the tooth root radii of the three variants, it is to be expected that the influence on the scatter of the tooth root load carrying capacity will be similar as well.

Apart from the geometry of the tooth root fillet, the roughness in the tooth root has an influence on the achievable load carrying capacity in the test [8, 12, 14]. High roughness values act as notches and thus promote the initiation of cracks on the surface. In order to evaluate the roughness of the investigated pinions, the average roughness depth \( R_z \) was measured in the range of the 30°-tangent. The measurement starts in the tooth root and runs in profile direction to the tooth tip. The curvature of the root fillet was filtered from the measurement using a fourth degree polynomial. The roughness was measured on two gears per variant at two gaps each.

On the right side of Figure 2, the \( R_z \) values of the left and right flank of the examined variants are shown. The mean roughness depths of the variants are similar. The \( R_z \) values of the variant Ref show a slightly larger scatter. However, since the influence of this measured roughness variation on the load carrying capacity according to ISO 6336 is small, no influence on the determined fatigue strength in the test is to be expected.

5 TEST SETUP AND TESTING PROCEDURE

The tests on the tooth root load carrying capacity were carried out in the pulsator test as an analogy test to examine the tooth root. In contrast to the running test, the number of influencing factors on the test result is reduced in the pulsator test. Thus, it is possible to consider the influence of the material cleanliness on the tooth root load carrying capacity in an isolated way. Furthermore, the test setup in the pulsator test allows several tests to be carried out on one gear, thus reducing the number of test gears required. In the following, the test setup, the verification of the load distribution, and the testing and evaluation procedure used are explained.
5.1 TEST SETUP AND ALIGNMENT CHECK

The pulsator test approximates a part of the load curve in the tooth mesh. Figure 3 shows the clamping situation of a spur gear in the pulsator. The gear is clamped between two pulsator jaws. One of the two jaws is stationary and connected to a load cell. The other pulsator jaw carries out a mechanically actuated, pulsating movement and thus loads the teeth with a sinusoidal load, which is monitored by the load cell. The positioning of the pulsator jaws is based on the support of the tip of the adjacent teeth, which allows central alignment of the gear in the pulsator jaw contact.

On the right side of Figure 3, a diagram is shown with the tooth root stress over the path of contact A - E of the spur gear used. The ordinate of the diagram is normalized to the maximum tooth root stress.

Furthermore, the areas for single tooth contact “1” and double tooth contact “2” within one tooth mesh are shown. It becomes clear that the point of maximum tooth root stress lies in the outer point of single tooth contact, since only one tooth transmits the entire torque and, at the same time, the lever arm is the largest. Because the number of clamped teeth defines the contact line in the pulsator test, it is not possible to test exactly the outer point of single tooth contact. For the tests, the number of clamped teeth is selected in a way that the resulting contact line is as close as possible to the outer point of single tooth contact. For further calculations of tooth root stresses, the position of the contact line during testing is considered. A mechanical minimum preload, the upper pulsator force $F_{\text{Puls,U}}$, must be present for the non-positive fixation of the test gear between the pulsator jaws, so that the gear remains at its defined clamping position during the test.

In contrast to the running test, the amount of preload cannot assume the minimum value zero. The associated influence on the load carrying capacity is classified as negligible, if the amount of the minimum preload lies within a range of 3-7.5 % of the amount of the maximum lower pulsator force $F_{\text{Puls,L}}$ [17]. For the tests presented, an upper pulsator force of $F_{\text{Puls,U}} = -1 \text{kN}$ was selected. With an expected mean lower pulsator force of $F_{\text{Puls,L}} < -20 \text{kN}$, the selected preload meets the Weigand criterion [17]. The number of clamped teeth was set to $z_{\text{clamped}} = 3$ for all tests.

The tooth root load carrying capacity determined in the test depends significantly on the correct load application in the test. The highest load carrying capacity is obtained with an even load distribution over the tooth width. Helix slope deviations of the clamped teeth, misalignment, damaged pulsator jaws or incorrect clamping lead to local stress peaks in the tooth root over the tooth width and influence the determined strengths with regard to mean value and scatter. In order to be able to analyze the influence of material cleanliness on mean value and scatter, the method shown in Figure 4 is used to check the load distribution in the pulsator.
The test results of the investigated variants with different material cleanliness show that the load carrying capacity is in some way affected by improved cleanliness. In addition to the load carrying capacity, the cleanliness also influences the scatter of the test results.

The Fujifilm Prescale pressure film can be used to determine the contact pressure in the gear-pulsator jaw contact. The pressure film turns red at loaded areas. The color density allows direct conclusions about the contact pressure. In this way, it is possible to identify and correct an uneven pressure distribution. During pulsator testing, the load distribution was checked every third test and, if necessary, corrected.

5.2 TESTING AND EVALUATION PROCEDURE

The tests to determine the fatigue strength in the tooth root are carried out according to the staircase method. In this procedure, the load of the following test depends on the previous test result [1, 7]. In the case of damage, the load is reduced by one step and increased by one step in the case of a run out. The damage criterion is a crack in the tooth root in the area of the 30°-tangent or a broken tooth. In addition to the small number of tests to determine the mean value, an additional fictitious point can be evaluated in this procedure [7]. The maximum number of cycles to be achieved for a run out is \( N_{G} = 6 \times 10^6 \) load cycles. The evaluation of the staircase is carried out according to Hück’s method and is shown in Figure 5. In order to make a conclusion about the scatter of the results in addition to the mean value, 15 tests were carried out for each material variant. The step distance for all tests is \( d = 1 \) kN.

In addition to the tooth root load carrying capacity, the scatter of the tests and the statistical reliability of the determined values are evaluated. For this purpose, the confidence intervals of the mean values of the variants are calculated as shown in Figure 6. The determination of a mean value from a finite number of tests corresponds to an estimated value \( x \) and usually does not correspond exactly to the true mean value \( \mu \). If the test points correspond to a normal distribution, the true mean value \( \mu \) and the estimated value \( x \) can be displayed as shown in Figure 6 on the left. The highest probability of occurrence is the true mean \( \mu \). For different sequences of test points, different estimated values \( x \) result. The probability of occurrence of the estimated values with a normal distribution of the test points is indicated by the curve in Figure 6.

Since the true mean value \( \mu \) is usually not known and the number of experiments to determine the estimated value \( x \) is finite, it makes sense to determine a range that contains the true mean value \( \mu \) with a defined probability, taking into account the scatter of the test results. The confidence interval for the estimated value \( x \) indicates the range in which the true mean value \( \mu \) with the defined coverage probability \( (1-\alpha) \) is located. The smaller the standard deviation of the experiments, the smaller the confidence interval around the estimated value. The same applies to a larger number of tests. For a larger coverage probability, the confidence interval increases [3].

Previous investigations on case-hardened steel gears have shown that the test points are normally distributed in the staircase method [6]. Accordingly, a normal distribution is assumed for the evaluation of the tests. Furthermore, the usual coverage probability of 95 percent is selected for evaluation. Based on the comparison of the calculated confidence intervals of the respective mean values, a statement can then be made as to whether the compared mean values are identical or not from a statistical point of view.

The calculation of the tooth root stress from the pulsator forces is carried out based on the ISO 6336-3 standard calculation [14].
The used factors and equations are shown in Figure 7. The first step is the calculation of the nominal tooth root stress $\sigma_{Pot}$ for a failure probability of 50 percent.

The factors $Y_F$ and $Y_S$ take into account influences from the form of the tooth root fillet and variance in force application on the tooth root stress. Both factors are calculated for the clamping position in the pulsator test rig using the position of the contact line as well as the measured tooth root radius $\rho_F$. The factor $Y_\beta$ rates the influence of the helix angle on the distribution of the tooth root stress and is one because a spur gear is tested. The K factors are all one, since the occurring loads in the pulsator test rig are measured and controlled and the load distribution in the contact of tooth and pulsator jaws is uniform.

The calculation of the allowable stress $\sigma_{FE}$ as well as the nominal stress $\sigma_{Flim}$ depend on several assumptions. One assumption is that the fatigue strength of the tooth root determined in the running test is 10 percent lower compared to the pulsator test because, in the pulsator test, the weakest tooth of a gear doesn’t always fail [6]. Another assumption is that it is possible to transfer the fatigue strength from a failure probability of 50 percent to 1 percent by the factor 0.86 for case-hardened steels [6]. This factor depends on the huge amount of data, which are the basis of the ISO 6336 standard. As these factors have not yet been confirmed for clean steels, a calculation of the values $\sigma_{FE}$ and $\sigma_{Flim}$ is subjected with uncertainties.

6 TEST RESULTS AND EVALUATION

The results of the investigations of the three material variants are presented in the following. Subsequently, a comparison of the determined load carrying capacities is made taking into account the confidence intervals and the increase in load carrying capacity of the tested steels is quantified. Finally, the resulting nominal stress numbers of the three variants are compared to the values of the ISO 6336-5.

6.1 REFERENCE MATERIAL

Figure 8 shows the test results of the Ref variant. The frequency of the applied load in all tests was approximately $f = 30$ Hz. The results were determined for a failure probability of 50 percent. All tests were carried out on the same test bench. The endurable mean double amplitude of the pulsator force is $F_{ppt,mean,Ref} = 22.63$ kN. The corresponding tooth root stress according to ISO 6336 is $\sigma_{F0,mean,Ref} = 1302.45$ N/mm². Four load steps occur in the staircase procedure. The S/N diagram of the tests carried out shows the damages lie in a range from $10^5$ to $10^6$ load cycles.

6.2 STEEL 1 MATERIAL

The test results for the steel 1 variant with a higher material cleanliness are shown in Figure 9. The endurable mean double amplitude of the pulsator force is $F_{ppt,mean,steel1} = 24.50$ kN. The increased material cleanliness is assumed to affect the increase of the fatigue strength, but the scatter of the test points in the staircase is comparable with the scatter of the variant Ref. The S/N diagram shows...
that the number of load cycles of damages decreases. For steel 1, no break occurs after $6 \times 10^5$ load cycles, which is significantly lower compared to the Ref variant.

The shift of the damages to lower load cycles is likely due to the improved material cleanliness. The reduced number and size of defects in the material result in fewer potential crack origins in the material. This reduces the local stresses in the material and increases the load carrying capacity. The defects still present in the material, however, represent potential crack starting points again under the increased load. In the case of crack initiation at a defect, the crack growth in the material progresses faster due to the increased stresses and a damage of the tooth root occurs earlier.

### 6.3 STEEL 2 MATERIAL

Figure 10 shows the test results of the steel 2 variant. The endurable mean double amplitude of the pulsator force is $F_{p_{\text{ptp,mean,steel 2}}} = 24.25$ kN. In contrast to the other two variants, only three load steps occur in the staircase of this variant. The scatter of the test results is therefore lower. The $S/N$ diagram of the tests carried out shows that the average number of load cycles in the event of damage is reduced analogously to variant steel 1. Accordingly, the further increase in the cleanliness of steel 2 does not lead to a further increase in the load carrying capacity, but to a reduced test scatter and a reduced number of load cycles in case of a breakage. The reduced size of defects in the material can explain this change.

Since the size of defects for steel 2 is smaller than for steel 1, the probability that a detrimental defect is in the critical area of the tooth root with the maximum stresses is lower. The scatter of the test results decreases accordingly. At the same time, however, the probability increases that other damage mechanisms, which are not caused by material defects, will limit the load carrying capacity. Accordingly, the average endurable load does not change. Nevertheless, it is to be expected that an improved surface quality and increased residual compressive stresses will increase the differences between the different steel grades. With residual compressive stresses, for example, the occurring failure modes will probably change from surface failures to sub-surface failures because the crack initiation at the surface is prevented [5]. In this case, the higher cleanliness of the material will lead to higher strengths.

### 6.4 COMPARISON OF RESULTS CONSIDERING THE CONFIDENCE INTERVALS

The test results of the investigated variants with different material cleanliness show that the load carrying capacity is in some way affected by improved cleanliness. In addition to the load carrying capacity, the cleanliness also influences the scatter of the test results. To quantify the influences, the endurable mean pulsator forces of the three variants are compared in Figure 11. In addition to the determined mean values $\bar{x}$, the standard deviations of the respective test series and the single-sided confidence intervals are shown.

### Calculation Factors

- $F_1 = F_{p_{\text{ptp}}} \cdot \cos \theta \rho$
- $Y_F = 2.2452$
- $Y_S = 1.1786$
- $\theta = 2.2275$ mm
- $F_p = K_S = K_{\text{eff}} = K_{\text{rad}} = 1$
- $f_{\text{mean}} = 0.9 \cdot 0.86 = 0.774$
- $Y_{\text{steel}} = Y_x = 1$
- $Y_{\text{root}} = 1.0348$
- $Y_{\text{surf}} = 2$

### Comparison of Nominal Stress Numbers

The load carrying capacity is in some way affected by improved cleanliness. In addition to the load carrying capacity, the cleanliness also influences the scatter of the test results. To quantify the influences, the endurable mean pulsator forces of the three variants are compared in Figure 11. In addition to the determined mean values $\bar{x}$, the standard deviations of the respective test series and the single-sided confidence intervals are shown.
intervals Clx of the mean values are shown. The load capacity increase of variant steel 1 to the reference variant Ref amounts Δ = 8.3 % or Δ = 107.63 N/mm². The examination of the confidence intervals shows that a significant increase in the load carrying capacity exists, taking into account the possible scattering of the mean value. The mean values of the variants steel 1 and steel 2 differ by Δ = 1%. The consideration of the respective confidence intervals makes clear that the mean values of these variants are equal from a statistical point of view, since the confidence interval of steel 2 lies within the interval of variant steel 1.

The standard deviations of the experiments lie within a range of s = 2.7 - 4.1% and thus correspond well with Höhn’s values [6]. A comparison of the test scatter on the basis of the calculated standard deviations is not performed, since more than the 15 tests performed per variant are necessary for a reliable determination of the standard deviation [7].

In order to classify the determined strengths of the different materials, the nominal stress numbers σlim of the ISO 6336 - 5 are shown in Figure 12. The classifications ML, MQ, and ME describe the material quality. The value of the respective class indicates the expected strength of the corresponding material qualities. Furthermore, the values of the nominal stress numbers σlim determined in the tests are shown. The calculation of the values is based on the formulas and factors presented in Figure 7. The class ML stands for moderate requirements on material quality and heat treatment. Experienced manufacturers can achieve the requirements of class MQ at moderate costs. The ME class represents requirements necessary for a high degree of operational safety. [13]

The strength of the Ref variant is σlim,Ref = 487.10 N/mm² and lies in the range of the class MQ-c so the strength of the material is already in the upper levels of the ISO 6336 - 5 classification. The variants steel 1 and steel 2 have strengths of σlim,steel 1 = 527.35 N/mm² and σlim,steel 2 = 521.97 N/mm². These values correspond to class ME and represent a significant increase in the nominal stress number. Since all material variants were manufactured and heat-treated in the same way, the increase in load carrying capacity is due to the improved material cleanliness. The level of the steels with high cleanliness corresponds to the class for the highest demands on the material quality ME of the ISO 6336 - 5.

In conclusion, it can be stated that the higher cleanliness of the material steel 1 leads to an increased tooth root load carrying capacity in the tests compared to the reference material Ref. A further increase in the material cleanliness does not result in a further increase in the load carrying capacity, but does reduce the test scatter. The service life of a component can thus be predicted very precisely for the material variant steel 2, since the fatigue strength value is subject to less uncertainty. In the design, the safety factor can thus be reduced and the power density additionally increased.

7 SUMMARY AND OUTLOOK

In standardized testing such as the pulsator testing for gears, it appears possible to distinguish between different steel performance levels. The investigations carried out show an increase of the fatigue strength of approximately Δ = 8% for the clean steels. For the reference variant, the fatigue strength is already high with a value of σlim,Ref = 487.10 N/mm². However, with clean steels, the distinction between the clean steel 1 variant and the ultra-clean steel 2 variant is more difficult to determine. Other limiting factors, including the surface quality and sometimes the test itself, can make these differences less obvious. One aspect that is apparent from the pulsator testing is that the scatter in material behavior decreases with improved cleanliness. From a statistical point of view, regarding the confidence intervals, the clean and ultra-clean variants have the same fatigue strength for the chosen test parameters. For a different residual stress state at the surface or an improved surface quality, it is assumed that the differences between the variants will increase due to changing failure modes. Regarding the classification of the ISO 6336 – 5, the investigated variants can be classified in the top range of MQ-c and ME.

In a continuation of this investigation, further analysis on the gears is to be done to enhance the understanding of the residual stress state, hardness profiles, and deeper examination of the failed gears.

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WHY
SELECTIVE
PLATING
STOPS GEARS FROM
GRINDING TO A HALT
Gears are a crucial part of many machines, and if they wear and corrode beyond repair, then it can be a costly expense to replace them. Brush plating can help prevent gears from being damaged, and the process can be used to restore worn or corroded gear components.

By MARK MEYER

When problems occur with gears, maintenance engineers know how much of a headache they can be to fix. During the manufacturing stage, despite all the modern machining centers, parts can end up undersized, whether that’s in the bore, the teeth, or the shaft. The extent of these dimensional defects is usually small, but the cost of remanufacturing the entire part would be prohibitive.

When in operation, gears are often subjected to harsh environments — with wear and tear from corrosion or day-to-day running in dusty conditions being common problems. With small gears, the capital cost of replacing these components in many cases will be tolerable. However, in larger equipment, such as in earth moving, industrial, or marine machinery, it is not just the capital outlay that maintenance engineers must factor in. Not only is the capital cost of larger gears much higher, but there is also the downtime from taking machines out of service that can make the true cost of replacing these components extraordinarily high.

Indeed, downtime is one of the biggest costs that any business can face. In Britain, the impact of machine downtime is costing manufacturers more than 180 billion pounds every year (The Manufacturer). The study, conducted by Oneserve, found that 3 percent of all working days are lost annually in manufacturing due to faulty machinery; 83 percent of those surveyed also said they replace machines at least once a year, no doubt carrying huge financial implications and operational costs to do so.

With that said, it is crucial that maintenance costs are kept down, so machinery components such as gears can be kept in service as long as possible, and if needed, they can be repaired quickly and effectively.

THE SELECTIVE ELECTROPLATING PROCESS

Selective electroplating, such as the industry leading SIFCO Process®, is a proven, efficient, and economical way of performing surface treatment repairs. The SIFCO Process® is a portable plating method used to enhance, repair, and refurbish localized areas on manufactured components.

The process uses fundamental electrochemical principles. An electrolyte solution, which contains ions of the metal to be deposited, is introduced between the negatively charged part to be plated and the positively charged plating tool, or anode. A portable powerpack provides the required direct current and allows precise control of amperage, voltage, and plating time for high quality and accurate plating results.

The circuit is completed when the anode touches the surface of the part to be plated. A suitable wrap around the tool provides a reservoir to evenly distribute the electrolyte. The current causes the metal ions in the electrolyte to bond with the surface of the part and build up the plating layer. The result is a highly adherent and dense metal plating. The metal or alloy to be deposited can be chosen from more than 50 different solutions, which allows the plating material to be tailored to the desired properties of the plating.

Selective electroplating is a proven, efficient, and economical way of performing surface treatment repairs. (Courtesy: SIFCO ASC)
be prohibitive to make the entire part from a more resistant material.

When assessing parts for repair, it is always important to consider the size and location of repair required and how much material needs to be plated, as this will determine whether selective plating is appropriate or not.

One example that illustrates two types of repair on the same part was the repair of a pinion gear of a dragline excavator used in surface mining.

**REPAIRING A DAMAGED PINION GEAR WITH SELECTIVE ELECTROPLATING**

Working with large gear manufacturer and repair specialists Horsburgh & Scott Co., SIFCO ASC’s brush plating solutions were used to repair two defects on the 16” diameter by 5” long bearing journal of this gear. They were caused by a seized bearing that damaged the seat and also created a gouge during the removal of the bearing.

The first defect was a 0.030” deep gouge measuring 0.75” wide and 12” long, while the bearing seat was 0.012” undersize after clean-up.

This was considered a good selective plating application because the groove was relatively shallow and could be quickly filled with copper using a 100 percent tool contact. The undersize condition required only 0.006” thickness of nickel.

Welding to fill the defect was rejected as an option due to the heat and associated structural changes in the metal associated with the welding process. Meanwhile, machining the entire diameter to remove the defect would have made the diameter 0.060” undersize, and so this was ruled out as well, as it would have made the journal too impractical for plating at such a high thickness.

For the resize deposit, the part required a deposit of approximately 30 Rockwell hardness. Nickel was chosen to meet that requirement.

First, the gouge was selectively filled with copper to bring it back to the overall OD. The bearing journal was first plated with 0.001” thickness of copper and then masked for the defect repair. A plating anode was used to cover the full length of the gouge, which shortened the plating time. The defect was filled with three layers of copper and hand finished between layers. The final layer was dressed flush with the OD.

Once the gouge defect was repaired, the entire OD was brought back to size by plating with 0.006” thickness of nickel. After the repair of the two defects, the journal was as good as new and ready to receive a new bearing, making the excavator ready for action once again.

**BUILDING LAYERS WITHOUT COMPROMISING GEAR STRENGTH, DURABILITY, AND SPECIFICATION**

Gears used in large applications are expensive to replace if damaged or worn.

In many cases, brush plating can return the gear components back to their nominal specification, and in some cases, even exceed the performance of the original material.

With brush plating, a frequently used plating material for repairs is nickel. Other materials such as cobalt are also popular, while certain alloys such as nickel tungsten alloys or nickel cobalt alloys can provide their own unique properties. With proper selection of deposition parameters, the grain structure of the nickel can be influenced to yield the desired properties such as hardness and corrosion resistance, thus enabling it to withstand the day-to-day operation that gears are subjected to.

For gears, the most common repairs are shafts, bearing journals, and bores. In the right circumstances, localized damage to teeth may also be considered. For gears used in a corrosive environment, the bores and outside machined surfaces that cannot be painted are also plated when new to provide corrosion resistance.

**ON SITE SELECTIVE PLATING BRINGS DOWN COSTS**

Another consideration that engineers face with repairing gears is how the maintenance can be achieved while incurring the least cost. These can start rising through directly associated expenses such as shipping the gear to a job shop, disassembly and reassembly of the
gear, and the repair itself. Then there are indirect costs to factor in, such as disruption, downtime, and loss of productivity.

Often, the gears that are too large to simply replace are also too large to easily disassemble and too impractical and costly to ship to off-site job shops for repair. Downtime is also prolonged, due to the need to take the gear and machinery apart, and wait for it to be repaired, sent back, and re-assembled.

Brush plating overcomes these obstacles. In many cases, technicians can assess the damage to the gears and make the repairs on-site. This was the case for the pinion gear repair on the dragline excavator. Of the repair, Dave Niederhelman, chief metallurgist with Horsburgh & Scott Co., said: “SIFCO ASC is a well-established partner of Horsburgh & Scott and their ability to work on-site is highly attractive. Over the years they have helped us to find the most efficient ways to repair and maintain our customers’ equipment, and this has added up to thousands of dollars, hours of downtime, and manpower time saved.

“In this application, the SIFCO Process® has extended the working life of the gear and improved the failure rate due to the nature of the nickel coating on the journal. The cost of manufacturing and material to replace the gear would have been extortionate in comparison, as well as causing weeks of downtime.”

**BRUSHING ASIDE GEAR REPAIR ISSUES**

While simple on the surface, gears are complex components, and once they start to wear and tear while in service, it can be an even more complex job to repair them.

Repairs must be well considered and executed correctly, and the gear must remain strong enough to handle the day-to-day operation or setting that it is in. Otherwise, it can cost even more than the initial cost of refurbishment when factoring in downtime and lost productivity costs.

This is where brush plating offers a versatile, flexible solution for many gear repair jobs. Along with being able to make repairs on-site, the SIFCO Process® of selective electroplating is highly effective. The precise nature of selective electroplating means it can apply the plating material accurately and requires very little time to set up. Unlike with alternative repair methods, post-machining or frequent treatment of the gears is not required because plating can be done to size. Due to the low temperature of the process, there is no risk of changing the structure of the base material and, with that, its properties.

**ABOUT THE AUTHOR**

Mark Meyer is the sales manager for North America at SIFCO ASC. For more about SIFCO ASC and its selective electroplating solutions, please visit [www.sifcoasc.com](http://www.sifcoasc.com).
COMPANY PROFILE

SOLBERG MANUFACTURING

AIR FILTRATION & SEPARATION EXPERTS

Oil mist eliminators. (Courtesy: Solberg Manufacturing)
Solberg Manufacturing creates quality filtration solutions in most industrial market segments that can improve the performance and longevity of critical machinery, including vacuum pumps, blowers, fans, compressors, and engines.

By KENNETH CARTER, Gear Solutions editor

Whether a company’s essential equipment takes up a table top or fills a cavernous production facility, its inner rotating components need protection from airborne contaminants. Equipment that does not have the proper filtration at best will not work properly, and, at worst, will break down completely, causing work delays and a dent in the company’s bottom line.

Solberg Manufacturing’s broad line of filtration and separation products helps ensure equipment is protected and work environments are clean and safe.

BREATHERS FOR GEAR BOXES, HYDRAULIC TANKS, AND LUBRICATION SYSTEMS

In a lubrication system for rotating equipment, a reservoir holds oil for circulation through the system. The reservoir must be vented to keep excess pressure from building up and causing seals to leak, according to Clint Browning, vice president of Marketing and Sales for Solberg Manufacturing.

“As the oils in the hydraulic tank or rotating equipment’s gearbox change temperature, the system needs to breathe,” Browning said. “When oil gets hot and pressure begins to increase, the system needs to vent out. When oil cools down, the system pulls air in. As the system breathes, our filters allow air to transfer in and out of the system, keeping harmful particulates from entering and oil mist from escaping into the environment.”

“Our breather products allow a lubrication system or gearbox to vent, and in some cases, operate under a slight negative pressure,” he said. “In either case, we also capture any oil mist that’s in the vented air stream, reclaim it, and return it to the lubrication system so oil and oil mist are not exhausted out into the environment. If not captured, oil mist can condense on floors, hand rails, and other surfaces within a facility, creating hazardous and unsafe working conditions.”

VACUUM FURNACES

Solberg also works with vacuum furnace manufacturers and users, according to Browning.

“We manufacture a full range of inline vacuum pump filters designed to protect pumps from harmful contaminants given off during metal melting and refining processes,” he said. “The heat-treat furnaces use vacuum to remove impurities from the metals, and our filters keep abrasive particles that can damage pump internals or degrade oils out of the pumps.”

One of the specific lines Solberg makes for vacuum furnace applications is its WL series, according to Browning.

“The WL series is a specialty filter for medium-high vacuum applications designed to offer superior protection and durability in demanding applications,” he said. “We can accommodate a variety of application parameters ranging from high temperature to particulate sizes as small as 0.12 micron. We can integrate options into the filters including oversized clean-out ports and reverse pulse self-cleaning technologies.”

Through protecting its customers’ equipment, Solberg is helping ensure its customers’ critical processes are up and running. Browning stressed that Solberg operates on guiding principles that always keep the needs of the company’s customers as a top priority.

“We take care of the customer,” he said. “Our customers tell us that they do business with us because we’re highly responsive and stand behind our products. We are committed to making sure the customer experience is exceptional all the time. That’s really what sets us apart.”

DRIVEN BY EXPERIENCE

“All we do is look for different problems to solve, and this is how we have fun at work,” Browning said. “We have a standard product line, but realize a one-size-fits-all philosophy doesn’t work for every application we encounter. One of the aspects of our sales philosophy that endears us to customers is our willingness to customize and create unique products and solutions for their applications.”

Solberg is very willing to accommodate special requirements from customers, whether it’s a simple modification of connection size or something highly complex that involves custom design.

Offering that final solution can mean a lot of leg work for Solberg’s Sales and Engineering teams, according to Browning.

“We ask lots of questions to understand an application, because understanding the details gives us and our customers the best chance at success,” he said. “Our sales team may be the initial point of contact, but the process moves on from there to involve those with expertise. It may be one of our veteran sales people for....
a particular industry, or our Technical Sales and Engineering staff. Even the owners are known to get involved on specialty projects. We use a collaborative process and pull in the right resources when needed. We make sure the customer has every bit of our expertise at their disposal when developing the solution that’s right for them.”

This customer-centric philosophy has allowed Solberg to launch multiple new product lines into many different industries, according to Browning.

“We’ve introduced more than 100 new products over the last 20 years,” he said. “I think our willingness to work with customers to create custom solutions — and the commitment to doing it until we get it right — leads to these product launches, which has driven the growth and development of our employees and our business.”

50 YEARS IN THE MAKING
Solberg was founded in the late 1960s by Charles Solberg Sr., who was selling electrical motors to compressor manufacturers and distributors.

“A customer said to him, ‘I don’t need any motors, but I sure could use something that makes this thing quieter,’” Browning said. “From there, Charles Solberg Sr. went on to create what we know as a filter silencer.”

Over the years, the company expanded and moved into different product lines, including a variety of filtration and separation technologies for particulate, liquid, aerosol, and vapor removal from air streams.

Through that expansion and diversification, Solberg has grown globally and now has 22 locations around the world with more to come over the next five years, according to Browning.

“Our product lines have evolved as we’ve gained exposure to different applications, processes, and industries over the years,” he said.

Additive manufacturing and 3D printing are areas that Solberg is supporting with both existing and newly developed products as well.

“It’s a brand-new technology, and we’re well suited for this market,” Browning said. “We’ve got standard product lines that attract people because they can buy something right off the shelf, put it in line, and they’ve got an instant proven solution. But there are those that require much more complex solutions for their systems, and we’re working with industry leaders in that space to deliver exactly what the market needs.”

SPECIALTY AREAS
As the company grows, Solberg will continue to focus on specialty areas.

“I anticipate we’ll continue to develop new products and new ways of tackling filtration-related issues for the heat-treat market and gearbox breather market,” Browning said. “We’ve got some straightforward and simple solutions. As the breather market grows, we’ll continue to grow right along with it. We separate and differentiate ourselves through service, product quality, and reliability.”

Browning stressed that Solberg’s devotion to product quality and reliability boils down to the company’s mission statement: We partner with our customers, colleagues, and suppliers to help them innovate and discover new possibilities.

“For us, this statement is very powerful,” he said. “Those 16 words give us great purpose. One thing that we feel differentiates us is that, not only do we focus on helping our customers to be successful, we focus on helping our suppliers and colleagues as well. Solberg believes that continued focus on cultivating these critical relationships is the secret to their success.”
WL Series vacuum filters are used for medium- to high-vacuum applications. (Courtesy: Solberg Manufacturing)
Koike Aronson presents newest waterjet cutting technology

Koike Aronson Ransome—a global leader in cutting, welding and positioning equipment—has released the company’s newest waterjet cutting machine, the ShopJet™. This machine will accommodate a wide range of cutting applications at an accessible cost.

The ShopJet waterjet cutting machine from Koike uses the same foundational tabletop design as the ShopPro™, the company’s renowned plasma/oxy-fuel cutting machine. The ShopJet is ideal for cutting applications like stonework and countertops, ferrous and non-ferrous metals up to two inches thick, shearing of textiles, and more. With a repeatability of 0.0015 inch, the ShopJet consistently delivers clean and precise cuts.

This machine is built with a direct drive helical rack and pinion to provide ultimate performance. The ShopJet has a smaller footprint than other machines in its class, allowing it to fit into shops of all sizes. Additional features include FlashCut Pro Series Waterjet Software, KMT waterjet systems and an Integral Diamond Eductor cutting head. This machine can be equipped with various pump options, based on the needs of the individual customer.

All Koike machines are manufactured in the United States, allowing for accessible service, parts and support. Each machine comes with an industry-leading two-year warranty and free phone support for life. Koike works collaboratively with their customers to find the right solution with customized machines and services.

MORE INFO    www.koike.com

Automatic coolant delivery system boosts CNC production

168 Manufacturing, which designs and develops practical automation technologies for CNC machine shops, has released its FullShop™ Automated Coolant Delivery System, which delivers properly mixed coolant to multiple CNC machines without human intervention.

The FullShop system monitors coolant usage at the machine tool sump and automatically replenishes the coolant before it runs low to keep the spindles spinning around the clock. This easy-to-install turnkey system consists of a centralized pumping station, controller, distribution manifolds, and a small sensor that drops into any machine tool sump to report level and temperature.

With its compact footprint and modular design, a single FullShop system automates shops with up to 120 CNC machines and could deliver up to 5,760 gallons of coolant a day. It also enables lights-out manufacturing, allowing machine shop owners to run high-volume jobs unattended overnight.

Features and benefits of the FullShop system include:

- Per machine concentrations with closed-loop flowmeter assurance.
- Internet-enabled features like email alarm notification, data reporting, remote operations, and teleservice.
- Advanced HMI for added insight into your operation.
- Modularity, allowing a single coolant system to handle up to 120 CNC machines.
- Rugged design intended for years of service—improving throughput and profitability.
- Small footprint: 50 x 60 inches.
- Remote distribution nodes for clean coolant delivery.
New software provides a solution for non-circular grinding

Powerful new software from NUM provides manufacturers of CNC cylindrical grinding machines with an elegant means of adding non-circular grinding capabilities to their products — without incurring significant development time and cost.

Non-circular grinding is used in a wide variety of automated manufacturing applications, such as the production of camshafts, crankshafts, cams, and eccentric shafts. However, it is an extremely complex task, because the non-circular contour leads to constantly changing engagement and movement conditions between the grinding wheel and the workpiece.

NUM has now added non-circular grinding functionality to its NUMgrind cylindrical grinding software, which forms an application-specific element of the company’s renowned Flexium+ CNC platform. It is fully compatible with other Flexium software, from release 4.1.20.00 onwards.

NUMgrind is specifically designed to simplify the creation of G code programs for CNC grinding machines through the use of a highly intuitive graphical human machine interface (HMI), conversational-style ‘fill in the blanks’ type dialogues or a combination of the two.

Unlike conventional CAD/CAM workstation tools for generating CNC machine tool control programs, NUMgrind is intended for use in the production environment. It enables shop floor personnel to handle everyday machining tasks very quickly and efficiently — and the work can be easily shared amongst several people and several machines. The NUMgrind HMI can of course also be run on an office PC. Application-dependent projects, and the corresponding ISO part programs, can be created, tested with NUM’s Flexium 3D simulation software and transferred to the targeted machine.

The operator simply determines the sequence of the grinding process via the HMI and enters the necessary data for the grinding operations, grinding wheels and dressing operations in the dialogue pages. Programming is further simplified by the fact that the HMI is supported by a comprehensive library of predefined shapes, which includes eccentric circles, hexagons, pentagons, polygons, Reuleaux triangles and rhombi. The CNC program is then created completely automatically and stored in an executable form.

The closed shape of the workpiece is defined in the XY plane. However, grinding is performed by interpolating or synchronizing the X axis with the C axis (workpiece spindle). Axial movement in the Z axis can also be accommodated, by means of oscillation or ‘multi-plunge.’ The Flexium+ CNC system’s NCK transforms the contour from the XY plane into an XC plane, and calculates the corresponding compensation and in-feed movements, taking the grinding wheel diameter into account. The speed profile is also transformed, so that the speed and acceleration are automatically adapted to suit the physical attributes of the machine.

NUM is one of the world’s leading suppliers of CNC solutions for machine grinding. Its expertise covers every aspect of the discipline,
KISSsoft ramps up engineering and consulting

Engineering and consulting are important components of KISSsoft’s range of services. Especially during these times, when there is enough work but sometimes limited capacity, the company is able to support customers in every phase of project development. By determining the best possible solutions and consulting with experts, KISSsoft can work together with the customers to ensure that the desired product is completed as efficiently and cost-effectively as possible.

The KISSsoft company has ample experience in virtually all types of gearings and different systems such as agricultural transmissions, wind-turbine gearboxes, EV vehicle drivelines, plastic gears, and planetary arrangements. Over the last decades, several hundred projects have been conducted by company experts. Designs range from gears with a diameter less than 1mm to gearboxes with a power rating of more than 6 MW.

Due to KISSsoft’s close collaboration with other Gleason entities, local and international universities, and plastic material suppliers, KISSsoft offers a unique set of skills. The team of engineers with background and expert knowledge in bevel, planetary, worm, crossed axis helical, beveloid, and face gears is available to provide targeted services. (Courtesy: KISSsoft)

MORE INFO www.kisssoft.ch

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MORE INFO www.kisssoft.ch
The four critical requirements for tool holders are clamping force, concentricity, rigidity, and balance for high-spindle speeds. When these factors are dialed in just right, there’s nearly no chance of holder error and considerable cost reduction is achieved thanks to longer tool life and reduction of down-time due to tool changes.

Easier said than done, so experts from BIG KAISER have shared some of their best, quick-hitting advice for top tool holder performance in different situations.

1 BALANCE HOLDERS AS A COMPLETE ASSEMBLY

Long-reach milling has some unique demands; when setting up this type of job, always balance tool holders as a complete assembly. While many tooling providers pre-balance their holders at the factory, it’s often inadequate, especially for long-reach applications.

2 HOLDER DAMAGE CAN GO FROM BAD TO WORSE QUICKLY

Wear-and-tear on holders can be costly in the end, but there are ways to protect against it. Inspect and care for your holders. Trauma on a holder or spindle — dings, scratches, gouges, etc.— can magnify quickly. One bad holder can spread its problems like an illness. If you’re seeing disruptions like these on your holders, get them out of the rotation.

3 THE RULE OF THUMB ON HOLDER DIMENSIONS

Looking for affordable ways to avoid vibration? Start by opting for a holder with a combination of the largest diameter and shortest length possible.

4 RIGIDITY CAN HARM TAPPING OPERATIONS

What many don’t realize about tapping operations is that a perceived strength of collet chucks — their rigidity — can actually be detrimental. Rigidity does very little to counteract the dramatic thrust loads imposed on the tap and part, exacerbating the already difficult challenge of weathering the stop/reverse and maintaining synchronization.

5 BALANCING IS CRUCIAL TO 5-AXIS MACHINING

Five-axis machining introduces a whole new set of tooling challenges. While important in any type of machine, balance may be of most importance in full 5-axis work. A well-balanced holder helps ensure the cutting edge of the end mill must be consistently engaged with the material in order to prevent chatter and poor surface finish quality.

6 CONSIDER SPINDLE SPEED REQUIREMENTS WHEN CHOOSING BETWEEN SHRINK-FIT AND HYDRAULIC HOLDERS

If you have to choose between shrink-fit and hydraulic holders in a long-reach application, consider the spindle
speed required. If a hydraulic chuck exceeds its rated RPM, fluid is pulled away from the holder's internal gripping gland, causing loss of clamping force. But when used within its recommended operating range, a hydraulic tool holder offers superior runout and repeatability. On average, a good shrink-fit holder has about 0.0003-inch runout, while a hydraulic chuck offers 0.0001 inch or better.

7 DON'T OVERLOOK THE TOOL'S EFFECT ON HOLDER PERFORMANCE
The cutting tool affects holding ability more than most machinists and engineers realize:

a: Polished shanks reduce friction, as does the cleanliness.

b: Oil and coolants reduce gripping power.

c: Cutter shank roundness is often assumed to be close enough to perfect to ignore, but in reality, a 25-millionths tolerance is necessary for high-speed performance.

8 NOT ALL DUAL-CONTACT TOOLING IS THE SAME
Anyone in the market for BIG-PLUS dual-contact tooling should consider this simple statement: Only a licensed supplier of BIG-PLUS has master gages that are traceable to the BIG grand master gages and have the dimensions and tolerances provided to make holders right. Everyone else is guessing and using a sample BIG-PLUS tool holder as their own master gage—a practice that any quality expert will advise against.

Look for the marking: “BIG-PLUS Spindle License BIG DAISHOWA SEIKI.”

9 YOU MAY HAVE A BIG-PLUS SPINDLE AND NOT EVEN KNOW IT
You'd be surprised how often BIG KAISER hears from its certified regrinders or engineers in the field about folks that didn't realize their machine had a BIG-PLUS spindle.

A smart damper for finish boring and milling applications incorporates a passive damping mechanism that functions as a counter action by way of high resonance friction action. This minimizes effects of high-frequency oscillations, absorbing vibrations and allowing higher machining accuracy. The system's modular design allows customers to customize and manage setups. (Courtesy: Big Kaiser)
— the message can get lost in the supply chain or during the sales process.

The easiest way to know if an interface is BIG-PLUS is to place a standard tool into the spindle and see how much of a gap there is between the tool holder flange face and spindle face. Without BIG-PLUS, the standard gap should be visible, or about 0.12 inches. If it is BIG-PLUS, the gap is half of this amount, or only 0.06 inches. These values change depending on 30-taper, 40-taper, or 50-taper sizes, but the gap is visibly less than usual.

10 USE POSITIVE OFFSETS DURING HOLDER SETUP

It may be how it’s traditionally been done, but touching off holder assemblies in each machine to establish negative tool offsets based on the zero-point surface — the vise, machine table, workpiece, etc. — is not the most efficient process. The experts at BIG KAISER think the choice is pretty clear: Adapting machines to a single pre-setter so they can receive positive gage lengths is superior to using all types of machine-specific negative offsets.

This is a change to “the way things have always been done” that can be met with some resistance, but in the grand scheme of things, it’s a relatively small and simple step that makes life much easier. It’s a relatively low-cost opportunity to introduce more standardization of holder setup to the shop floor.

Holders are the bridge between the machine and the part. That’s a lot of pressure — literally and figuratively. It’s important to select, care for, and use holders careful-

ABOUT THE COMPANY

From collet chucks to coolant inducers, BIG KAISER is North America’s source for standard-bearing tool holders that guarantee high performance. For more information, go to www.bigkaiser.com.
“I don’t always buy workholding but when I do, I prefer König”

“Stay Productive, My Friends”
WHY PRECISION CLAMPING MATTERS

How a workpiece is held throughout its manufacturing process is key to achieving the desired result.

By KENNETH CARTER, Gear Solutions editor

Precision clamping devices can be custom designed for applications and can vary over a wide range of industries. David Jones, precision workholding manager for Emuge Corp. in West Boylston, Massachusetts, talked with Gear Solutions about the importance of workholding and designing precision clamping devices.

What role does precision workholding have at Emuge Corp.?
We are a precision cutting tool manufacturer, first and foremost. We began offering workholding solutions because we needed a better way to hold tools and parts in the machining process. Originally starting with our German parent company, EMUGE-FRANKEN, we are one of the leading workholding solution manufacturers worldwide, especially for demanding, challenging applications. We have a lot of collective knowledge — in fact, EMUGE-FRANKEN is celebrating its 100-year anniversary this year.

I make sure that our field salespeople have the workholding solutions they need in their toolbox and also ensure communication with our engineers in Germany is concise and accurate. Sometimes, there’s a little bit of a different way of thinking engineering-wise in Europe compared to over here, so we have to be able to accurately relay that information. I’m basically a facilitator, if you will, of technical details. There are a lot of T’s to be crossed and a lot of I’s to be dotted. We sometimes call it “attentive engineering.”

A finished part’s dimensional accuracy is directly proportional to the clamping device and its application — what are the challenges?
What that means is you need to hold the workpiece so it doesn’t move in the operation being performed. And I think that’s something that most people agree with — you don’t want the part moving once you put a tool to it.

It can be a little tricky from there, in terms of what the workpiece has available for areas to hold on to — geometrically speaking. In other words: Is there enough surface to hold the part, or is there a very short surface area available?

If you don’t start with accuracy, you’re going to lose even more accuracy moving forward.

You want to use as much of an available surface as possible to average out the tolerance. When holding to a turned surface, I can get a good, nice grip. When holding on to say, a cast surface, it is challenging because it may have some taper to it, and it is a rough surface to begin with. I want to hold on to as much of that available surface as possible in order to average out those highs and lows of the casting.

How does this procedure relate to gears?
Emuge workholding solutions for gears include hobbing, shaping, shaving, and inspection operations— grinding as well. And for many of these processes and with most round gears, say in a transmission for a car, you’re holding that gear in the bore. Generally, you’re going to mount that bore somewhere on a shaft or drive. And the tolerance goes from the bore to the pitch line and its teeth on the gear. What you want to do is hold that bore and make it your primary datum for the operation or operations being performed. Some of these operations, such as hobbing the teeth, may call for very high transferable torque values. So, in some cases, a little extra tailstock or axial face pressure is applied to the gear in order to overcome these higher torque values and keep the gear stable during the cut. In this instance, the geometrical relationship between the gear bore and the
faces is very important. Remember, you want the bore to be the primary datum, so if one of the gear faces has excessive runout to the bore of the gear, it may strongly influence the final part quality.

If there is excessive runout to the bore of the gear, you would do something different with that face, including not having it touch a solid surface but having it touch a wobble plate of sorts. In a gear, if that bore doesn’t run back to the teeth, it’s bad news. That’s why that bore-to-face geometric tolerance needs to be good to begin with — maybe a few more pennies in the customer’s bank, if you will, to get a good part out the other side.

Basically, if you hold that part and the face has an influence on your geometric tolerance, the gear teeth are not going to run out to the bore when you’re done.

**What’s the difference between the final assembly datum and the preferred workholding datum?**

Final assembly datum is when you have all components assembled, and now you’ve got to mount that assembly to a flange or whatever device it’s going into. That assembly has accuracy to the surfaces that it’s going to mate to. If that assembly is made up of several machined components and the final assembly has that 10-micron runout to a taper mounting face, how accurate do the components need to be that make that assembly carry a 10-micron runout?

If I have 10 building blocks and, at the end, I need to have five to 10 microns runout, then each of the 10 individual building blocks has to be a portion of that tolerance. In essence, it has to be that much more accurate than the assembly is, because as you start to add those blocks together, that tolerance starts to build. That’s why you really want a preferred workholding datum so that the outgoing component and subsequent assembly are as accurate as possible.

The machining surface should have a datum that goes back to where the workholding is, if possible. And that’s something engineers should think about when they’re designing a part.

**Why is having the clamping locations with tolerance important? And how does it help produce a better workpiece?**

If I’m going to hold something from say, a cast surface, it is inherently going to be less accurate because that tolerance on the cast is not as accurate. For example, when turning a round bar and half of it is cast, and the other half is machined, when holding that round bar on the cast end, some inaccuracies result simply because of the less-than-desirable cast surface. Now, if you hold that same workpiece on the machined side, then you automatically have more surface contact to the workpiece, which affords options such as higher transferable torque.
values for your machining process or even perhaps less workholding force as well.

**What’s wrong with delaying processes to ensure accuracy until the final operations?**

What you put into something is what you get out, and if you don’t have good tolerances going in, it is hard to compensate with machining processes later on. In some cases, it can be done with slowing down the tooling pass and making a light finish cut. But time is money, and we want to produce parts as accurately and efficiently as possible. A good tolerance is important from the beginning, because you cannot expect to put a bad workpiece into a precise workholding device and still achieve optimal results.

Generally speaking in a turning operation, the workpiece turns, and the tooling stays still. In a milling operation, the tooling moves, and the workpiece stays still. Both need to be accurately held, so the workholding processes are critical from beginning to end of the machining process. And the manufacturer may not be using a precision workholding device, designed and built like Emuge provides. It may be something as simple as a three-jaw chuck in the lathe, but it still needs to be accurate. That first cut is going to potentially set the tone for the rest of the manufacturing process, so you definitely don’t want to wait until the end to address accuracy issues.

**What other issues need to be addressed when working with those higher tolerances?**

Repeatability is key. That’s not only for your workholding that has been designed and built to the tolerances in a drawing, but also the blanks being used. When blanks are received from their supplier, and the tolerance is different than the device it is designed for, there may be repeatability and consistency issues. That repeatability is important because that keeps scrap rates down.

It can be a perpetual cycle. For example, when a workpiece is not accurate, and you are holding on a bad surface, then you can have chatter and excessive tooling wear. Also, for example, there is wear to the workholding device because of variations resulting from lot-to-lot differences in tolerance. To compensate, the workholding device has to stroke farther and farther.

It’s like a paperclip; you can only bend it so many times. A paperclip is designed to do one thing. If you bend it the other direction so many times, it’s going to break. And that goes for your tooling, too. If the clamping element in your workholding has to move farther because of a bad tolerance lot of blanks, then it is clear you will have additional wear and, over time, a potential failure of the element.

**How does insufficient rigidity compromise a workpiece quality?**

I like to use the analogy of a pencil. Why do we hold a pencil down at the business end where the lead is and not at the eraser? Because when we hold it at the eraser, there’s no rigidity. The rigidity is down at the business end where the lead is. You don’t even have to hold it tight, but you get much more rigidity by holding it close to where the business end is being operated. If you think about it as a cutting tool or milling cutter, same thing — you want to hold that cutter down there where the business end is, not way up on the shaft. It’s the same for workholding. You want to get as close to the action
as possible. It simply adds rigidity.

How does the geometry of a workpiece dictate the end-stop location?
The end stop is basically where the workpiece gets loaded into a workholding device, and physical metal-to-metal stops, so it indexes the workpiece at a specific location. At that point, the actual clamping pressure is applied, and the workpiece is held. Many of our designs have a slight axial pull in the clamping cycle, which physically pull the workpiece toward the end stop, helping to achieve a very rigid design. If the rigidity is not present, issues such as tooling wear and surface-finish degradation begin to show their faces.

Conversely, if the face that’s touching the end stop is not good and it doesn’t have a good run-out to the primary workholding location, then we may not use what we call a solid-end stop, which is basically a solid piece of metal that generally has a ground surface. What we would do in this case with a bad face runout is put a wobble plate in there as a stop. We still have surface touching on the wobble end stop, but it’s not a primary location. That surface is allowed to float a little bit and find its home. So, we still add some rigidity to the application, but we limit the influence this face has on the runout of the workpiece.

What’s the purpose of the wobble plate?
We’ll use a shaft, for example. With a shaft, there is a diameter to hold on, as well as a left and right face. When loading the shaft into the chuck, one of the faces is going to go to an end stop to locate the shaft within a device.

If that face that’s inside hits the end stop and it isn’t flat or isn’t square or it doesn’t run out to the bore, then you may have a fixed runout issue in that shaft before it’s even clamped. We don’t want that to happen. If that face is bad, we will put in a wobble plate for an end stop. The wobble plate is still an end stop, and it still has some rigidity, but it lets the workpiece find its home as it’s coming through the clamping cycle, so that the clamping location is still the primary location, and this bad face had little influence. If we had a shaft, and the backside of its face was cut at 4 or 5 degrees (as an example only), it doesn’t look like a significant angle, but for workholding it is. In the end, you haven’t even put chips on the floor yet, but you already have runout issues.

What’s the importance of having a rigid workholding solution?
Rigidity is key, and that goes for almost all machining operations. Rigidity will result in better tool life, better surface finish and better machine life. It boils down to rigidity, rigidity, rigidity.
**Dillon’s custom full-grip jaws securely grip the workpiece**

Dillon Manufacturing introduces custom full-grip jaws with special heights, diameters, materials, and configuration to securely grip any workpiece. They can provide a matching serration location that is exactly perpendicular to the slots, and a solid gripping surface to provide more friction for drive, with reduced distortion. In addition, these special pie jaws can reduce and simplify set-up times, enhancing project profitability. Custom full-grip chuck jaws are made in the U.S. with industry-leading lead-times. They are available in A356 aluminum, 6061 aluminum, 1018 steel, and cast iron. This latest workholding introduction complements Dillon’s broad line of standard full-grip pie jaws, making them ideal for high-speed machining, as well as precision boring, tapping, drilling, and finishing across virtually all industries.

These wrap-around type top jaws distribute more of the gripping pressure across the workpiece, reducing part distortion. Dillon custom full-grip jaws are available in serrated, tongue and groove serrated, Acme serrated, and square serrated designs. Additional information on standard or special full-grip jaws is available on video at [www.youtube.com/watch?v=MMJKKL41jJ8](https://www.youtube.com/watch?v=MMJKKL41jJ8).

Dillon Manufacturing, Inc. manufactures a complete line of standard and custom workholding solutions including chuck jaws, chucks, vise jaws, soft jaws, hard jaws, collet pad jaw systems, chuck lubrication.

**MORE INFO**  www.dillonmfg.com

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**Big Kaiser expands jet-through chuck line for 5-axis machining**

Big Kaiser, a global leader in premium high-precision tooling systems and solutions for the metalworking industries, expands its jet-through hydraulic chuck line to include the BCV interface and additional inch sizes.

HDC tool holders are simple to use: Only one hex key wrench is needed to clamp or loosen the cutting tool, making tool changes easy without special equipment. Every HDC toolholder is guaranteed to 0.00012” TIR at five times diameter.

Big Kaiser is a worldwide leader in high-precision tooling systems and solutions for the metal-cutting industry that guarantee extreme accuracy and repeatability. Quality products are manufactured with materials and craftsmanship that enable superior performance. As a member of the Big Daishowa Group (Osaka, Japan), Big Kaiser has grown into a well-recognized global tooling provider, with manufacturing facilities in North America, Switzerland, and Japan. In addition,
Big Kaiser expands its jet-through hydraulic chuck line to include the BCV interface and additional inch sizes. (Courtesy: Big Kaiser)

Monaghan Tooling presents versatile burnishing tools

Monaghan Tooling Group offers the full line-up of Elliott Tool Technology burnishing tools, which produce a 4 to 8 Ra surface finish in one pass, thus eliminating secondary machining operations and their requisite set-up time and costs. With tooling to burnish ID, OD, ID/OD, and flat surfaces, Monaghan has the capability to handle virtually any burnishing project. By improving surface irregularities and tool marks, these easy-to-use tools also eliminate secondary machining operations such as grinding, honing, and polishing, thus cutting project costs and lead times. Fast cycle times mean that burnishing projects are measured in seconds, not minutes. Speed is coupled with accuracy, as ID burnishing tools produce accurate sizing in 0.0001” increments. Roller burnishing results in a 25 percent size improvement in steel and up to a 50 percent size improvement in high ductility materials. Burnishing increases the surface hardness through the cold working process and compressive forces. It increases metal’s resistance to fatigue and failure at stress points. These benefits make burnishing ideal for sealing or bearing surfaces, various seats, areas that require pre-stressing, tight diameter tolerances, or just areas that require good surface finishes.

Monaghan Tooling Group and Elliott Tool Technology improve upon the 100-year tradition of burnishing success with new innovations and custom tooling to suit specific project parameters. In addition to custom tooling, the company offers standard tooling for ID multi-roller burnishing, OD carbide roll burnishing, ID/OD carbide roll burnishing, and diamond burnishing. All tooling styles are easy to operate and require limited training. They are easy to maintain and repair, and common repair parts are available from a fully stocked inventory.

Video demonstration is available at www.youtube.com/watch?v=eAwqtMtzNYs.

Monaghan Tooling Group provides the world-class engineered tooling and services, including application-related consulting, to solve machining challenges. They have partnered with industry-leading standard and custom tooling manufacturers including Elliott Tool Technologies, Diatool, UC Tools, RE-AL, MK-Tools, Reamtec, and Axis to address the challenges of precision metal finishing and high performance cutting.

MORE INFO www.MonaghanTooling.com

Metal tool industry nears green, clean era using ionized, cooled air

Expensive metalworking fluids are no longer needed to cool and lubricate workpieces and cutting tools in the machine tool industry. Instead, there is now a proven green and clean method, EcoCooling, that uses only ionized and cooled air and has none of the environmental hazards and costs related to oil-based fluids.

EcoCooling is the result of long-term, interdisciplinary R&D from the same team that developed the technology behind Big Kaiser expands its jet-through hydraulic chuck line to include the BCV interface and additional inch sizes. (Courtesy: Big Kaiser)
Amazon’s ground-breaking family of front-lit Kindle devices. Now the group of scientists, engineers, and experienced businesspeople from various disciplines has developed a dry, clean, and environmentally friendly method to lubricate metal workpieces with ionized and cooled air using no emulsions.

“Workshops have wanted to get rid of fluids and many have tried to find a solution to the problem, but with poor results,” said Leo Hatjasalo, co-founder and CEO of EcoCooling. “Now we have the answer to this demand, since EcoCooling can be used even with the hardest known metals like chrome, titanium and tungsten carbides.”

The global market value for metalworking fluids is estimated at approximately $12 billion this year. It is growing steadily, with estimates for the global market value for machine tools expected to grow from $120 billion to $150 billion in five years’ time. The growth is driven, for example, by the accelerating need for components in the aerospace, automotive, and transport sectors.

“EcoCooling is based on the fact that ionized air penetrates the cutting zone and forms a dry lubricant that decreases cutting friction and generated heat, at the same time speeding up the oxide layer formation”, Hatjasalo explains. “The process is patented on all continents, and at the moment we are validating it to include all types of machine tools.”

Hatjasalo emphasizes that EcoCooling is not only a way to cut down the costs of emulsions, but also a way to improve productivity through higher cutting speed, reduced wear of cutting tools, and minimized maintenance costs.

“Since the metal chips are not contaminated by any fluids, they can also be fully recycled without cleaning,” he said. “Another big advantage is that it eliminates toxic fluid waste and fumes, in addition to minimizing CO2 emissions, since no oil is used.”

The technology makes it possible to build smaller and cheaper metalworking machines, since the EcoCooling unit is very compact.

“The unit does not need any service and it has proved to prolong the lifetime of the cutting tools significantly. The system can also be easily retrofitted to older machine tools,” Hatjasalo said.

During the past few years, EcoCooling has been successfully trialed in numerous commercial tests in demanding surroundings internationally. Now that the process has proved to give excellent results, big savings and substantially less environmental impact, the aim is to create a versatile EcoCooling product family that includes all machine tools in addition to just turning machines.

“We are also planning to integrate the system to suit different CNC machine tools and to create optimal solutions for all machine tools and workshop environments,” Hatjasalo said. “However, for that purpose we need more funding than we can raise on our own. Therefore, the next step is to find an industrial partner to help us to commercialize EcoCooling globally and to develop the ways the technology can be used.”

The patented, ionized EcoCooling air-cooling system is a completely different story, since it is aimed at eliminating the use of harmful metalworking fluids in industrial material cutting processes. The system has been industrially researched and developed since the end of the 1980s. It has been thoroughly tested in real-life processes and assessed in third-party tests and is now ready for global commercialization with the support of an industrial partner that operates globally.

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July 2020
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Woodward Inc., with more than 50 years heritage in the aerospace industry, is a leader in developing and delivering motion control and integrated propulsion systems. Much of its success can be attributed to its unique approach to applying total system solutions in meeting the needs of its customers and staying at the forefront of the industries it serves.

By MICHAEL SCHMIDT

Woodward Inc. works with leading optical metrology instrument supplier ZYGO to “tune” its manufacturing processes by leveraging precise 3D surface data. In many cases, the insight gained by using 3D optical metrology has improved Woodward’s component design, quality, and overall product performance.

Through this technology, Woodward has been able to identify key characteristics of its manufactured surfaces that result in a real differentiator in the markets it serves.

Jack Clark leads the “Materials and Surface Engineering” group as a senior scientist in the Woodward Technology Development family. Clark’s group focuses on developing surface finishing processes specific to the role of a particular component to ensure proper function, reliability, and potential cost savings. Varying materials and machining processes necessitate confirming the inspection of production lot samples quickly and efficiently to confirm that manufactured parts meet or exceed specifications. To accomplish this, the Materials and Surface Engineering Group relies on instrumentation and software that meet their stringent manufacturing demands and deliver the functional measurands necessary to control critical part performance.
3D OPTICAL METROLOGY

To meet Woodward’s exacting applications and requirements, Clark prefers to use 3D optical metrology instruments.

"Many of the advantages of 3D optical metrology start with being able to gauge the component in all dimensions, and the entire functional area," he said. "That is why we refer to 3D optical metrology as ‘areal.’ You are characterizing the entire part or region of interest (ROI), not just segments of it, as you do with 2D (linear measurement) lines. 3D optical metrology enables much faster data acquisition. Data for an entire ROI can be collected simultaneously instead of one data point at a time. Also, the measurements are more repeatable because users are including so many more data points, allowing the local part uncertainties to be a smaller percentage of the overall measurement than that of 2D."

Manufacturing processes are multidirectional. A single line profile (2D) "sees" the process from only one direction and cannot visualize the gauge-able process variations in any other dimension. The manufacturing process will vary in many dimensions, and that is why it is essential to capture all the pertinent data through the use of 3D optical metrology. 3D optical metrology can report form deviation, thickness, parallelism, roughness, leak paths, edge radii, defects, etc. all in a matter of a few seconds, with one instrument, in one set-up. This single instrument can replace two to three alternative gauges that may not necessarily report the same required functional information.

"Manufacturing is slow to change, and despite the inherent advantages of 3D optical metrology, there is still some resistance to replace legacy solutions," Clark said. "2D metrology — especially profilometry and CMM — is the standard throughout manufacturing, and the ISO and ASME GD&T and surface standards were developed around the 2D measurement methods of the day. However, times have changed, and now there are 3D and areal standards to control those measurements and allow designers to put 3D callouts on drawings."

"Effectively, manufacturing’s resistance to this paradigm shift is because of not being familiar with the tremendous advantages of 3D metrology, and a lack of understanding of the ‘function’ of the components they produce and what must be measured to ensure functional parts and assemblies," he said. "Therefore, adapting to new manufacturing methods and metrology is sluggish. Engineers and scientists in companies..."
“Many times, problem-solving and development does not come at a fast pace. When you have a solid, intimate relationship between companies, great accomplishments are produced in a timely manner to help both companies thrive.”

Knowing for sure that the manufacturing process as a whole has been characterized is vital. Not only for adherence to drawing specifications, for example, but detecting manufacturing process issues such as machine tool vibration due to a “bad bearing,” poor tool set-up, or worn cutting inserts. All these can be characterized with 3D optical metrology, and subsequently controlled by the manufacturing team.

**METROLOGY AT WOODWARD**

At Woodward, Clark specifies the use of ZYGO 3D optical metrology instruments in particular.

“The criteria for the choice of any metrology instrument is extensive,” he said. “In terms of reliability and uncertainty, ZYGO instruments are proven to produce less noisy data and are faster in data acquisition and analysis. (Data collection and analysis time is critical in automated applications.) On ZYGO instruments, long-term instrument reliability is outstanding, which results in consistent long-term results. Plus, the software is designed specifically for manufacturing applications and conforms to international standards. ZYGO is also adept at providing ‘special equipment and function’ to accommodate demanding metrological applications, part handling, and varying surfaces that can cause uncertainties in optical measurement. ZYGO’s instruments are also flexible to change over for the multitude of applications appropriate for this technology.”

Woodward uses a range of ZYGO 3D optical profilers, a Verifire™ laser interferometer, and distance measurement systems for a wide variety of applications including:

- Surface roughness and waviness.
- Flatness and parallelism.
- Height/thickness measurements.
- Edge radii.
- Component wear (life testing).
- Material porosity.
- Corrosion characterization.
- Material failure analysis.
- Coating thickness.
- Burr characterization.
- Defect detection and classification.
- GD&T, where applicable.

Woodward’s dedication to reliable metrology helps ensure critical parts and assemblies will function as designed with the reliability their customers expect.

ZYGO’s 3D optical metrology instruments also have made a significant impact on other aspects of Woodward’s manufacturing operations. For example, the company uses areal measurements to examine and analyze component wear. Combining the 3D data with in-house scanning electron microscopy information, Woodward can determine the root cause of an issue more quickly and more precisely than using either method independently. Also, the company has been able to “tune” its manufacturing processes using the 3D data. In many cases, insights into the surface quality and process control have improved Woodward’s overall product performance. The company has been able to identify key characteristics of its manufactured...
surfaces that, when monitored by 3D non-contact inspection, result in a real differentiator in the markets served.

“When we finally needed to fix on one supplier for all of our metrology needs, we chose ZYGO because the company supplies specialized optics (and other hardware) to accommodate various areas of interest and resolutions required to gauge the components,” Clark said. “ZYGO is (also) an optics manufacturer and, therefore, can design and build many instrument components that are specific to the metrological/application task. There are other metrological instrument companies that can integrate components to produce a solution, but ZYGO has capabilities to create new designs to satisfy more sophisticated customer expectations.

“Also, ZYGO’s data acquisition speeds outperform the competition, and the company’s data analysis is a crucial differentiator between instrument suppliers. Apart from adhering to the ‘standard’ algorithms to produce ‘standard’ measurements, ZYGO provides tools to segment/parse the data to produce functional results that other suppliers cannot. The metrologist must be aware of the functional characteristics that can be reported via ZYGO software tools and use that knowledge to help decide what instrument to specify for a particular application.”

“ZYGO has been and will continue to be a strategic partner in Woodward’s quest to be an example of the best use of advanced metrology,” he said. “All ‘standard’ and technically demanding non-contact applications are supplied by ZYGO. We are continuously working with their application engineers to expand the technologies offered. This close relationship allows Woodward to implement the advantages of non-contact, interferometric 3D methods throughout our manufacturing and reap the benefits of improved quality and component performance.”

“Many times, problem-solving and development does not come at a fast pace,” Clark said. “When you have a solid, intimate relationship between companies, great accomplishments are produced in a timely manner to help both companies thrive. We have individuals in both companies that are dedicated to offering feedback and requirements, interacting together and coming to a metrological solution that supports Woodward’s needs and, in many cases, expands the offerings of ZYGO.”

ABOUT THE AUTHOR

Michael Schmidt is market development manager with ZYGO Corporation. ZYGO Corporation is owned by AMETEK, Inc., a leading global manufacturer of electronic instruments and electromechanical devices. For more information, go to www.zygo.com.

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By TYLER STEELE

Technological advances over recent years have elevated metrology from being a “necessary evil” in manufacturing scenarios to enabling technologies, allowing the measurement of previously impossible part characteristics and, therefore, driving innovation across numerous industry sectors.

It is arguable that best-in-class metrology solutions are the catalyst that drive the trend toward miniaturization, higher precision, faster throughput, and fewer rejects.

As the old adage goes, “If you can’t measure it, you can’t make it,” but if you can measure to the required accuracy repeatably, then the sky is the limit in terms of producing cutting-edge parts and components.

One company operating on the bleeding-edge of precision is Cambridge Technology, based in Taunton in the United Kingdom. Cambridge Technology boasts a 50-plus-year pedigree manufacturing ultra-lightweight coated beryllium mirrors for its parent facility in Bedford, Massachusetts. These mirrors, which are integrated into laser beam steering assemblies, are used in various applications from PCB drilling to laser eye surgery.

Cambridge Technology had a goal to advance its design and manufacturing capabilities with a focus on integrating and leveraging process metrology to optimize quality control and manufacturing yields.

The exacting nature of the mirrors manufactured by Cambridge Technology has meant that over time, it has learned to partner with innovative technology suppliers to enable optimal manufacturing processes. The company chosen to help advance its metrology capabilities was ZYGO, which supplied Cambridge Technology with new state-of-the-art laser interferometer systems operating on ZYGO’s Mx™ metrology software.

This article analyzes the role of laser interferometry as an integral part of an optimized automated manufacturing process, highlighting key issues in supplier selection and providing first-hand testimony from Cambridge Technology as to how it used ZYGO’s advanced optical metrology solutions to advance innovation in product design and manufacturing process development.

ASSESSING THE ADVANCED METROLOGY LANDSCAPE

ZYGO has elevated the status of metrology to a disruptive, enabling technology with its non-contact, non-destructive 3D optical profilers and laser interferometers.

Optical metrology is extremely versatile and has an important role in the verification of quality and
design intent. Today, in many scenarios, it has become the preferred solution, benefitting from the fact that it is non-contact (meaning it can be used to measure delicate deformable components), non-destructive, fast, highly sensitive, and exhibits exceptional resolution and accuracy characteristics.

For ZYGO, however, the use of its optical metrology instruments goes well beyond quality control as its benefits are being used in advanced R&D, process development, process control, and overall manufacturing optimization.

Cambridge Technology understands that interferometry is the logical choice for the advanced characterization of its critical parts and recognized there are no other metrology solution innovators that came close to matching the level of experience and understanding of ZYGO.

**CAMBRIDGE TECHNOLOGY AND ZYGO’S LASER INTERFEROMETRY**

Cambridge Technology uses laser interferometry to measure the surface form of almost every precision beryllium mirror it manufactures, and at various stages in the production lifecycle, for a clear understanding of performance characteristics.

The company’s original laser interferometry solution was seen as being deficient in two key areas: First, it was prone to environmental vibrations, and second measurement data was stored as individual text files (or text reports), which meant it was extremely difficult to analyze.

Each unique mirror in the Cambridge Technology range required a different application, which, in turn, required specific configuration of the laser interferometer. This made the metrology operator-intensive and required technicians to manually load different masks for each mirror type and for every measurement performed, sometimes three times per mirror.

To overcome these deficiencies, the company required a metrology solution that would promote process automation and relieve manual workload pressure while minimizing sensitivity to environmental vibration, which had led to some mirrors requiring remeasuring.

The solution chosen was to replace existing laser interferometers with current generation instruments operating on ZYGO’s Mx™ software, which immediately allowed the company to realize improvements in processing times and a reduction in operator errors.

“The reduction in processing times comes as a result of our ability to customize Mx™ using scripting,” said Greg Salter, quality engineer at Cambridge Technology. “The reduced processing times for parts with multiple masks (apertures) has been a massive improvement, along with the removal of the necessity of operators from having to manually load each mask, or having to select different parts of a mask to re-analyze different apertures of a mirror.”

Using ZYGO’s Mx™ software and Python scripts, Cambridge Technology now has a database of all its parts, with corresponding tolerances, settings, and masks that are easily selectable by the operator. Tolerances can be adjusted remotely in a centrally located database by the production engineer without disrupting the production workflow.

“Mx™ loads the correct masks and tolerances for each part automatically by selecting the part number from a drop-down menu,” Salter said. “The ZYGO laser interferometer software can now automatically load and swap different masks during measurement without operator input, which means measurement is quicker, throughput of mirrors is increased, and operator errors have been substantially reduced.”

ZYGO has elevated the status of metrology to a disruptive, enabling technology with its non-contact, non-destructive 3D optical profilers and laser interferometers. (Courtesy: ZYGO Corporation)
The flatness data automatically outputs to a database for easy analysis and monitoring of each stage of manufacturing (SPC, etc.). This has already enabled us to use control limits at various manufacturing stages to ensure that the mirrors will be compliant at the end of the manufacturing process. As we continually improve our methods of manufacture, the analysis that this system provides will enable us to gradually reduce how many mirrors we inspect per batch of mirrors, whilst still providing flatness compliance.

“If a mirror is not suitable for the application for which it was intended, Mx™ can check similar mirror types and advise if we can use that mirror for an alternative application, thus reducing scrap,” he said. “Our parent company in Bedford, Massachusetts, also uses our database to control their ZYGO interferometers. It gets instantly updated at both sites simultaneously, which has, once-and-for-all, ironed out discrepancies between our methods of measurement. Our parent company also stores measurement data so we can monitor mirror performance as it progresses through manufacturing. All of this is achieved using the ability of Mx™ to allow us to customize how it works by using Python scripts to adapt to our required methods.”

It was vital that whatever software solution Cambridge Technology chose could be deployed over multiple instruments across manufacturing facilities in multiple locations to support a 24/7 manufacturing operation. Minimizing the amount of downtime and levels of operator training was a must, and this was achieved through a good partnership between ZYGO and Cambridge Technology.

“We found MX™ to be a simple, efficient, and supportable solution that minimized impact on resources and capacity within the manufacturing environment,” Salter said. “The intuitive design of Mx and its overall simplicity were hugely important, as was the help and assistance from Lambda Photometrics and ZYGO with our particular issues and requirements when it came to problems we were unsure how to overcome, especially with python scripts. Lambda and ZYGO provided an understanding of how to achieve certain goals using python (including sending us code examples), and providing us with a way of using a catalog of existing Mx™ masks on the new interferometer.”

**CREATING A ‘SET-AND-FORGET’ APPLICATION SOFTWARE ENVIRONMENT**

The use of the scripting function within ZYGO’s Mx™ software has allowed Cambridge Technology to create a recipe driven “set-and-forget” application.

“This was achieved by utilizing a database, which we designed and built to work within Mx™, containing all of the parameters required to enable the measurement of any mirror,” Salter said. “These include mask names, number of masks, and flatness tolerances. All the operator has to do is select a part number from a list (or scan a barcode on our manufacturing data pack) and Mx applies the predetermined settings for that particular mirror prescription, records its serial number, acquires and analyzes the data, and informs the operator if it is a pass or a fail in simple terms.”

“With ZYGO’s Mx-based metrology instruments, our configuration control is much more efficient, and we now have the ability to embark on a statistical process control (SPC) methodology for monitoring our operations,” he said. “ZYGO’s solutions have helped us drive our mirror yields up to 99 percent with excellent correlation between our two sites.”

**ABOUT THE AUTHOR**

Tyler Steele is the product manager of ZYGO’s laser interferometer products. Steele studied optical engineering at the University of Arizona between 2006 and 2009, joining ZYGO in 2009 as an applications engineer. In 2012, he became associate product manager for laser interferometers before taking on the role of product manager in 2015. For more information, go to www.zygo.com.
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Improved quality control for steel manufacturers from Olympus

Olympus, a leading manufacturer of industrial microscopes, is improving the efficiency of nonmetallic inclusion analysis for steel manufacturers who use Olympus Stream™ image analysis software. The newly released Olympus Stream version 2.4.3 enables users to more precisely choose the areas of the sample they wish to analyze, helping speed up the inspection process of high-purity steel. New line measurement features also ease the process of capturing multiple line measurements on a sample for cleaner reporting.

In high-purity steel manufacturing, it is critical to identify nonmetallic inclusions as part of quality control. This time-consuming process is simplified with Olympus Stream image analysis software. Along with streamlined image capture, the solution offers greater flexibility with a new option to define an area using a polygon rather than a rectangle to improve accuracy, save time and better align with the sample shape.


Some inspections require users to measure multiple features on an image, but it can be difficult to review multiple line measurements if they overlap. The updated software measurement mode enables users to simply drag lines and labels to a position where they are easy to read, creating a neat, professional image for analysis.

Olympus Stream software is now compatible with Office 365 for generating Microsoft Word, Excel, and PowerPoint reports. Microsoft Office 2010, 2013, 2016, and 2019 also work with the software.

All version 2.3 and 2.4 customers may use their existing license card for a free update to Olympus Stream 2.4.3. Customers with licenses for Olympus Stream v. 2.2 or older can purchase an update license to access version 2.4.3.

MORE INFO  www.olympus-ims.com/microscope/software

Exact Metrology provides updates on two products, adds online tutorials

Exact Metrology, a comprehensive metrology service provider, recently published informational videos on PolyWorks Inspector™ and Hexagon Romer Absolute Arm on the company’s YouTube channel at www.youtube.com/user/ExactMetrology/videos.

A new feature in the PolyWorks Inspector™ is multi-piece editing. Users can now make changes in one piece that can be propagated to other pieces. If a user has multiple pieces, they can make changes such as creating, editing features, alignments, reporting items, etc. Then, these changes can be transmitted to past and future pieces/templates, create custom propagations or just apply the changes to the current piece. After choosing the propagate option, the user sees the changes in the other pieces and/or templates including report(s) or report items.

Another update of PolyWorks Inspector™ pertains to augmented GD&T. Center point features can now be reported with more capabilities. These include circularity, flatness, perpendicularity, etc. Users can also see MIN/MAX deviations and can view the color arrow deviation tags.

An online tutorial shows how to make sure the Hexagon Romer Absolute Arm is still in calibration. First, the bar artifact needs to be placed correctly to scan it. The ideal location is centered with the main axis of the arm at a distance away where it will be just below the elbow when the arm is extended. To secure the bar, use pre-drilled tapped holes. They accept simple machinist fixturing to hold it in place. C-clamps can also be used to secure the bar to a rigid table. When doing a length checkout, only the 15 mm master probe should be used. Next, the user needs to open RDS Data Collector. Used with Hexagon Romer Absolute Arm, the software allows the operator to check the accuracy of the arm and probes and...
Vanta™ Data Viewer app simplifies XRF data sharing

The new Olympus Data Viewer app for Vanta handheld XRF analyzers provides Olympus Scientific Cloud™ (OSC) users with a central location to remotely view and share real-time analysis results from multiple analyzers.

Data handling for industrial equipment can be difficult to manage, but the Vanta Data Viewer makes it easier. Operators can use the app to remotely view data and test results from their Vanta analyzers across the world. Users can view analysis results, including the spectra and chemistry, as well as the instrument location. For greater ease of use, the app enables users to filter results by date and serial number.

In addition to providing convenient data viewing tools, this new OSC app helps Vanta users future-proof their investment as workplaces adopt Industry 4.0 practices and Internet of Things (IoT) platforms.

The OSC is a single-source platform for all connected Olympus industrial devices to provide continuously enhanced, comprehensive solutions. By signing up for a free OSC account, users with Olympus wireless-enabled devices — including Vanta XRF analyzers — can expand their instrument’s capabilities with free features, including wireless software updates, cloud access to manuals and calibration certificates, user registration, role management and more. (Available features vary by instrument. Optional wireless dongle required for Vanta analyzers.)

Users can find the Vanta Data Viewer app and browse other free and paid apps designed to ease some of their most pressing pain points in the OSC’s App Marketplace.

The OSC and Vanta Data Viewer make it easier to get the right information to the right people quickly. Each OSC tenant receives 10 GBs of free data storage, and users can upload any type of file. If more storage is required, users can add more by subscribing to a higher tier of service.

The OSC is protected by leading-edge security features and is built on the Microsoft Azure platform. Users maintain full ownership and control over their data, and Olympus does not access or share customer information.

AIMS offers cleaning tips for equipment maintenance

For most manufacturers, spring cleaning means more than just manually wiping down machine surfaces and removing waste particles. And besides, basic cleaning, lubrication, and maintenance should be done on a regular basis. Some experts say it’s about organizing paperwork and optimizing production processes. Others might advise looking for ways to digitize and streamline manufacturing flow. Companies also take this time of year to review partnerships, find ways to identify inefficiencies, save time, and communicate with personnel more effectively.

When it comes to quality and inspection practices with coordinate measuring machines (CMM), Advanced Industrial Measurement Systems (AIMS) offers cleaning tips of its own, beginning with software. Are systems up-to-date? In January, Microsoft announced it would no longer support Windows 7 operating system. If you’ve been dragging your feet about making the change, you no longer have an option. You have to transition to Windows 10. And if you are using Modus software, you will need to upgrade to Version 1.8 or higher because the previous version won’t run on Windows 10. Ensuring software is current also means having the latest performance improvements from AIMS as well as maintaining virus protection and malware software, something that is increasingly important these days.

Calibration isn’t necessarily a job reserved for spring but it is something to consider. The general rule of thumb is to calibrate CMMs one year after installation and then annually. If there are multiple CMMs, scheduling calibration for all of the machines at the same time will provide a cost savings. Annual calibration ensures accurate results and establishes documentation that can be traced to NIST standards in support of ISO requirements.

If it’s been a while since the CMM was calibrated, there are several things to keep an eye out for. Are you getting unrealistic numbers from the CMM or data it generates? When you measure a part multiple times without moving it do you get results...
that vary from run to run? A major crash is a scenario manufacturers look to avoid, but it can be the end result if regular calibrations are overlooked for too long.

Retrofitting older equipment is an effective way to upgrade operations and it might also be something to consider if you’re preparing to support pent-up demand as more business operations resume. Retrofitting an older CMM probe head like a PH10 with a 5-axis PH20 or REVO can boost throughput significantly.

Vanta Element-S XRF analyzer offers fast light-element detection

The Vanta Element-S handheld X-ray fluorescence (XRF) analyzer delivers fast light-element detection at an affordable price, joining a family of cost-effective, entry-level Vanta Element XRF instruments. The S model is equipped with a silicon drift detector (SDD) to analyze light elements such as magnesium (Mg), aluminum (Al), silicon (Si), sulfur (S), and phosphorus (P) in alloys.

Ideal for scrap recycling, basic PMI, metal manufacturing, and precious metals, the Vanta Element-S effectively measures ferrous metals, aluminum, copper, stainless steel, nickel, and gold karats. The analyzer offers clear on-screen grade ID and comparison for the light elements Mg, Al, and Si in seconds. Its SDD detector can distinguish similar alloy grades such as 303 stainless steel from 304 and aluminum 6061 or 6063 from 1100.

For greater uptime and reliability, the analyzers are IP54 rated to resist dust and moisture and built to pass a 1.2 m (4-foot) drop test (MIL-STD-810G) to help protect from the occasional drop or jostle. Other protective features include a stainless-steel faceplate and a Prolene® window with Kapton® mesh support that easily sticks on and peels off for tooless window changes in the field. The analyzers continuously perform in temperatures from –10 °C to 45 °C (14 °F to 113 °F).

Vanta Element-S analyzers come with the essential features the Vanta™ series is known for: speed, reliability, ruggedness, connectivity, and smartphone-like ease of use. Weighing a slim 2.9 lb. (1.32 kg), the analyzer is up to the challenge of all-day testing for alloy and metal analysis. Powered by Olympus’ proven Axon Technology™, the S model brings the same high-count rate and stability as the rest of the Vanta series for fast results and ROI.

Optional wireless connectivity helps future-proof the analyzer for Industry 4.0. Connect to the Olympus Scientific Cloud™ for wireless data sharing and access to convenient fleet management tools, as well as the Olympus mobile app or a network. The analyzer also has a 1 GB microSD™ card to store results and two USB ports to easily export data. For added flexibility, the analyzer is compatible with accessories such as the Vanta field stand, soil foot, probe shield, and holster.

MORE INFO www.aimsmetrology.com

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“We actually have 10 hob-sharpening machines on the floor for sharpening straight flute hobs; that’s what allows us to offer the customer quick turnaround.”

What does the Koro Sharpening Service offer the gear industry, and how long have you been in business? We sharpen only gear cutting tools. Most of the business is hobs. The changes we’ve seen in the industry over the years is the move away from vitrified grinding wheels to more super abrasives — the borizon and diamond wheels.

That’s changed the processing a little bit, so we don’t run vitrified wheels much anymore.

Our main business is Koro Industries Incorporated, which is a gear manufacturing company. We found that we could not find a timely service to get our hobs sharpened. And so we thought, “Well, there’s got to be other people in the same boat. Let’s get a hob sharpening machine and start sharpening hobs.” We bought a Mikron hob sharpener. It’s a special built machine for sharpening hobs. Once we started sharpening hobs, the business just grew from there.

Today, we actually have 10 hob-sharpening machines on the floor. That’s what allows us to offer the customer quick turnaround. This is important because hobs are expensive. It’s not like end mills or drills. You can send out a box of drills for sharpening, and you still have a box of drills that you can use for running your work. But hobs are not like that. Due to cost, you might have one or two hobs for a job, and you have to get it back right away so that the machine isn’t standing idle.

Because we have so many machines, we’re usually sharpening hobs with all the different hole sizes, anywhere from 8 millimeters up to an inch and a quarter to anywhere in between. Within this range are the common sizes we run daily.

How does sharpening accuracy affect the quality of a gear? It affects the shape of the tooth — its profile accuracy. Proper tooth geometry will ensure that the gears will run smoothly with the mating part when it’s in use.

The main factors that drive gear quality, and the things that we see that are wrong on hobs sometimes when they’re sent in for sharpening, are they’re not sharpened on center line. Also, the spacing between the rows of teeth is not right.

Say it’s a 10-flute hob for ease of discussion. The cutting edge of each row of teeth should be exactly 36 degrees from those adjacent to it. If it’s spaced incorrectly, then it changes the pressure angle of the workpiece gear, and therefore could cause it to be noisy when it’s in use.

As the gear industry has evolved, how have you seen the sharpening needs of your customers change? There are more carbide hobs being used now, so we run diamond wheels a lot more than we did at the start.

One of the other things we do is — since we’re using a special built hob sharpening machine — we have coolant capabilities, so we can keep the hobs cool when they’re being ground.

If it’s not kept cool when you’re sharpening a high-speed steel hob, it can affect the temper in the steel.

With carbide, if you get carbide hot and it cools incorrectly, it can crack.

How do you work with a customer when they come to you with a challenge? Usually the challenge is that they’ve had the tool sharpened somewhere else that didn’t have a hob sharpening machine, and so the errors that they usually get involve spacing error and center line.

We have to measure the hob first before we put it in the machine, because we want to start grinding on the tooth that has the most stock to bring it into center line and into the proper location. Otherwise, we run the danger of breaking the wheel.

By observation, which is usually just by visual inspection under the microscope, you can get a pretty good idea of how it was sharpened before and what method was used.

We always inspect prior to running the tools. If it’s a long-time customer, we know they don’t have that issue at their plant. But with new customers, we have to be a little guarded to be sure that we don’t break a wheel.

Where do you see the gear industry in the next decade and Koro’s place in that future? I think there are going to be more gears made than ever before — pretty much like anything else that’s in some kind of motion transmission.

The auto industry is changing with more and more electric vehicles, but there are still gears and worms being used. I think that as far as gear use goes in our manufacturing side, we see more worms and helical gears being used and running together than 30 years ago. And that could be because of the electronic motor control that’s available. You don’t need a gearbox on the end of the motor. The electronics can control the motor. You still need a worm and a gear to get that motion to where you need it, but you don’t need a gearbox on the motor to reduce the RPMs to get the power.

We enjoy the diversity of industries in our customer base. We see a lot more work from medical device manufacturers now than in 1965 when Koro Industries started. For the future, we see ourselves providing open gearing for medical devices while maintaining our footprint in aviation and aerospace, which is where we started. We are problem solvers at Koro, and we see ourselves continuing to establish lasting customer relationships as we help solve manufacturing problems in an ever-changing world.
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