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INTEGRATED APPROACH FOR GEAR TESTING OF HIGH-PERFORMANCE CLEAN STEELS

In this report, a test gear geometry for investigating contact fatigue strength (pitting) of high-performance clean steels is determined, and based on two well-established test gear geometries for contact fatigue test, a detailed comparison with regard to their potential of maximum contact pressure is performed.

By CHRISTOPH LÖPENHAUS, DIETER MEVISSEN, LILY KAMJOU, and ELIAS LÖTHMAN

HIGH-END COATING CAN INCREASE GEAR CUTTING PRODUCTIVITY

Using Oerlikon Balzers coating solutions, customers are able to increase their productivity, which results in higher total production output and lower manufacturing costs.

By OSNY FABRICIO

MACHINING TOOLS; MACHINING OPPORTUNITIES

COMPANY PROFILE  By offering 5-axis grinding machines and customizable application software that can perform multiple operations, Haas Schleifmaschinen GmbH is making quite a name for itself in several industries, including gear manufacturing.

By KENNETH CARTER
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ROUGHNESS MEASUREMENT TIPS: THE SCRATCH PAD
You can check a profilometer’s overall performance following a quality-control-defined procedure and frequency using this traceable calibration specimen.

CROSSED HELICAL GEARING A.K.A. SCREW GEARS
How using different helix angles can produce unique gear combinations.

FOUR BASIC TYPES OF FRACTURE MECHANISMS
Ductile failure and brittle fracture are examined in the first of two articles on possible causes for component failure.

Monaghan Tooling adds industry veteran Brett Scruggs to sales team.
Simufact improves metal additive manufacturing efficiency.

American Gear Manufacturers Association

New products, trends, services, and developments in the gear industry.

Mark Michaud

Brian Dengel

D. Scott MacKenzie

American Gear Manufacturers Association

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

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Years ending with a zero always seem to bring out the nostalgia in people as they look back at what was and plan for what will be.

Ever since Gear Solutions began sharing some of the best gear-manufacturing information with the industry, we have constantly changed and morphed to better serve you, our readers.

As it is every year, there are some big things coming to the gear manufacturing industry in 2020, and now that the new year has arrived, we can take a moment to reflect on what’s on the gear horizon.

The bi-annual International Manufacturing Technology Show is set for September 14–19 in Chicago. This will mark the 33rd edition of the show in North America, and more than 2,400 exhibitors from the manufacturing industry are scheduled to display their products and services.

IMTS 2018 hosted the highest number of exhibiting companies ever (2,563) and was the largest in number of registrations (129,415) and in net square feet of exhibit space (1,424,232) at the McCormick Place complex.

Expect IMTS 2020 to be even bigger.

That’s definitely something to look forward to in the coming months, but as far as this January’s issue is concerned, there is quite a bit of content to sift through, including:

Christoph Löpenhaus, Dieter Mevissen, Lily Kamjou, and Elias Löthman share their integrated approach for gear testing of high-performance clean steels.

Osny Fabricio with Oerlikon Balzers presents an article on how high-end coating can increase gear-cutting productivity.

And make sure you check out what our columnists have cooked up for January as well. They are always sharing some fascinating information.

Since it is the first of the year, I will take this opportunity to remind all of you that I am always on the lookout for articles and other submissions. It’s a great way to share your expertise while shining a spotlight on you and your company at the same time. Hit me up if you have an article idea.

I hope 2020 brings you much prosperity and happiness, and I also hope Gear Solutions can bring you the best the gear manufacturing industry has to offer this year and many years to come.

Happy New Year, and, as always, thanks for reading!

KENNETH CARTER, editor
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WE OWN WHAT WE SELL, AND WE KNOW WHAT WE’RE SELLING!
Monaghan Tooling adds industry veteran Brett Scruggs to sales team

Monaghan Tooling Group has hired Brett Scruggs as a technical account manager. He will work out of his home office in northwest Indiana and is responsible for servicing existing accounts and developing new business in Indiana, Illinois, Wisconsin, and Iowa. Scruggs has experience in manufacturing, distribution, and cutting tool sales.

“We’re excited to add Brett to the sales team,” said Monaghan president Scott Monaghan. “His experience in three facets of the industry including manufacturing, distribution, and cutting tool sales gives him a unique insight that will serve customers well.”

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

Simufact improves metal additive manufacturing efficiency

Simufact, a global operating software company providing process simulation solutions and services to manufacturing industries, announced Simufact Additive 2020. This powerful solution for the optimization of metal-based additive manufacturing (AM) processes now provides cost estimation of the build process and improves interoperability with Materialize build preparation software and Renishaw printers to streamline manufacturing processes. Based on new technologies, the software also provides higher performance and robustness.

Simufact Additive 2020 expands the scope of manufacturing simulation. In addition to designing and optimizing the build process virtually, users can now estimate print job costs for single components or assemblies. Not limited to the build process, the capability also includes subsequent processes such as cutting, machining, drilling, and grinding. This helps the user identify the best build variant by taking into account printing costs.

Following Simufact’s efforts to simplify data exchange in the AM process chain, Simufact Additive 2020 now interfaces to Materialize using the 3MF industry standard 3D printing data exchange format. 3MF enables simple and reliable data transfer with third-party software and considerably reduces timely efforts for the model set up.

Simufact Additive 2020 includes an integrated Renishaw QuantAM API for build job preparation and export, which provides the user an error-free-data transmission from Simufact Additive directly to Renishaw printers. This functionality also improves productivity because the entire work process from design to printed part is possible within the software. More interfaces are under development to allowing easy connection to other printing machines.

This new software release applies new Adaptive Voxel Meshing technology to improve the simulation speed by automatically adjusting the voxel sizes in the part. This provides more immediate results to users, and makes the simulation even more reliable and robust. Another release highlight, hybrid manufacturing, helps manufacturers to combine powder bed fusion additive manufacturing processes with conventional manufacturing. Simufact Additive 2020 makes it possible to define a given part upon which the printing will begin, including any internal stresses. Thus, stresses and...
Simufact Additive 2020 broadens our scope from pure-play process build optimization software to provide cost optimization. This new release also underlines our commitment to openness and interoperability with third-party products. We believe manufacturers should start wherever they want in the process to improve quality and efficiency and make additive manufacturing smarter.

Simufact Additive is used by leading manufacturers such as Safran and BAE Systems to improve quality and reduce costly physical prototyping. Simufact Additive 2020 can be licensed alongside any MSC Software products through the MSC One token-based licensing system.

MORE INFO  www.simufact.com

RadTech announces 2020 conference program focusing on AM

With a focus on 3D printing/additive manufacturing, new materials, UV LEDs, and sustainability, RadTech, the nonprofit for the advancement of UV+EB training and education, announces the conference program for RadTech UV+EB Technology Expo and Conference 2020, March 8–11, at the Disney Coronado Springs, Orlando, Florida. Enabling applications in printing and packaging, wood and building products, electronics and industrial coatings will be detailed with key material, formulation, and process considerations.

New, first time RadTech conference sessions include Industry 4.0, exterior coatings, dual cure and micro-patterning. Three full sessions on 3D printing/additive manufacturing will offer a deep dive into formulation, materials and post cure. The event also provides academic educational opportunities including an introductory basics of UV+EB course and “undergrad” and “graduate” level polymer chemistry; and a course on design of experiments. The RadLaunch Class of 2020 will be presented at the event, showcasing start-up companies and ideas for new UV+EB applications and materials.

RadTech UV+EB Technology Expo and Conference 2020, the world’s largest industry event, will also include more than 80 exhibitors demonstrating the application of this exciting technology.

MORE INFO  www.radtech2020.com

MC Machinery launches new electric press brake at FABTECH

MC Machinery Systems recently introduced its new ball screw press brake, the BB306, at FABTECH 2019. This fully electric press brake is designed with a smaller footprint to fit any facility and form smaller parts. The new machines come with the same standard features customers expect from MC Machinery, including an integrated all-axis pulse handle, thickness detection, multi-axis back gauge, front and back LED lighting, and one of the largest user-friendly controls in the market.

Additionally, the BB306 comes with the new MOS control found on all BB and BH series and 100 percent Mitsubishi electronics, motors, and servo drives featuring an AC Servo motor and ball screw drive mechanism for high speed productivity and repeatability. The machine’s design includes a folding front table, 5-axis back gauge, and a tilting controller able to be adjusted by the operator. It is designed to support workers ergonomically in a standing or sitting position.

MORE INFO  www.mcmachinery

Simufact improves quality with new simulation solution

Simufact, a global operating software company providing process simulation solutions and services to manufacturing industries,
announced a dedicated simulation solution to help manufacturers improve quality for Direct Energy Deposition (DED) metal additive manufacturing processes.

Offered as a module inside its Simufact Welding 2020 software, it enables the user to quickly set up robust DED simulation models by simply importing existing tool paths direct from G-Code instead of defining weld paths manually. The software evaluates the stresses, strains, distortions, thermal history, and hot spots during the manufacturing to clearly identify distortions that are out of tolerance, and recommend compensations. Based on this, the user can adapt the G-code to optimize the DED printing process and improve quality.

DED incorporates several metal 3D printing technologies that create parts by melting and fusing material as it is deposited, and is also known as 3D laser cladding, wire arc additive manufacturing (WAAM), direct metal deposition (DMD), or laser metal deposition (LMD). It’s typical fields of application are repairing and rebuilding damaged parts but also manufacturing of new large metal parts that may not be possible with powder bed fusion.

“We are seeing significant demand for our new simulation solution because it helps to optimize such cost-efficient deposition production processes. DED offers a lot of innovation potential for hybrid manufacturing that combines conventional manufacturing technologies with additive manufacturing,” said Dr. Hendrik Schafstall, CEO and managing director at Simufact Engineering.

Call for technical papers issued for 2020 CMS conference

The Coordinate Metrology Society (CMS) is calling for technical papers for its Coordinate Metrology Society Conference (CMSC) to be held July 20–24, 2020, in New Orleans, Louisiana. In its 36th year, the CMS will again host an interactive educational conference for novice and expert users of portable and stationary measurement solutions.

For the first time, abstract submissions will be accepted from experts working in the traditional CMM field, in addition to master practitioners from the portable metrology discipline. Commercial content is not accepted. The CMS community convenes each year to learn about breakthroughs in measurement technologies and emerging trends impacting manufacturing, scientific research, and data-driven quality platforms.

The CMS conference is designed to provide attendees with thought-provoking technical presentations and open discussions of advancements in 3D metrology applications. Subject matter experts and expert teams are encouraged to submit abstracts covering original research, best practices, technology benchmarks, successful implementations, data-driven Smart Factory trends and metrology-assisted competencies gained in automation, process control, and assembly. Overall, the CMSC delivers an inclusive knowledge platform to engage professionals at different skill levels, as metrology continues to dramatically impact the entire manufacturing landscape.

Authors have until March 6, 2020, to submit abstracts to the Coordinate Metrology Society. The CMSC is a selective conference and each abstract is rigorously peer-reviewed by the CMS executive committee. Abstracts must describe original, unpublished research or relevant case uses pertaining to the portable and stationary metrology field at large. If an abstract is accepted, the author will receive a notification of acceptance on April 3, 2020. CMS membership fees and conference registration fees are waived for accepted individual speakers. If a technical paper has more than one author, the CMS will waive one conference registration and membership fee.

Directly following CMSC 2020, the CMS executive committee reviews, scores, and selects the top technical papers for publication in the prestigious Journal of the CMSC. Since 1984, more than 525 original technical papers have been presented at the annual conference. The CMS maintains a digital library of more than 120 technical papers captured in the Journal of the CMSC publications over the past 13 years. This is the most extensive repository of metrology knowledge and information in the world. The archive serves as reference point and a reputable resource to support researchers in the industry. Authors are encouraged to cite CMSC technical papers if referenced in their own technical papers.

The 2019 CMSC agenda delivered a host of novel and authoritative technical papers presented during the event. Conference programming included 20 presentations covering a wide berth of topics including “How to get the Most Accuracy Out of Your PCMM,” “Thickness Inspection of Composite Parts,” and “Noise Filtration of 3D Scanned Data Points in Metrology of Highly Reflective Surfaces.” The speaker roster covered an array of leading manufacturers, academia, and scientific research organizations such as Porto Performance, Spirit Aerosystems, Newport News Shipbuilding, Electroimpact, Wagstaff Inc., National Institute of Standards and Technology (NIST), National Sonar Observatory, Argonne National Laboratory, Los Alamos National Laboratory, UNC Charlotte Center for Precision Metrology, University of Ontario Institute of Technology, University College London, University of Nottingham, and Shanghai Institute of Metrology and Testing Technology.

Call for papers www.cmsc.org/call-for-papers
Starrett names David Allen vice president of metrology systems

The L.S. Starrett Company, a leading global manufacturer of precision measuring tools and gages, metrology systems, and more, appointed David Allen as vice president, Starrett metrology systems in November. In this newly-created role, Allen will be responsible for the strategy, growth, and profitability of the advanced metrology systems including Starrett Bytewise, Starrett Tru-Stone Technologies, Starrett-Kinematic Systems, metrology software development, force measurement systems, and Starrett special gage department.

“We are excited to have found a leader to provide focus on our high-end metrology businesses,” said Douglas A. Starrett, president and CEO of Starrett. “David has deep experience with products and channels similar to Starrett, a global perspective, and a growth mindset that will help these businesses grow faster and more profitably.”

Allen has spent nearly 20 years in commercial and general management of highly engineered product businesses. Most recently, he was vice president, energy and industrial markets for Mott Corporation, an employee-owned manufacturer of porous metal filtration and flow control products. Before that, he spent 13 years with the Danaher Corporation in general management, marketing, and engineering leadership roles in the United States, Europe, and China. Early in his career, he was a manager with the Boston Consulting Group and an active duty U.S. Army officer.

Allen has Bachelor’s degrees from the University of Pennsylvania and a Master of Business Administration from the Tuck School at Dartmouth. He will be based out of Starrett corporate headquarters in Athol, Massachusetts, and reside with his family in central Connecticut.

MORE INFO www.starrett.com

Swiss CNC technology leader expands sales, service to India

NUM AG opened a branch in Bangalore in November. With this expansion in Asia, the international company with headquarters in Teufen, Switzerland, further reinforces its position as a technology leader in the field of CNC controls. With the expansion to India, NUM increases its local presence there as well as its customer-oriented sales and service offering.

“The location in Bangalore will enable us to respond much more quickly to customer enquiries and further expand our brand in the region. We have been well represented in China and Taiwan for many years and would now like to further strengthen our position in Asia,” said Rajesh Nath, managing director of NUM India. This latest expansion secures jobs worldwide, as well as creating new employment opportunities in India.

Nath and NUM CEO Peter von Rüti set up the branch in the south of Bangalore. The offices are in a modern office complex in the business area of Jayaprkash Narayan
Nagara district. “By opening a branch in India, we are exploiting our growth potential. At the same time, the Indian team is expanding our expertise in sales, service and after-sales support,” said von Rüti. NUM believes that Bangalore, as a high-tech location, will strongly influence the CNC market in the future and thus significantly promote the development potential for CNC controls.

With the new office in Bangalore, NUM is now represented internationally at 12 locations.

MORE INFO www.num.com

New generative design solution cuts AM design processes

MSC Software Corporation (MSC), a global leader in computer-aided engineering (CAE) simulation software and services, announced MSC Apex Generative Design, a new design optimization solution that improves quality through unparalleled automation of design processes with embedded manufacturing knowledge.

MSC Apex Generative Design aims to improve productivity by up to 80 percent compared to classic topology optimization. The software produces a part design that is ready for additive manufacturing (DFAM) within a few hours — a fraction of time usually required — making reliable additive manufacturing cost efficient and accessible.

In MSC Apex Generative Design, the designer only needs to specify the boundary conditions and design objective. Multiple lightweight design candidates that explore the possibilities of the design space will be produced that provide optimal stress distribution and minimize weight. This enhances the creative process, so designers have more time to optimize the product’s concept and integrate additional features that add value. The software’s intelligent smoothing technology ensures that every candidate has a perfect finish that is ready for print.

“New design freedoms in additive manufacturing require a new generation of software solutions that take full advantage of the new DFAM possibilities. We make the generative design process smarter by producing design candidates that both satisfy the engineering criteria and look as the designer intended when 3D printed,” said Dr. Thomas Reiher, Director of Generative Design.

Conventional topology optimization workflows require manual work and multiple tools to achieve production-ready results, which can lead to information loss as data is converted. MSC Apex integrates all relevant steps within one Computer Aided Engineering (CAE) environment to improve productivity with a single user experience from design to additive manufacturing preparation.

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The design process is workflow-oriented, providing easy and fast model setup from existing geometries or mesh in common CAD, STL, or MSC Nastran BDF formats. Designers can find optimized design candidates and perform design validation within the same CAE environment, simplifying the work process and reducing design iterations dramatically.

The result is a fully integrated, automated optimization process in which compatibility for previous and subsequent operations plays a vital role. This unique capability implies the conversion from the CAE mesh to CAD with no manual reconstruction of geometry, considerably simplifying the work process for designers.

The MSC Apex Generative Design for Additive Manufacturing solution combines print-ready geometries with robust metal (Simufact) and polymer (Digimat) build process simulation from Hexagon's additive manufacturing portfolio. Designers only generate part designs that can be successfully manufactured using their chosen material and print process to eliminate costly prototyping.

“Additive manufacturing promises innovation and manufacturing productivity advances. But to truly transform, the new technologies require automated design workflows with embedded process knowledge. We are integrating our structural analysis, design optimization, and manufacturing simulation solutions to optimize and validate designs for additive processes before a single part is printed,” said Hugues Jeancolas, VP product management.

MSC Apex Generative Design is available now.

MORE INFO www.mscsoftware.com

Radzevich book on gear tooth flanks released in second edition


The book presents a highly accurate specification for gear tooth flanks to be machined/finished. Precise specification reduces the cost of this widely used industrial operation as accurately specified and machined tooth flanks do not need to undergo costly final finishing. Radzevich describes techniques in this volume based primarily on classical differential geometry of surfaces. He then transitions from differential geometry of surfaces to engineering geometry of surfaces, and examines how gear tooth flanks can be accurately machined by means of gear cutting.

The book goes on to explain specific methods, such as derivation of planar characteristic curves based on Plücker conoid constructed at a point of the part surface, and that analytical description of tooth flanks is vital for surfaces machined using modern gear technology. Providing readers with a powerful tool for analytical description of gear tooth flanks machined on conventional gear generators, as well as on numerically controlled machines, this book maximizes understanding on optimal treatment of gear tooth flanks to meet the requirements of today’s high-tech industry.


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METALEX 2019: Great demand for German know-how

The German contribution to METALEX 2019, the international machine tools and metalworking exhibition in Bangkok was deemed a success. Forty-eight leading German companies from the metal working and machine tool industries presented products and services as the partner country of the exhibition in November. With 100,475 visitors and 970 exhibitors, METALEX continued its success from previous years.

Exhibitor president Peter Weber, managing director of Gebr. Heller Maschinenfabrik GmbH, said, “METALEX is an established event. The partner country delegation and the industry exhibition provided the companies with an excellent opportunity to present their products in the ASEAN region. It is very pleasing that Germany was represented this year by 48 companies, 30 more than the contribution last year.”

“We received a positive response from visitors to the German pavilion. Our presence enabled us to conduct good discussions with visitors. We discussed very specific projects and were able to talk jointly about drawings and specimen parts. Overall, we regard our participation with this perceptible interest as a great success,” said James Tan, managing director of Mapal Tooling Thailand.

Trade visitors gained an insight into German cutting-edge technology during the special show with a forum on the standardized interface umati. German manufacturers used the show to demonstrate how easy and simple it is to use umati. Three machines from DMG Mori, Heller, and Trumpf were connected and gave a live demonstration of production at the Exhibition Centre in Bangkok.

In 2019 Germany was the first partner country of the largest metalworking exhibition in the ASEAN region. (Courtesy: Metalex 2019)

The industry exhibition at METALEX 2019 was initiated by the German Machine Tool Builders’ Association (VDW) and staged by the German Federal Ministry of Economics and Energy (BMWi) and the Association of the German Trade Fair Industry (AUMA) in cooperation with Messe Stuttgart.

MORE INFO www.metalex.co.th

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We do it all for you — the member. Members are behind everything we do from curated programming, education, and events tailored for those in the gear industry. AGMA is — with the recent purchase and establishment of AGMA Media Services, the launch of the AGMA National Training Center, and the new management role with our sister trade association, the American Bearing Manufacturers Association — focused on making sure our customers receive the best service out there. After all, what makes AGMA unique is that we put the member in the driver’s seat.

In 2019, a lot of big things happened at AGMA for members, and now it is time to make sure you are getting the most out of what we offer. To start, we want to make sure members really understand the benefits of being an AGMA member. Here are some benefits that you might not yet be taking advantage of:

- Free full set of AGMA standards and updated information sheets every year.
- Direct participation in the AGMA standards process allowing a voting position to make the gearing standards in the U.S. and internationally.
- A 15- to 50-percent savings on education courses (face-to-face and online).
- Complementary participation and results in the AGMA Operating Ratio Report where you can benchmark how your company is doing in comparison to others in the industry.
- Exclusive access to the AGMA Gear Market report where you will receive the latest information on U.S. economic conditions, gear-industry conditions, gear-market bookings, and gear-market shipments beyond the macro level.
- Unlimited and free use of the online workforce training series that has been downloaded more than 700 times.
- No-cost subscription to AGMA’s bi-monthly Member Newsletter and weekly Industry Newsletter.
- Ability to post unlimited job openings at your company to reach thousands of AGMA followers and potential employees.
- VIP invitations to industry plant tours through the Annual Strategic Resource Meeting.
- Daily news about emerging technology and weekly videos sharing the latest in automation, 3D printing, materials, electric vehicles, and IIoT.
- Opportunities to join AGMA committees that direct the programming and strategic plan of the association for its members.
- Unmatched networking opportunity with industry executives at the AGMA/ABMA Annual Meeting.
- Incredible savings and discounts on the Motion + Power Technology Expo tradeshow booths.

Really, the list above is just the beginning. We know the changing markets, coupled with the emerging technologies in manufacturing, are making it difficult to predict what is going to happen. At AGMA, we want to take some of that burden off you by supplying the business intelligence and resources you need to be successful. Make 2020 the year you work with an association that exists solely to benefit your company, your employees, and the future of the gear industry. Contact any one of our team members today, and see how we can help you!

CONTACT US TODAY

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Meet the AGMA Staff

AGMA is here to provide members with personal assistance. If there is anything we can do for you, please let us know.

MATTHEW E. CROSON
PRESIDENT
I oversee the great team that delivers programs and services for all AGMA members. I have been an association executive for 20 years and joined AGMA in 2016. The AGMA team is a capable and responsive group, and I encourage you to contact them directly for any help you need. We are here for you! croson@agma.org.

AMIR ABOUTALEB
VICE PRESIDENT, TECHNICAL DIVISION
My team coordinates the efforts of more than 250 of the best minds of the industry experts within 23 technical committees to develop and maintain the standards that have helped the gearing industry since 1916. I am also the secretary of ISO TC 60, the technical committee responsible for gearing-related matters at the International Standardization Organization. Feel free to contact me today for any questions that you have or to join a committee! aboutaleb@agma.org.

JENNY BLACKFORD
VICE PRESIDENT, MARKETING
I oversee marketing, communications, and event activities with AGMA. I manage the Motion + Power Technology Expo, and I am the liaison to the AGMA Tradeshow Committee. I have been with AGMA since 2000 and have greatly enjoyed getting to know membership over the years while watching the industry grow and develop. Contact me with all your tradeshow and marketing needs! blackford@agma.org.

CASANDRA BLASSINGAME
VICE PRESIDENT, EDUCATION SERVICES
I have the responsibility of providing relevant and real-world application education and training to our industry. Our department offerings and services have grown significantly, and I am here to answer any questions or needs you might have to help train and educate your staff. blassingame@agma.org.

MARY ELLEN DORAN
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Technological advances provide both opportunities and disruptions for manufacturers. What are these technological advances? What are the impacts specifically for the gear industry and for suppliers to our industry? These are the questions I answer on a daily basis. We have five committees that gather members and experts for high-level discussion on 3D-printing metal (for gears), electric drive technology, industry IIoT, new materials, and automation. Contact me today to learn more or to join one of these committees! doran@agma.org.

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DIRECTOR, MARKETING & COMMUNICATIONS
Every time you receive an email, press release, video, photos, or see a post from AGMA on social media, most likely it is coming from my computer. I handle not only our digital platforms, but I also work with magazines throughout the power-transmission industry. Please contact me today to see how you can blog for hundreds of readers about your expertise or to post an open position with your company and if you need any help with marketing and communications in your business. brinkley@agma.org.

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My job is to ensure that all AGMA members and our guests have a great experience at the education courses, conferences and meetings, and tradeshows you attend. From selecting venues that meet the needs of our attendees to planning the strategy behind our event content and meeting design, I am always there behind the scenes. Contact me on all questions related to the Annual Meeting, how to be a speaker at one of our events, sponsorship, and hotels and travel for all AGMA events. lewis@agma.org.

PHILLIP OLSON
STAFF ENGINEER
My main responsibility is facilitating standards development. A valuable perk of your AGMA membership is the opportunity to create new standards, revise old standards, or just listen...
in on the committee meetings where the gear standards you use every day are developed. Contact me today to join one of the 23 technical committees, to present at the FTM, or if you have any specific engineering questions about our standards. olson@agma.org.

TESHIA PAYNE
PUBLICATIONS COORDINATOR, TECHNICAL DIVISION
My job is to assist the standards process by editing and formatting standards and information sheets used all over the world. I also organize and manage the Fall Technical Meeting, where I work directly with presenters, the SCOPUS Publication, and our marketing team to gather more than 125 attendees from around the globe. Contact me if you would like to join a technical committee, would like to know more about the standards process, or to just say hi!

KARINA NUNEZ
DATABASE ADMINISTRATOR
I am the person you go to when you get locked out of your account or need assistance updating your profile. I work with members on collecting information regarding dues, invoices, orders, and registration information. I am here as a resource for all members on services that we offer. Call me with any questions, and I will get you what you need!

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I plan and manage logistics of AGMA trainings and education programs. I am responsible for ensuring that our AGMA training programs are compliant with IACET standards, so we can deliver the best education possible. Contact me today if you have any questions about our face-to-face, online, and onsite training opportunities. I am happy to help get you the education you need for your employees.

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DIGITAL MARKETING SPECIALIST, AGMA & ABMA
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I am your contact for anything Foundation related. Please contact me for anything related to the annual golf tournament, scholarship program, the Get into Gears Employee Recruitment Toolkit, Spin it Forward Machine and Material Campaign, the AGMA National Training Center, and any donations or fund raising that affects the Foundation. Contact me today and see how you can make a difference in the industry!

Upcoming Education

Gear Manufacturing and Inspection
JANUARY 28-30 | GARDEN GROVE, CALIFORNIA
Discover key factors in the inspection process that lead to better design of gears. Develop a broad understanding of the methods used to manufacture and inspect gears. Interpret how the resultant information can be applied and interpreted in the design process.

This course also includes a tour of Western Precision Aero in Garden Grove, California. Participants will be required to fill out paperwork prior to the tour and must be U.S. citizens. AGMA will distribute the paperwork upon registration.

Fundamentals of Worm & Crossed Axis Helical Gearing
FEBRUARY 18-20 | ALEXANDRIA, VIRGINIA
Provides an introduction and emphasizes the differences between parallel (the experience base) axis and worm and crossed axis helical gears. Describes the basics of worm and crossed axis helical gears, their fundamental design principals, application guidelines and recommendations, lubrication requirements, a discussion of accuracy and quality, and summarizes with a brief review of common failure modes.

Steels for Gear Application
MARCH 24-26 | ALEXANDRIA, VIRGINIA
Gain a basic understanding of steel and its properties. Learn to make use of steel properties in an application and understand the potential that different steel and heat treatment options can offer. Explore how performance of the material depends on how the steel is produced.
### AGMA LEADERSHIP

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<td>President</td>
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<td>VP, Sumitomo Drive Technologies</td>
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### 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.

#### JANUARY
- January 7 — Helical Gear Rating Committee Meeting — WebEx
- January 14 — Metallurgy and Materials Committee Meeting — WebEx
- January 21 — Nomenclature Committee Meeting — WebEx
- January 23 — Gear Accuracy Committee Meeting — WebEx

#### FEBRUARY
- February 5 — Bevel Gearing Committee Meeting — WebEx
- February 6 — Powder Metallurgy Committee Meeting — WebEx
- February 20 — Helical Gear Rating Committee Meeting — WebEx
- February 25 — Metallurgy and Materials Committee Meeting — WebEx
- February 26 — Plastics Committee Meeting — WebEx

#### MARCH
- March 17 — Helical Gear Rating Committee Meeting — WebEx
- March 21 — Metallurgy and Materials Committee Meeting — WebEx
- March 25 — Aerospace Gearing Committee Meeting — WebEx
- March 26 — Gear Accuracy Committee Meeting — WebEx
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Roughness measurement tips: The scratch pad

You can check a profilometer’s overall performance following a quality-control-defined procedure and frequency using this traceable calibration specimen.

From the perspective of the shop floor environment, the previous Materials Matter column “Roughness Measurement Tips: 2 V 5” discussed the contact stylus 2-micron radius tip versus a 5-micron radius tip. It was recommended in either case to use a skidded stylus for its increased durability. The skidded stylus removes the surface waviness and measures only the R-parameters. For gears that are ground or superfinished, ISO-3274 gives a little wiggle room in specifying the stylus tip size. Flank roughness between \( R_a > 0.5 \) micron and \( < 2 \) micron can use the 5-micron tip as the difference in roughness measure is minor.

However, precision tooth flank roughness is now typically in the \( 0.1 – 0.5 \) micron \( R_a \) range. Based on data previously presented, the use of a 2-micron tip is needed for accurate measurements when the roughness is approaching the lower end of this range. This column will be about checking the profilometer’s overall calibration condition via use of a scratch pad. For the record, I am not talking about a device employed by house cats to sharpen their claws! I am talking about the profilometer calibration specimen, commonly called a “scratch pad.”

**CALIBRATION CHECKING**

A calibration check is a comparison of any measuring instrument to a known standard. The quintessential example is the use of gage blocks to calibrate measurements of length. Surface roughness is a dynamic measurement, not a static one. The condition of the individual elements of a profilometer that collectively capture the data contributes to the measurement results. These elements are the diamond tip contact stylus, the pick-up or drive head and the controller-processor unit. These elements must be considered as a whole when calibrating a profilometer.

A complete mechanical and electrical calibration of all the features of a contact profilometer involves lengthy, complex, and costly procedures. In my next Materials Matter column, I will briefly describe these procedures along with checking the stylus. Fortunately, modern shop floor profilometers are very stable instruments and do not need calibration often. They do not generally offer calibration adjustability to the daily operator for “fine tuning.” My guidance regarding profilometer calibrations will be to contract annually with an independent calibration service to recertify the instrument. For now, my recommended practice is to check a profilometer’s overall performance following a quality-control-defined procedure and frequency using a traceable calibration specimen — the scratch pad.

**THE SCRATCH PAD**

Due to the increasing quality of engineered surfaces, roughness measurement capability developed greatly during the second half of the 1900s. Many different types of surface roughness instruments emerged that are capable of measurements down to the atomic scale. However, the fractional uncertainty of roughness measurement increases rapidly as the surface \( R_a \) value decreases. The result was that by the 1980s, surface roughness measurement results varied widely for a given surface. To improve the accuracy of engineered surface measurement among different instruments, operators, and locations, J.F. Song and T.V Vorburger [1], working at NIST, published a definitive treatise on surface roughness calibration methods using calibration specimens. ISO-5436-1 (1996), “Calibration Specimens — Stylus Instrument — Types, Calibration and Use of Specimens,” and ASME B46.1-2002, “Surface Texture (Surface Roughness, Waviness, and Lay),” incorporate their work. These two standards define contact stylus profilometer calibration specimens and their use. These standards describe the two classes of calibration specimens — a comparison specimen, and a precision reference specimen.
COMPARISON SPECIMEN
Comparison specimens are used to guide personnel with respect to the feel and appearance of a surface of known roughness grade that is produced by a selected manufacturing process. Though useful to the experienced trained eye, a comparison specimen is not suitable for measurement and documentation of a traceable engineered surface roughness. Figure 1 shows a typical set of comparison specimens undergoing a “fingernail” roughness assessment. The operator rubs his fingernail over the comparison specimen and then over the engineered surface under examination and makes a judgement on its roughness. This is not a suitable method for modern surface roughness analysis! In addition, comparison specimens are not intended for checking the performance of a modern profilometer. It is recommended they are not to be used for profilometer calibration.

PRECISION REFERENCE SPECIMEN
Precision Reference Specimens (PRS) are intended for use in the calibration of profilometers for measuring surface roughness. They come in four basic types, designated A-D, and in varying ranges of roughness. They are not intended to have the appearance or characteristics of commonly produced surfaces, nor are they intended for use in visual or tactile comparisons. Precision reference specimens are typically made from high hardness metal or from silicon glass. A national standards body (i.e. NIST) should certify the specimen for traceability.

The profile of the PRS depends upon its intended use. Specimen types A, B, and C are used for checking the vertical magnification...
of the profilometer, stylus condition, and R-parameters calibration respectively. These precision reference specimens will be discussed further in my next Materials Matter column. D-type specimens are used for the overall checking of the performance of the profilometer. It is the type of specimen that is recommended by the author for the day-to-day calibration checking of a shop floor profilometer.

**D-TYPE PRECISION REFERENCE SPECIMEN**

A D-type specimen simulates an engineered surface of a workpiece. It contains a wide range of asperity spacing and has an irregular surface profile. The profile pattern repeats every evaluation length, typically every 4 mm of the test surface. The grooves in the test area must have a constant profile, meaning the surface is essentially smooth along the direction perpendicular to the direction of the measurement asperities. D-type specimens are available with nominal Ra values from 0.01 micron to 3 micron. By definition, the D-type specimen must be made of a material with a hardness of 500 HV (Vickers) or higher to ensure repeatability and adequate life. The reference area of the specimen must be larger than the traversing length required by any national or international standard.

During its manufacture, all PRS must be calibrated and labeled by its specimen type. Included in its labeling is its nominal value, the effective stylus tip radius used to calibrate the specimen, the type of filter and cutoff used in the calibration process, and details of its calibration procedure. F. J. Song and P. Rubert (Rubert & Co, LTD, UK) are often credited for the development of the D-type specimen. As such, this precision reference specimen is sometimes called a “Rubert-Song” specimen. Figure 2 is a representation of a D-type specimen showing a repeating surface profile.

Figure 3 is a photograph of an actual Rubert-Song D-type Specimen. This is a cost effective, certified, durable, electroformed specimen suitable for ongoing calibration checking.

For use in calibration, the D-type specimen should be in the same roughness range as the manufactured engineered surface that is being monitored for quality control. The use of a Rubert-Song specimen is the recommended specimen for use on all shop floor profilometer calibration checking.

**SHOP FLOOR PROFILOMETER CALIBRATION**

Having established the use of a certified Rubert-Song specimen as the basis for monitoring the condition of a shop floor profilometer, the actual checking procedure is rather simple. Starting with a certified, calibrated instrument, a profilometer tracing, or a series of tracings, are taken of the PRS, based on a quality control plan. The tracing’s Ra value should match closely with the specimen’s documented value. Normally, the overall performance of the profilometer is considered acceptable if the measured result is less than ten percent different from the specimen’s averaged value. The tracing(s) can be retained for comparison against future measurements. Then, periodically, the specimen is reused to verify the profilometer’s calibration. If the measured result deviates more than ten percent of the specimen’s stated value, and/or the previous measured result, the profilometer’s performance should be questioned. Further evaluation of the profilometer is needed. If this evaluation fails to lead to a correction of the deviation, the profilometer may need a full calibration-recertification by an independent calibration expert.

![Figure 4: Example of Calibration Check. (REM Surface Engineering)](image-url)

**CONCLUSION**

I recommend that only a certified precision reference specimen be used for shop floor calibration checking. A D-type Rubert-Song specimen that is in the same range of roughness as the surface being checked should be used for the calibration checking of precision gear flanks. It is a cost effective, durable representation of the ground surface.

**REFERENCE**


---

**ABOUT THE AUTHOR**

Mark Michaud, REM Technical Fellow of REM Surface Engineering, is the inventor and pioneer of REM Surface Engineering’s chemically accelerated finishing technology. He has authored numerous patents and technical papers and served a term on the AGMA Board of Directors. He continues to serve as vice chair of the AGMA Aerospace Committee, as a member of the AGMA Wind Turbine Committee and as a shadow delegate on the ISO 61400-4 Wind Turbine Committee. He can be reached at mmichaud@remchem.com.
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FOREST CITY GEAR

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Crossed helical gearing a.k.a. screw gears

How using different helix angles can produce unique gear combinations.

A common refrain from my childhood was “if you keep crossing your eyes, they are going to get stuck like that!” It never did happen, but it was a real-life example of what nonparallel meant. In gearing, the axis of the pair is usually parallel, or they are intersecting. Crossed helical gears, also known as screw gears, are both nonparallel and nonintersecting. They allow for some very unique designs.

The term screw gearing includes various types of gears used to drive nonparallel and nonintersecting shafts where the teeth of one or both members of the pair are helical in nature. The Figure 1 below shows the meshing of screw gears where the pitch and pressure angles are the same but the helix angle of the teeth on each gear is different.

Two screw gears can only mesh together under the conditions that normal modules \( m_{n1} \) and \( m_{n2} \) and normal pressure angles \( \alpha_{n1}, \alpha_{n2} \) are the same.

If we set a pair of screw gears to have the shaft angle \( \Sigma \) and helix angles \( \beta_1 \) and \( \beta_2 \):

- If they are the same hand (both left hand or both right hand), then
  \[ \Sigma = \beta_1 + \beta_2 \]
- If they are the opposite hand (one left hand and the other right hand), then
  \[ \Sigma = \beta_1 - \beta_2 \]

If these screw gears are profile shifted, then the meshing would become a little more complex. If we let \( \beta_{w1} \) and \( \beta_{w2} \) represent the working pitch cylinders:

- If they are the same hand (both left hand or both right hand), then
  \[ \Sigma = \beta_{w1} + \beta_{w2} \]
- If they are the opposite hand (one left hand and the other right hand), then
  \[ \Sigma = \beta_{w1} - \beta_{w2} \]

The unique situation of crossed axis helical gears is that if you set the helix angles \( \beta_1 \) and \( \beta_2 \) to 45 degrees and both gears are of the same hand, then the resulting shaft angle \( \Sigma \) becomes 90 degrees and the gear pair will operate as a right angle drive. However, if the same gears are opposite in hand and the helix angles \( \beta_1 \) and \( \beta_2 \) are 45 degrees, then the resulting shaft angle \( \Sigma \) becomes 0 degrees and the gear pair will operate as a set of regular helical gears. For all configurations of crossed helical gears, the speed ratio of the gear pair is equal to \( z_2/z_1 \). Thus the speed ratio of these gear pairs is limited by the size of the larger gear and practically speaking are usually less than 6:1.

Table 1 presents the equations for a profile shifted screw gear pair. When the normal profile shift coefficients \( x_{n1} = x_{n2} = 0 \), the equations and calculations are the same as for standard helical gears and the following apply:

\[
\begin{align*}
d_{w1} &= d_1 & d_{w2} &= d_2 \\
\beta_{w1} &= \beta_1 & \beta_{w2} &= \beta_2
\end{align*}
\]

For all screw gears, the proper thrust bearings must be selected so that they absorb the thrust loads imparted by the helix angle.

Although the most popular helix angle for screw gears is 45 degrees, any helix angle greater than zero degrees is possible. The ability to mix helix angles allows for screw gears to be used in unique applications where the input and output shafts are neither intersecting nor parallel and when combined with profile shifting, they also allow for a variety of center distances. These features are not found in any other form of gearing.
<table>
<thead>
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<td></td>
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<td>Pinion (1)</td>
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<tr>
<td>1</td>
<td>Normal module</td>
<td>$m_n$</td>
<td></td>
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<td>2</td>
<td>Normal pressure angle</td>
<td>$\alpha_n$</td>
<td></td>
<td>20°</td>
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<td>3</td>
<td>Reference cylinder helix angle</td>
<td>$\beta$</td>
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<tr>
<td>4</td>
<td>Number of teeth &amp; helical hand</td>
<td>$z$</td>
<td></td>
<td>15 (R)</td>
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<td>5</td>
<td>Normal profile shift coefficient</td>
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<td>6</td>
<td>Number of teeth of an Equivalent spur gear</td>
<td>$z_v$</td>
<td>$\frac{z}{\cos^3 \beta}$</td>
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<td>7</td>
<td>Transverse pressure angle</td>
<td>$\alpha_t$</td>
<td>$\tan^{-1} \left( \frac{\tan \alpha_n}{\cos \beta} \right)$</td>
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<td>Involute function $\alpha_{w_n}$</td>
<td>inv$\alpha_{w_n}$</td>
<td>$2 \tan \alpha_n \left( \frac{x_n + x_{n_{\alpha_n}}}{z_{v_1} + z_{v_2}} \right) + \text{inv} \alpha_n$</td>
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<td>Normal working pressure angle</td>
<td>$\alpha_{w_n}$</td>
<td>Find from involute function table</td>
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<td>Transverse working pressure angle</td>
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<td>Center distance modification coefficient</td>
<td>$y$</td>
<td>$\frac{1}{2} \left( z_{v_1} + z_{v_3} \right) \left( \frac{\cos \alpha_n}{\cos \alpha_{w_n}} - 1 \right)$</td>
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<td>Center distance</td>
<td>$a$</td>
<td>$\left( \frac{z_1}{2 \cos \beta_1} + \frac{z_2}{2 \cos \beta_2} + y \right) m_n$</td>
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<td>Reference diameter</td>
<td>$d$</td>
<td>$\frac{z m_n}{\cos \beta}$</td>
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<td>14</td>
<td>Base diameter</td>
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<td>$d \cos \alpha_t$</td>
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<td>Working pitch diameter</td>
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<td></td>
<td></td>
<td>$d_{w_2}$</td>
<td>$2a \frac{d_1}{d_1 + d_2}$</td>
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<td>Working helix angle</td>
<td>$\beta_{w}$</td>
<td>$\tan^{-1} \left( \frac{d_{w}}{d} \tan \beta \right)$</td>
<td>20.4706°</td>
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<td>Shaft angle</td>
<td>$\Sigma$</td>
<td>$\beta_{w_1} + \beta_{w_2}$ or $\beta_{w_1} - \beta_{w_2}$</td>
<td>51.1025°</td>
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<td>18</td>
<td>Addendum</td>
<td>$h_{s_1}$</td>
<td>$(1 + y - x_{m_2}) m_n$</td>
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<td></td>
<td></td>
<td>$h_{s_2}$</td>
<td>$(1 + y - x_{m_1}) m_n$</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Tooth depth</td>
<td>$h$</td>
<td>$\left( 2.25 + y - (x_{m_1} + x_{m_2}) \right) m_n$</td>
<td>6.6293</td>
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<td>20</td>
<td>Tip diameter</td>
<td>$d_s$</td>
<td>$d + 2h_s$</td>
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<tr>
<td>21</td>
<td>Root diameter</td>
<td>$d_t$</td>
<td>$d_s - 2h$</td>
<td>42.7880</td>
</tr>
</tbody>
</table>

Table 1: The equations for a screw gear pair on nonparallel and nonintersecting axes in the normal system.
Four basic types of fracture mechanisms

Ductile failure and brittle fracture are examined in the first of two articles on possible causes for component failure.

When a component fails, the fracture surface of the broken component can tell a great deal regarding the mechanism of failure. It can often provide details or suggestions as to why a component has failed. In this short column, I will attempt to describe the four basic types of fracture and indicate possible causes. Often, multiple fracture mechanisms will be present on the failed component, and can lead the investigator to determine why a component failed.

Examination of the fracture surface and metallography are used to determine the cause of failure. First, it is necessary to determine the fracture mode. Unfortunately, there is no clear or logical classification of fracture. Generally, classification is based on the crack growth mechanism. We will discuss four types of fracture mechanisms: ductile failure, brittle fracture, intergranular fracture, and fatigue.

**DUCTILE FAILURE**

Ductile failure is a very common mechanism of failure. In this mechanism, the material is loaded beyond its ultimate tensile strength. Loading beyond the tensile strength could be due to the designer failing to apply a suitable factor of safety; or service conditions beyond design criteria.

On a macroscopic scale, a ductile fracture is accompanied by a relatively large amount of plastic deformation before the part fails. After failure, the cross-section is reduced or distorted. Shear lips are observed at the latter part of the fracture and indicate the final failure of the part. The fracture surface is dull, with a fibrous appearance. Examination with an SEM shows that the fracture is by micro-void coalescence [1] (Figure 1).

In this failure mechanism, the creation of a free surface from a small particle such as an inclusion occurs first. The free surface around the particle creates a void. The void grows by plastic strain and hydrostatic stress. Finally, the voids grow to a size that they join or coalesce with adjacent voids. These voids coalesce to form a central crack, perpendicular to the applied tensile stress. Depending on the applied stresses, the shape and configuration of the dimple shape can be changed (Figure 2). This fact is useful in determining the type of loading in a failure analysis investigation [2].

Ductile failure can occur with any of the types of inclusions. This is true whether it is the brittle alumina type inclusion or the more ductile sulfide type inclusions. Inclusions generally initiate ductile cracking above a critical size. Coarser inclusion sizes tend to have a larger local stress concentration factor, which can cause local decohesion and micro-crack formation.

In a similar fashion to that of inclusions, the distribution of carbides can also influence the toughness and ductility of the steel. The strain needed for void formation decreases with increasing carbide volume fraction. Spheroidal carbides will not crack at small strains and exhibits decohesion. Spheroidized steel is much more ductile than similar steel of the same hardness containing only ferrite and pearlite. Pearlite has a lower critical strain for void formation.
Metallurgical notches arise from abrupt changes in microstructure gouges, and similar machining marks create mechanical notches during the manufacture of the component. Welding strikes, deep welded. Fabrication details result from the production of notches members that were rigidly joined at angles less than 90 degrees and material flaws. Notches were of three types: design features, fabrication details, or concentration, and propagated with little plastic deformation. These indicated that brittle failures would initiate at a notch or stress con- the failed material. Analysis of fracture surfaces of brittle failures with rapidity — often at speeds approaching the speed of sound in the failed material. Analysis of fracture surfaces of brittle failures indicated that brittle failures would initiate at a notch or stress concentration, and propagated with little plastic deformation. These notches were of three types: design features, fabrication details, or material flaws.

Design features were notches such as tight radii or structural members that were rigidly joined at angles less than 90 degrees and welded. Fabrication details result from the production of notches during the manufacture of the component. Welding strikes, deep gouges, and similar machining marks create mechanical notches. Metallurgical notches arise from abrupt changes in microstructure

addition, once a crack or void forms in a pearlitic matrix, it will tend to run along the length of a pearlite lamella. Examining this type of fracture under the SEM, the base of the dimples will contain fractured pearlite lamella.

BRITTLE FRACTURE

Very little plastic deformation and a shiny fracture surface characterize brittle fractures. Often, chevron patterns point back to the origin of failure [3] (Figure 3). It can occur at low stress and propagate with rapidity — often at speeds approaching the speed of sound in the failed material. Analysis of fracture surfaces of brittle failures indicated that brittle failures would initiate at a notch or stress concentration, and propagated with little plastic deformation. These notches were of three types: design features, fabrication details, or material flaws.

Design features were notches such as tight radii or structural members that were rigidly joined at angles less than 90 degrees and welded. Fabrication details result from the production of notches during the manufacture of the component. Welding strikes, deep gouges, and similar machining marks create mechanical notches. Metallurgical notches arise from abrupt changes in microstructure or porosity from welding or casting. These flaws can also be related to mill practice and can be large inclusions, internal oxidation, or porosity.

In brittle fractures, limited energy is absorbed by the fracture. Energy is absorbed through regions of small plastic deformation. Individual grains separate by cleavage along specific crystallographic planes (Figure 4).

Visually, little or no plastic deformation or distortion of the shape of the part characterizes brittle fractures. The fracture is usually flat and perpendicular to the stress axis. The fracture surface is shiny, with a grainy appearance. Failure occurs rapidly, often with a loud report. Because the brittle cleavage is crystallographic in nature, the fracture appearance is faceted (Figure 4).

There are three basic factors that contribute to brittle cleavage type of fracture in steels: a triaxial stress state, low temperature, and a high strain rate or rapid loading rate. These three factors do not have to be present for cleavage-type fracture to occur. Most brittle, cleavage-type fractures occur when there is a triaxial stress-state and low temperature. This is actuated by a high rate of loading.

The notch toughness of low- and medium-strength steels is high- ly dependent upon temperature. There is a transition from ductile fracture to brittle fracture as the temperature decreases. One crite- rion for the transition temperature is the Nil Ductility Temperature (NDT). The Nil Ductility Temperature is the temperature where fracture becomes 100 percent cleavage, and there is essentially no plastic deformation.

Changes in the NDT can be produced by changes in microstruc- ture and chemistry. The largest change can be affected by changes in the amount of carbon and manganese. The NDT is lowered by about 10°F for every 0.1 percent increase in the Mn concentration. Increasing the carbon content also lowers the NDT. The Mn/C ration should be approximately 3:1 for good notch toughness.

Nickel is beneficial for increasing ductility. Up to 2 percent Ni is effective in lowering the Nil-Ductility Temperature. Increasing concentrations of silicon have the effect of increasing the NDT. Chromium has nearly no effect, while molybdenum is extremely effective in increasing the ductility of steels, and drastically decreases the NDT. Oxygen strongly decreases the ductility. It can also cause increased propensity to intergranular fracture, by creating brittle oxides at the grain boundaries. Decreasing the grain size has a strong effect on increasing the ductility and notch toughness.

Section thickness can also influence ductile and brittle behavior [5]. Investigations [6][7] showed that there was considerable varia- tion of toughness with the thickness of the specimen. Further, at large thickness, the toughness appeared to reach a constant value [8] (Figure 5). Within this curve, there are three regions apparent: First, there is the region where maximum toughness is obtained (thin sections). Second, there is the region of intermediate toughness, with the final region, a region with relatively constant toughness (thick sections).

In the first region, the fracture appears to consist entirely of a shear lip, or in other words, the fracture surface is inclined at angle of approximately 45˚ to the tensile axis. In this situation, the stress in direction of the thickness of the specimen tends toward zero, and a state of plane stress is achieved.

In the intermediate range, the fracture behavior is complicated. The fracture does not consist of entirely “slant” type fracture, nor does it contain entirely a “flat” plane strain-type fracture. Instead the regions of “flat” and “slant” fracture are approximately equal. It has been found that the amount of “flat” fracture depends only on the
thickness of the test specimen and was independent of crack length.

In the third region, the fracture consists of predominantly “flat” fracture. Some evidence of very small shear lips may be present at the later part of fracture. Fracture is catastrophic and rapid. No plastic deformation is evident. In this third region, any increase in the thickness of the test piece causes no further decrease in the toughness.

One famous failure involving brittle fracture was the “Great Boston Molasses Disaster” [9]. In this failure, the United States Alcohol Company fabricated a large cast iron molasses tank in Boston in December 1915. This tank was 90 feet wide and 58 feet tall, with a head of 49.5 feet of molasses. It was fabricated of cast iron plates, riveted together. It held 2.3 million gallons of molasses, ostensibly used for the fermentation of ethanol used for liquor. The man who oversaw construction could not read blueprints, nor had any technical training. No engineers or architects were consulted to ensure that the tank was constructed safely. On January 15, 1919, the tank exploded and molasses flooded the streets of Boston with waves eight to 15 feet tall (Figure 6). This great wall of molasses was reported to have moved at speeds up to 35 miles per hour, and it devastated a large section of Boston.

Half-inch steel plates were torn apart, and these plates were thrown with enough force to cut girders of the elevated railway. This explosion, and the subsequent wave of molasses, resulted in 21 people killed, 150 people injured, many buildings destroyed, and an entire area devastated.

Investigation many years later indicated that the probable cause was brittle fracture of the tank at rivets, with the temperature below the ductile to brittle transition temperature. One interesting result of this disaster was that Massachusetts and many other states created laws to certify engineers and to regulate construction. It also required stamped drawings certifying that an engineer had reviewed the drawings. It was this failure that was the origin of the Professional Engineer’s License and stamp as we know it today. As a side note, the 18th Amendment was ratified and Prohibition was signed into law on January 16, 1919.

CONCLUSIONS
In this short article, two types of fracture were described. Ductile failure is the result of overload and exceeding the ultimate tensile strength of a material. Extensive plastic deformation is observed. In brittle fracture, catastrophic failure is observed, with little or no warning. No plastic deformation is observed. Triaxial stress states, a stress concentration, or rapid loading are usually required for brittle fracture to occur.

In the next article, intergranular fracture and fatigue will be discussed. Should you have any questions regarding this, or have any suggestions for further articles, please contact the editor or myself.

REFERENCES

Figure 6: The Great Boston Molasses Disaster. Twenty-one people were killed and more than 150 buildings were destroyed as the result of 2.3 million gallons of molasses flooding North Boston. (Courtesy: Photo by the Boston Globe via Getty Images)
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INTEGRATED APPROACH FOR GEAR TESTING OF HIGH-PERFORMANCE CLEAN STEELS
In this report, a test gear geometry for investigating contact fatigue strength (pitting) of high-performance clean steels is determined, and based on two well-established test gear geometries for contact fatigue test, a detailed comparison with regard to their potential of maximum contact pressure is performed.

By CHRISTOPH LÖPENHAUS, DIETER MEVISSEN, LILY KAMJOU, and ELIAS LÖTHMAN

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

In this paper, an integrated approach for gear testing of high-performance clean steels is presented. In order to determine the differences between steels of different cleanliness levels, the testing approach for pitting damages has to be improved as a whole. Based on experimental results with a standardized gear geometry for pitting load carrying capacity tests, the limits of the existing test setup are derived. Furthermore, the demands for a new test setup are defined. The main requirement for the gear design is to ensure a clear separation of different damage patterns up to highest loads, which are expected for improved cleanliness levels.

For pitting investigations, a sufficient tooth root strength is obligatory. Analysis of the safety factors according to ISO 6336 parts 2 and 3 confirm that the two damage patterns cannot be separated up to the highest possible load of the back-to-back gear test rig. It is emphasized that a change of face width does not lead to a better separation of the damage patterns. Therefore, the tooth-root strength is increased by a stepped tooth shape to each side. Furthermore, it is shown that the FZG C-type gear shows better potentials for flank fatigue testing than the 17/18 test gear geometry.

Finally, the tooth mesh is analyzed with regard to premature tooth meshing. In case of a premature tooth meshing, scraper marks influence the pitting strength of the gear. If the test load needs to be increased because of the higher cleanliness of the steel, the effects of a premature tooth meshing become higher keeping the same micro geometry. For the standardized FZG C-type gear, a look-up table for an optimized tip relief is derived for different face widths and torques, which can be easily applied.

As a conclusion of the presented work, it is necessary to guarantee an excellent gear design and a high manufacturing quality for testing of high-performance clean steels with highest load carrying potentials. Only in this case, can the full potential of cleaner steel be outlined.

1 INTRODUCTION AND MOTIVATION
The optimization of power density is one of the most important criteria during the design process of transmissions. The power density of transmissions has a direct impact on the production costs as well as on the performance of the drivetrain. Furthermore, the carbon footprint depends on the power density because the amount of raw material for manufacturing each gearbox component can be reduced with increased power density on the one hand. On the other hand, less weight of the drivetrain leads to less emission during operation of the transmission in its application.

For a continuous improvement of power density, there are different strategies for transmissions (Figure 1). Besides the optimization of the gear design regarding gear macro and micro geometry or tooth root geometry, the application of surface finishing processes is an established approach to increase the load capacity of gears [20, 17]. Furthermore, the development of new materials as well as the improvement of the material quality shows a high potential for increasing the power density of gearboxes. In this report, the focus is on the improvement of the steel performance concerning a higher cleanliness.

A further increase of the power density of transmissions affects the design process in two ways. On the one hand, the center distance of the gearbox can be reduced transferring the same load (Figure 1). On the other hand, the nominal torque can be increased using the existing design of the gearbox, both using high performance clean steels. Regarding the validation of the strength potential by testing on standardized back-to-back test rigs, the center distance is constant, and a higher nominal torque is applied to force damages on test gears. The design of a test-gear geometry has to ensure that only the desired damage pattern is most critical and the other damage patterns are avoided.

In this report, the focus is on the determination of pitting strength of improved materials. In this case, the safety factor against tooth root breakages should be high enough for the endurance limit of contact fatigue. By continuous increase of pitting load capacity,
the safety factor against tooth root breakage decreases for the same gear geometry, if the same allowable stress number for bending fatigue is assumed. For this reason, the well-established test gear geometries for contact fatigue do not guarantee a secure separation of tooth root breakages for improved materials any more. In this report, the well-established FZG C-type and 17/18 test gear geometry are analyzed regarding their potential for pitting tests of high-performance clean steels. Finally, an optimized design of the FZG C-type gear regarding face width and profile correction is introduced for contact fatigue tests.

2 STATE OF THE ART AND DEFICIT

2.1 PROPERTIES AND POTENTIALS OF HIGH-PERFORMANCE CLEAN STEELS

Steel cleanliness as a means to increasing power density or lifetime — although already proven a valid method in real applications — is still being investigated in many areas [31]. One reason for this is because of the capabilities of available current standards such as the ISO 6336, as well as the limitations of current standardized test methods. These standards, meanwhile, are reliable due to their conservative nature and are perhaps expected to be more of a guideline to manufacturers’ own specifications. The reasoning behind it can partly be because of the weaknesses in how materials are classified from a cleanliness point of view and the impact it has on the performance of the components. Steel making practices have evolved since the standards were put in place, as have the ways of verifying steel cleanliness.

Steel cleanliness can be challenging to define and somewhat depends on application and starting point. However, it can be described as size and frequency of non-metallic inclusions in the steel, such as Al₂O₃-MgO particles. It is then understandable that different applications have different requirements. Steel cleanliness depends on the steel making process, casting format and size, reduction-ratio-to-finished product, and how inclusions are dispersed throughout the material. Large MnS inclusions, for example, located along the tooth root, will likely increase the failure probability at a lower stress level than a smaller inclusion. For high-strength steels, material cleanliness will be a determining factor, especially for high-cycle fatigue.

A recent comparative study clearly reflects the effect of steel cleanliness on material performance [25]. The study was performed on customized gears, not standardized type reference gears. The same gear geometry, manufacturing, and heat treatment was applied to a reference 18CrNiMo7-6 steel and a high cleanliness 18CrNiMo7-6 isotropic property steel. It is then understandable that different applications have different requirements. Steel cleanliness depends on the steel making process, casting format and size, reduction-ratio-to-finished product, and how inclusions are dispersed throughout the material. Large MnS inclusions, for example, located along the tooth root, will likely increase the failure probability at a lower stress level than a smaller inclusion. For high-strength steels, material cleanliness will be a determining factor, especially for high-cycle fatigue.

Some of the challenges with the ISO 6336-5 standard are how the requirements of the different material classes or performance levels do not deal well with steel cleanliness. One weakness is the demands on O, Ca, and S do not take into account how cleanliness is achieved and how steels can be produced in different ways. Top performing clean steels might not meet all of these requirements, whereas many lower performing steels might adhere to these limits. As mentioned in previous papers, micro-inclusion rating according to the standards only look at a very small area, approximately 100-200 square millimeters per sample, resulting in approximately 1,000 square millimeters for an entire heat or delivery, which gives a poor indication of material performance [10]. Other challenges using the ISO 6336 standard are the way material cleanliness affect factors such as the size factor. These factors do not take steel cleanliness into account in a relevant way.

TESTING OF GEAR LOAD CAPACITY

One challenge of gear testing is the diversity of the different damage types and the multitude of damage mechanisms. According to DIN 50322, there are different levels and test categories for testing of gear load capacity [30]. The back-to-back test rig is an established and standardized testing concept on the level of model tests [32]. During the test run of the so-called running test, a single gear set is tested regarding a specific damage type. The running test is suitable for testing the load capacity of all damage types, because the real meshing of the teeth is ensured. The running test is mostly used for material and lubricant qualification in research using standard reference gears. The center distance is constant and usually a = 91.5 mm. Furthermore, this
The test principle can also be used to determine the gear load capacity of industry applications using back-to-back test rigs with flexible center distance [16].

Testing of gear load capacity is an obligatory task in order to secure an optimized design of gearboxes. On the one hand, the functionality with regard to load capacity has to be guaranteed over the whole lifetime, while on the other hand, the production costs of each gear set have to be reduced to a minimum. The objective of gear testing regarding load capacity is the derivation of design parameters for the different damage patterns of gears (Figure 2). The design parameters can be used for calculating the gear load capacity according to ISO 6336 [8; 5-7].

The selection of a gear geometry is a crucial point for performing gear load capacity tests on a back-to-back test rig to derive design parameters. There are different damage patterns occurring on gears (see Figure 2). Besides scuffing, the fatigue damages tooth root breakage, contact fatigue strength (pitting), and tooth flank fracture are the most important damage types to avoid in application. The selection of a test gear geometry always has to fulfill the requirement that an appropriate separation of the different damage patterns is guaranteed. Therefore, the safety factor for the intended damage pattern should be below one, and the safety factors for all other damage patterns should be reasonably higher than one. For this reason, the module of the test gear for tooth root bending tests on a back-to-back test rig is always smaller compared to a pitting-critical gear geometry (Figure 2).

2.2 DEFICIT OF GEAR TESTING WITH STANDARDIZED GEAR GEOMETRY

For testing of pitting load carrying capacity, there are different standardized test gear geometries. The 17/18 test gear geometry is a well-established gear set for a back-to-back test rig with a center distance of a = 91.5 mm and was used in several research projects in the Forschungsvereinigung Antriebstechnik e.V (FVA, German Community for Drivetrain Research) [11, 29, 27]. Depending on the improvement of a surface finishing process of the tooth flank, the pitting load carrying capacity of the 17/18 gear could be improved to a level that tooth root breakage occurred instead of pitting damages [29]. For a center distance of a = 91.5 mm, the C-type gear is another pitting-critical test gear geometry that is mainly used for pitting tests with regard to oil performance [21]. The C-type gear also shows a potential for testing of pitting load carrying capacity of new or improved materials, such as high-performance clean steel. Furthermore, there are pitting-critical test gear geometries for back-to-back test rigs with center distances of a = 112.5 and 200 mm, such as the 21/23 and 24/25 test gear geometry [19, 12]. In order to securely avoid tooth root breakages, the face width of these test gears was improved by a stepped design of the face width [27, 2].

In order to determine the pitting endurance strength of a steel with higher cleanliness, several tests were performed on a back-to-back test rig using the C-type gear geometry (Figure 3). The endurance limit was determined using the stair case method [15, 9]. Because of the higher material performance, the contact fatigue strength (pitting) could be increased compared to existing test series based on the C-type gear geometry [23, 1, 26]. The allowable stress number according to ISO 6336-5 could be increased up to $\sigma_{H, lim} \approx 1,950$ MPa compared to the baseline of $\sigma_{H, lim} \approx 1,500$-1,650 MPa for MQ and ME material quality.

With increasing torque, the safety factor for tooth root strength decreases faster than for contact fatigue strength because of a linear relationship between the torque and the bending stresses (Hertzian pressure: square root relationship). Therefore, there was no clear separation of the damage pattern. On the highest load level, tooth root breakages as well as pitting failures occurred (Figure 3). For this reason, the endurance limit of the component can only be determined. Because of this, the full potential regarding pitting strength cannot be derived because tooth root breakages occur before the contact fatigue finite life limit is reached.

Furthermore, the damage patterns were evaluated in terms of micro pitting and scratches in the area of the tooth tip. For the increased torque of the test series, a premature tooth meshing could not be avoided with the applied tip relief of $C_{a1/2} = 20 \mu m$. Besides the impact caused by the premature tooth meshing, the contact area of the premature tooth meshing is also loaded twice because the contact starts in the direction of the tooth root and moves upwards again. Both effects influence the pitting load capacity and should be avoided [24, 14]. In order to determine the full potential regarding pitting strength...
of this material in gear applications, an optimization of the gear geometry is necessary to ensure a clear separation of different damage patterns and avoiding premature tooth meshing.

3 OBJECTIVE AND APPROACH
The continuous improvement of material performance levels leads to a change of the critical damage pattern of existing standard test gear geometries. The aim of this report is the definition of a test gear geometry for investigating contact fatigue strength (pitting) for these types of materials (Figure 4). For increasing endurance limits of high-performance steels, a secure separation of the different gear damage pattern still has to be guaranteed. For testing of contact fatigue, especially tooth root breakage has to be avoided because a tooth root failure directly finishes the test, and the data point cannot be used for the evaluation of the contact fatigue S/N Curve.

The increasing load in order to damage gears of high-strength material also leads to higher elastic deformations and a change of the pitch error under load from the tooth in contact and the following non-loaded tooth. In this case, the resulting premature tooth meshing has a more significant influence compared to smaller loads. The premature tooth meshing should be avoided in order to reduce the occurrence of scratch marks and resulting abrasive wear as well as micro pitting. Furthermore, the maximum torque of the test rig has to be considered in order to avoid damages of bearings and clutches of the back-to-back test rig. In future working packages, the changes of the macro and micro geometry of the test gear geometry are validated by experimental tests for high-performance clean steels.

There is a two-step approach for determining a pitting-critical gear geometry for high strength materials. In the first step, the macro geometry for a back-to-back test rig with a center distance of \( a = 91.5 \) mm is selected considering the potential regarding maximum contact pressure and a sufficient tooth root load carrying capacity. Therefore a comparison between the well-established, pitting-critical test gear geometries 17/18 and C-type performed using a diagram for defining an optimum face width depending on the test rig limits and the tooth root strength. The chosen macro geometry is optimized in terms of tooth root strength as well as the maximum Hertzian pressure considering the torque limit of the test rig. In order to fulfill both requirements, the face width is designed in a stepped way guaranteeing a sufficient tooth root strength as well as high contact pressure in the area of the smaller face width. The lead crowning is not changed to increase the contact pressure, since a point contact leads to a change of the lubrication conditions [13].

In the second step, the micro geometry regarding profile corrections is optimized for high loads. The premature tooth meshing resulting from the increased elastic deformation of the tooth is avoided by a circular tip relief. The tip relief is short according to NIEMANN/WINTER [18]. The definition of the amount of the tip relief is based on a FE-based calculation approach according to BRECHER ET. AL. [3, 4]. The other micro geometry corrections are taken over from the original design of the C-type gear [21].

4 SELECTION AND OPTIMIZATION OF TEST GEAR MACRO GEOMETRY
For the selection of the test gear macro geometry, the well-established gear sets 17/18 and C-type are compared to each other in the following chapter [11, 21]. Both gear geometries are pitting-critical for the contact fatigue strength of existing steels from standard gear applications, but showed tooth root breakages as the torque increases for high-performance steels or special surface finishing processes, see section 2.2 and [27]. In order to guarantee a high comparability to existing test results.
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of these gear geometries, the macro geometry is only optimized with regard to face width. All other gear parameters are kept constant compared to the original design of the 17/18 and C-type gear set (Table 1).

The aim of the adaptation of the face width is the increase of the maximum Hertzian pressure and likewise a sufficient tooth root strength. The contact pressure and the safety factor against tooth root breakage are calculated according to ISO 6336 [5-7]. At the beginning of the calculation, the constant input parameters are defined (Figure 5). Besides the material properties of the gears (Young’s Module: \( E_{1/2} = 206,000 \) MPa; Poisson’s number: \( \nu_{1/2} = 0.3 \)) the allowable stress number for tooth root strength is defined for a reference gear material (16MnCr5 case hardened: \( \sigma_{F,lim} = 430 \) MPa).

The tool geometry of the soft machining process (hobbing) is given in Table 2. The grinding stock is \( q = 120 \) µm with a tooth span of the finished part for the C-type gear of \( W_{k1/2,3\text{ teeth}} = 34.68/48.44 \) mm and for the 17/18 gear of \( W_{k1/2,3\text{ teeth}} = 39.72/39.69 \) mm. Based on the gear geometry and the input parameters of the material properties and the manufacturing process, the \( \text{Y- and Z-factors} \) according to ISO 6336 are calculated (Table 3). According to the standard, all factors are constant for a certain gear geometry and testing condition. An increasing load does not affect the \( \text{Y- and Z-factors} \) according to the overall calculation approach of ISO 6336. The test rig limitations of the back-to-back test rig with a center distance of \( a = 91.5 \) mm is a minimum torque of \( T_{min} = 150 \) Nm and a maximum torque of \( T_{max} = 715 \) Nm [22]. The maximum torque refers to the gear and the minimum torque to the pinion. The \( \text{K-factors} \) according to ISO 6336 for the back-to-back test rig are given in Table 4.

Finally, the calculation of the contact pressure and the safety factor for bending strength are calculated according to ISO 6336 depending on the face width and the torque. Based on the results, the maximum contact pressure can be derived considering the test rig limitations (maximum torque) and the safety against tooth root breakage (Figure 5).

The results of the calculation are shown for the 17/18 gear geometry in Figure 6. Based on the face width on the x-axis and the limitations of the test rig, the field of the contact pressure can be determined for different face widths. The maximum contact pressure is also limited by the safety factor for bending strength of the gear. The safety factor for bending strength \( S_F \) is a horizontal line because the ratio between the normal force and the face width \( F/b \) is always constant to achieve the same contact pressure. For small face widths, the maximum contact pressure is limited by the safety factor for bending strength. This type of diagram can be used to derive the optimum face width for contact fatigue tests depending on the expected range of contact pressures of the S/N curve. The derivation of the correct face width is important for high strength steel, but also for weaker materials, because the expected torque of the endurance limit should not fall below the limit of test rig.

Determining a critical safety factor for root strength \( S_F = 1.3 \), the maximum contact pressure limited by the bending strength is \( \sigma_{H,max,SE} = 1,900 \) MPa (Figure 6). Regarding the test rig limitations, there is a higher potential of the maximum contact pressure for small face widths, because with the same maximum torque of the test rig, the contact pressure progressively increases if the face width is lowered. In comparison to the 17/18 gear set, the C-type test gear geometry shows the same pattern in this type of diagram (Figure 7). The maximum contact pressure is also limited by the bending strength for low-face widths instead of the test-rig limitations. Considering the bending strength of the C-type gear geometry, the maximum contact pressure is similar to the 17/18 gear (\( \sigma_{H,max,SE} = 1,900 \) MPa).

For high performance materials and based on the test series in section 2.2, the contact pressure needs to be higher than the maximum contact pressure limited by the bending strength (\( \sigma_{H,max,SE} = 1,900 \) MPa). Therefore, the face width can be designed in a stepped way, determining a different face width in two sections. In this case, the face width below the pitch diameter \( b_{diff} \) of pinion and gear is wider in order to strengthen the tooth root. At the same time, the contact width \( b \) is small for the whole path of contact because the face width of either the pinion or the gear is small. At no point in the path of contact are the wider face width \( b_{diff} \) of pinion and gear in contact at the same time. This design approach has already been applied on a test gear with module \( m_n = 8 \) mm by TOBIE [28].
Applying a stepped tooth shape to both gear geometries, the maximum contact pressure increases and is therefore limited by the test rig limitations. In this case, the general potential with regard to the maximum contact pressure is higher for the C-type than for the 17/18 gear set. Choosing a face width of \( b = 10 \text{ mm} \), the maximum contact pressure for the C-type gear geometry is \( \sigma_{\text{H,max}, \text{C-type}} \approx 2,450 \text{ MPa} \) compared to the 17/18 gear set with \( \sigma_{\text{H,max}, \text{17/18}} \approx 2,300 \text{ MPa} \) (Figure 6 and Figure 7). Based on this analysis, the macro geometry of the C-type gear should be chosen as a test gear geometry for high strength materials.

It has to be noticed, that pinion and gear of the C-type gear set have an integral common divisor, which might lead to higher loaded teeth depending on pitch errors (hunting teeth).

Considering the high manufacturing quality of modern grinding machines, this hunting effect is not the main criterion for the choice of a test gear geometry.

For the final design of the optimized C-type gear, a smaller face width of \( b = 10 \text{ mm} \) is chosen in order to achieve the largest contact pressures. The face width below the pitch diameter \( b_{\text{diff}} \) is increased by factor 2 (\( b_{\text{diff}} = 20 \text{ mm} \)) in order to strengthen the tooth root (stepped tooth shape). The highest diameter of the wider section is \( d_{\text{stepped,1/2}} = 69/105 \text{ mm} \) with a radius of 2 mm between the wide and small face width. The design of a stepped tooth root guarantees a secure separation of the different damage pattern and high contact pressures.

5 OPTIMIZATION OF MICRO GEOMETRY

The elastic deformation of the tooth increases due to the higher endurance limit and, thus, required torque for testing of high-performance steels. The additional elastic deformation may cause premature tooth meshing. This irregular tooth contact is the reason for an increase of the stresses on the tooth flank. The purpose of a tip relief is to prevent premature tooth meshing and corresponding negative effects on the contact fatigue strength. The tip relief for the chosen C-type gear geometry in this report is designed based on a FE-based calculation approach according to BRECHER ET. AL. [3, 4]. In the first step, the elastic deformation is calculated for the point of contact, where the single tooth contact ends (D) (Figure 8, left). Based on the amount of deformation, the theoretical penetration of the following tooth is calculated. In the following step, further influences on the penetration caused by geometrical deviations are considered. Finally, the resulting theoretical penetration at the following tooth is calculated with regard to the local stiffness and the geometrical deviations caused by modifications and manufacturing tolerances.

Figure 8 shows the result of the calculation of the tip relief for the C-type gear geometry depending on the torque of the pinion and the face width of the contact area. In the upper part of the diagram, the contact pressure according to ISO 6336 is shown, whereas in the lower part, the amount of a circular tip relief is given to avoid premature tooth meshing. The tip relief is short according to NIEMANN/WINTER with diameters \( d_{\text{Ca1/2}} = 79.43/115.63 \text{ mm} \) [18].

In order to define the amount of the tip relief, the maximum contact pressure of the test series has to be estimated. From this point on the upper y-axis the intersection with the curve of the face width in both parts of the diagram leads to the amount of the tip relief in the lower part, compare Figure 8. Based on the test series in section 2.2, the expected maximum contact pressure for the endurance limit is approximately \( \sigma_{\text{H,max}} = 2,100 \text{ MPa} \). With a face width of the contact area of \( b = 10 \text{ mm} \), the premature tooth meshing is securely prevented with a tip relief of \( C_a = 85 \mu\text{m} \).

The wider face width below the pitch diameter increased the stiffness of the contact. Therefore, the design of the tip relief is on the safe side and a premature tooth meshing can also be avoided for higher loads. The test rig torque of the pinion for the contact pressure of \( \sigma_{\text{H}} = 2,100 \text{ MPa} \) is \( T_{\text{pinion}} = 350 \text{ Nm} \).

6 SUMMARY AND DISCUSSION

Increase of power density is a continuous challenge for the development of modern transmissions. The power density influences the production cost as well as the performance within the application because of weight reduction. During the design phase of transmissions, the fulfillment of load carrying capacity is guaranteed by the application of different calculation methods. For the calculation of pitting load capacity according to ISO 6336, the allowable stress number for contact fatigue \( \sigma_{\text{H,lim}} \) is required. In order to determine the allowable
stress number, experimental tests for different materials and process chains are performed on back-to-back test rigs. There are different, well-established test gear geometries, which are usually used for these standard tests in order to guarantee a comparability between different test series. The test gear geometries are designed in a way to force pitting damages and to avoid all other damage types such as tooth root breakage. With regard to an increasing power density, the endurance limit of the test gear geometry in terms of maximum torque increases. In this case, the safety factors for the different damage patterns (pitting and tooth root breakage) merge and a secure separation of the different damage patterns cannot be ensured.

In this report, a test gear geometry for investigating contact fatigue strength (pitting) of high-performance clean steels is determined. Based on two well-established test gear geometries for contact fatigue test, a detailed comparison with regard to their potential of maximum contact pressure is performed. The C-type test gear geometry is finally chosen and optimized regarding face width and amount of tip relief. The further gear macro geometry is not changed in order to guarantee a high comparability to existing test results. The face width is designed in a stepped way with a high face width below the pitch diameter and a small face width above the pitch diameter. In this way, the tooth root load capacity can be increased and at the same time, the contact pressure can be maximized because of the small contact area on the entire path of contact. The contacting face width is defined as \( b = 10 \text{ mm} \), and the face width below the pitch diameter is \( b_{\text{diff}} = 20 \text{ mm} \). Furthermore, the amount of the tip relief is optimized in order to avoid premature tooth meshing for the increased endurance limit. Based on a FE-based calculation method, a lookup table for the maximum contact pressure and different face widths are developed. The design of the tip relief is circular with an amount of \( C_v = 85 \mu \text{m} \).

Based on the optimized test, gear geometry pitting load carrying capacity can be investigated for high strength material without the risk of tooth root breakage and premature tooth meshing. In the next work package, this will be investigated for high performance clean steel. The allowable stress number for contact fatigue can be securely determined for future material improvements regarding pitting load capacity.

REFERENCES


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Gear Solutions magazine has been the most trusted source for information and technical knowledge in the gear manufacturing industry for more than 15 years.

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HIGH-END COATING CAN INCREASE GEAR-CUTTING PRODUCTIVITY
Using Oerlikon Balzers coating solutions, customers are able to increase their productivity, which results in higher total production output and lower manufacturing costs.

By OSNY FABRICIO

The machining industry’s demand for increased productivity and reduced costs continues to drive developments that focus on innovative, state-of-the-art tools and cutting materials as well as changes in production technologies. In addition, tailored tool coatings play a special key role in increasing cutting speeds, raising productivity, and lowering costs for demanding gear-cutting processes. Excellent performance can be achieved as demonstrated in customer tests with Oerlikon Balzers’ high-end coating Balinit Altensa.

The manufacture of durable, low-noise, and highly efficient gears, such as for transmission applications, is associated with enormous quality demands and a correspondingly high production effort. Industrial competition therefore demands both the shortest possible production times and low production costs.

MANUFACTURING COSTS AS A MAJOR ISSUE

Gears transmit movement, forces, and power in a system. Thus, they must perform even at the highest of stress levels, and cutting these high-precision geometries demands the utmost in performance of machines, tools, and coatings. The industry focuses on the best quality with the lowest processing times in order to provide long-lasting products with low-noise emission and high-gear efficiency. The key to this is the manufacturing process used for the gears, including the cutting tools, their coatings, and the productivity of the production process itself.

Production costs are a major issue in the machining and cutting industry. A closer look at the influencing factors shows the savings potentials that lie within the process:

- The tools themselves amount to only 8 percent of the total manufacturing costs, on average.

- Depending on the cutting process, cooling costs amount to 12 percent. Dry machining operations are used in many gear cutting applications, but this is not suitable for all of them.

- Setup costs (24 percent) can be lowered using coated tools that have a longer service life while maintaining the same level of operational reliability.

A minimum of 26 percent of total costs is allocated to other, restricted factors.

This leaves the actual cutting costs at about 30 percent — by far the largest single factor. The easiest way to reduce these costs is by improving the cutting speed: An increase of cutting speed from \( v_c=180 \text{ m/min} \) to \( v_c=350 \text{ m/min} \) makes it possible to reduce production costs by 25 percent, for example. (Figure 1)

EFFICIENCY THROUGH LONGER SERVICE LIFETIME

Modern wear protection coatings increase tool service life and, thereby, also ultimately reduce setup costs. Their strengths are, however, above all displayed in cutting applications, in which they enable significantly higher cutting speeds.

An example calculation based on tests with Balinit Altensa coating demonstrates this: If the speed of gear cutting can be increased from 200 to 300 m/min, machining time (primary and secondary times) goes down from 0.56 to 0.42 minutes per gear. This reduces machining costs by about 25 percent, based on the machine-hour rate. If one considers the overall costs of producing a gear, this represents a cost saving of about 10 percent. It thus pays to invest in new substrate materials or coatings.

CONFIRMED PRODUCTIVITY GAINS WITH BALINIT ALTENSA

Tests conducted on the premises of an Oerlikon Balzers customer, a renowned car manufacturer, used 90mm HSS hobs with Balinit Altensa. Compared to Oerlikon Balzers’ Balinit Alcrona Pro coatings, it was shown that a significant increase of 30 percent in cutting speed — from \( v_c=200 \) to \( 260 \text{ m/min} \) — was possible with no difficulty thanks to the innovative gear-cutting coating (Figure 2). What’s more, tool life was extended by 20 percent. A second series of tests showed that even at cutting speeds of 300m/min, which represents an increase of 50 percent, tool life was still longer than the original values obtained.

Balinit Altensa showed great results for carbide hobs as well. Under the high-speed cutting conditions of \( v_c=480 \text{ m/min} \), tool life was extended by more than 30 percent.
Carbide stick blades are used to produce bevel gears. Tests at an automotive supplier showed that tool life at moderate cutting speeds of \( v_c = 148 \text{ m/min} \) was increased by 70 percent with Balinit Altensa. At the same time, output rose from 1,200 to more than 2,000 parts. After this successful initial test, the customer agreed to increase the cutting speed by more than 35 percent. Even then, a 30 percent improvement in tool life was achieved. (Figure 3)

In addition to hobs and stick blades, tests with shaper cutters and power skiving tools were also carried out. Balinit Altensa delivered remarkable results here as well. HSS shaper cutters with a diameter of 130 were tested in wet operation — with the result being an increase in tool life of 140 percent. (Figure 4)

**IMPROVED CONDUCTANCE AND HOT HARDNESS**

Balinit Altensa is the coating from Oerlikon Balzers’ successful AlCrN-family to excel, above all, in terms of wear resistance, thermal shock stability, and hot hardness. In essence, Balinit Altensa reduces thermal conductance and improves the hot hardness of the coating by more than 20 percent. This produced even greater crater wear resistance, which can, in particular, occur at high service temperatures and reduce tool service lifetime.

Abrasive wear resistance was, moreover, optimized by about 35 percent, as was oxidation resistance. This reduces flank wear at moderate and high cutting speeds and extends tool service life, even with dry machining. The bottom line is that the numerous improvements in layer development enable considerable productivity gains with longer tool lifetimes, significant performance boosts at the highest cutting speeds for all substrates (PM-HSS, MC90, carbide), as well as...
higher cutting speeds and feeds.

**BALINIT ALTENSA: MORE PERFORMANCE, REDUCED COSTS**

Using Oerlikon Balzers coating solutions, customers are able to increase their productivity, which results in higher total production output and lower manufacturing costs. Balinit Altensa, the innovative Oerlikon Balzers gear-cutting coating, leads to unprecedented tool service life and more reliable processes at higher cutting speeds. This not only saves money, but also sets the performance level for the ever-demanding gear cutting process.

**ABOUT OERLIKON BALZERS**

Oerlikon Balzers is one of the world’s leading suppliers of surface technologies that significantly improve the performance and durability of precision components as well as tools for the metal and plastics processing industries. Extremely thin and exceptionally hard coatings, marketed under the Balinit and Baliq brand names, reduce friction and wear. The Balitherm brand opens up a broad range of heat-treatment services, whereas Baltone comprises coatings that are available in a full range of elegant colors, perfectly suited for decorative applications. Balimed ThinFilm coatings — with wear-resistant, biocompatible, antimicrobial, and chemically inert properties — have been developed especially for medical applications. Under the Balifor technology brand, the company has introduced technologies that provide tailor-made solutions for the automotive market, while ePD allows the metallization of plastic parts with a chrome look.

Worldwide, more than 1,100 coating systems are in operation at Oerlikon Balzers facilities and its customers. Equipment engineering and assembly of Balzers’ systems are processed in Liechtenstein, in Langenthal (Switzerland) and in Bergisch Gladbach (Germany). Oerlikon Balzers operates a dynamically growing network of more than 100 coating centers in 35 countries in Europe, the Americas, and Asia. Oerlikon Balzers is — together with Oerlikon Metco and Oerlikon AM — part of the Surface Solutions Segment of the Switzerland-based Oerlikon Group.

**ABOUT OERLIKON**

Oerlikon engineers materials, equipment, and surfaces and provides expert services to enable customers to have high-performance products and systems with extended lifespans. Drawing on its key technological competencies and strong financial foundation, the group is sustaining mid-term growth by executing three strategic drivers: addressing attractive growth markets, securing structural growth, and expanding through targeted mergers and acquisitions. A leading global technology and engineering group, Oerlikon operates its business in two segments — Surface Solutions and Manmade Fibers — and has a global footprint of more than 10,500 employees at 175 locations in 37 countries. In 2018, Oerlikon generated CHF 2.6 billion in sales and invested around CHF 120 million in R&D.

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Using a multi-purpose machine will aid in reducing potential manufacturing errors while significantly reducing a shop’s overall footprint. (Courtesy: Haas Schleifmaschinen)
By offering 5-axis grinding machines and customizable application software that can perform multiple operations, Haas Schleifmaschinen GmbH is making quite a name for itself in several industries, including gear manufacturing.

By KENNETH CARTER, Gear Solutions editor

When a gear or a geared shaft is being produced, it’s often moved through several machines before the finished product is ready. But Haas Schleifmaschinen GmbH has the capability of offering gear manufacturing that takes the multiple machines out of the process.

“We’re about combining operations,” said David Drechsler, business development manager for Haas Multigrind® LLC in the U.S. “For example, shoulders, diameters, threads, worms, and much more complex parts typically would move through a shop on several machines — four, five, six machines. And, of course, every time a part moves, it’s an opportunity to introduce error. What we are about in the gear market is combining multiple operations — multiple complex high precision features — into one clamping.”

Not only will one machine aid in reducing potential manufacturing errors, but it can also significantly reduce a shop’s overall footprint, according to Drechsler.

“When you combine that floor space, you combine the operations, and you improve the overall precision of the workpiece by grinding all those features off of one set of locating features (datum features),” he said.

**5-AXIS CNC GRINDING CENTERS**

Haas Schleifmaschinen offers in the Multigrind® series several models of 5-axis CNC grinding centers that can grind parts from three millimeters up to three meters. All of the company’s machines have an option for an automatic wheel changer and onboard wheel dressing. Those technologies are what enable Haas’ customers to combine operations, according to Drechsler.

Another advantage that Haas offers is its custom application software that allows for customer-specific jobs, according to Haas Multigrind® LLC General Manager Harry Schorner.

“Our machines are built to base models, but then the last 20 percent are application specific,” he said. “We do customer-specific designs, and we have the capability to provide a solution very, very quickly because of the combined effort of machine design as well as the application software, which then allows us to program to the machine in a particular environment, which is very cost effective and easy to do for the customers.”

With increased automation being the trend in the gear-manufacturing industry, Drechsler stressed that Haas is riding the crest of that innovation wave.

**TURNKEY SOLUTIONS**

Haas also offers what Schorner refers to as turnkey solutions that allow a customer to add secondary operations to the machine.

“With robotic automation, we can also include additional secondary operations such as cleaning, marking, deburring as well as measuring the part and then feeding the measurement results of data back to the machine where the machine automatically makes the adjustments for the next part,” he said. “We offer different forms of automation and integrate all this within one complete system.”

Of course, the machines are only as functional as the software allows, and Schorner said Haas’ software is something he is extremely proud of.

“Multigrind® Horizon is the name of our application software, and we spent a lot of time and effort on it as well as money,” he said. “Multigrind® Horizon today is very universal to use, and it is operator friendly within the industries we serve, such as aerospace, cutting tools, gears and the medical industry. We are, for example, the leading machine tool supplier for producing medical implants such as knee...
implants or medical surgical instruments.”

**3D SIMULATIONS**

Schorner said Haas Schleifmaschinen recently had a breakthrough with their software’s ability to create 3D simulations, where it uses NC or ISO codes to generate a 3D model of a part, which simulates the exact features and geometries of the actual physical part that would come off the machine.

“With this simulation, called Multigrind® Styx, the programmer or engineer is now capable of verifying that the tooling, the grinding technology parameters, and other geometry data he inputs into the software will actually create the part he desires,” he said. “The other thing is, within our application software, the customer has the ability not only to simulate or illustrate the part itself, but the entire machine can verify collision detection and take a big portion out of the trial and error approach throughout its setup.”

This software ability to create 3D simulations can save time, which ultimately saves the customer money, according to Schorner.

“When a machine is not running, it’s just sitting while waiting for it to be set up; this all costs money,” he said. “With the things we are offering to the customer, there is a significant reduction in setup time. We also have the ability in our application software to utilize these features not just to determine the grinding parameters, but also to design the tooling.”

If the operator or the customer is not familiar with the grinding technology, he can input his 3D model or even create a 2D profile of the part he wants to produce, according to Schorner. Haas can take that data and calculate the profile of the grinding wheel needed.

**TAKING IT TO THE CUSTOMER**

“One-stop grinding” is definitely the direction much of gear manufacturing is headed, but it still can be a challenge to convince potential customers of that, according to Drechsler.

“A lot of people believe, correctly, that if it sounds too good to be true, sometimes it is, so we do look for opportunities, niches,” he said. “We’re not competing head-to-head against the established, dedicated gear-grinding machine builders. They make very fine machines that are used to mass produce gears. Likewise, with an OD grinder, we don’t compete directly with OD grinders, although our machines can do that operation. It’s the same way with thread grinders, even cam grinders. What we’re looking for is niche applications where it makes technical and commercial sense to combine those operations.”

**MOVING INTO GEARS**

Since Haas Schleifmaschinen opened its doors in the southwest of Germany in 1934, it has always produced multi-axis high precision grinding machines. In the beginning, those machines served the automotive and watch-manufacturing industries, but Haas has been making more and more inroads into the gear industry, according to Drechsler. Haas Multigrind® LLC is Haas Schleifmaschinen’s daughter company in the U.S.

“With regard to gears, it’s a relatively new market for us,” he said. “When people think about gear-grinding machines, Haas probably doesn’t rise to the top of the list, but we’re having this conversation and other conversations in an effort to improve that.”

Part of that conversation is creating a larger U.S. presence, according to Schorner. That includes relocating to Charlotte, North Carolina.

“We are already securing a bigger facility where we’ll have the possibility to better serve our customers with more resources, including more service technicians to provide repair and maintenance,” he said.

Those resources will allow for better response times, as well as application engineering side with training seminars and program-
“Many times, machine tool builders offer a standard product and a standard approach on how to produce the product. We actually like the challenges. We like to take new challenges and develop new technologies, working with customers when they have ideas. We take those ideas, and we turn them into reality.”

Family Owned
Schorner pointed out that with Haas being a fairly common German name, the company sometimes gets associated with Haas Automation; however, the two companies are not related.

“The only thing we have in common is the name,” he said. “It is a very common name in the southern region of Germany.”

But Haas is making a name for itself in its own right. And with all of its innovation, it’s sometimes easy to forget that Haas Schleifmaschinen is, ultimately, a third-generation, family-owned company, according to Schorner. That familial bond often carries through to the relationships Haas forges with its customers.

“We are the first ones raising our hands to say, ‘Yeah, we will work this; we will help,’” he said. “We have a strong R&D and software development department, and this is what we’re focusing on.”

And that boils down to offering more to its customers than just an off-the-shelf product, according to Schorner.

“Many times, machine tool builders offer a standard product and a standard approach on how to produce the product,” he said. “We actually like the challenges. We like to take new challenges and develop new technologies, working with customers when they have ideas. We take those ideas, and we turn them into reality.”

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Hexagon asset management solution optimizes CMM

Hexagon’s Manufacturing Intelligence division launched HxGN SFx | Asset Management, a cloud-ready software solution that helps manufacturers achieve operational excellence by offering easy access to real-time machine status and utilization reporting.

The software unlocks the data typically siloed in individual coordinate measuring machines (CMM) to provide real-time insight into the performance, use, and status of multiple CMMs across one or several sites. A web- and mobile-enabled dashboard provides real-time visibility of the health, availability, and performance status of CMMs, in single or multiple locations. Manufacturers can shift from managing assets as a cost center to optimizing equipment profitability and value creation. And the data aggregated by SFx Asset Management can be used to preemptively schedule maintenance and identify sources of downtime.

With HxGN SFx | Asset Management, it is also possible to quickly identify which site has spare capacity and gain insight into how systems are used. And because SFx Asset Management is cloud-based, information can be accessed anywhere from a PC, smartphone, or tablet.

Asset performance management software plays a crucial role in optimizing overall equipment effectiveness (OEE). As its name suggests, OEE is a measure of how effective machines are. It can be calculated either for a single coordinate measuring machine (CMM) or for a set of CMMs over various periods of time. An understanding of a CMM’s OEE can help reduce spending on maintenance while achieving better overall machine performance and efficiency.

“SFx Asset Management moves manufacturers towards the smart factory by giving them the real-time data that makes them more flexible, effective, responsive, and competitive. Smart manufacturing is based on the most accurate and actionable information, and the first step is to reach a deeper knowledge of your machinery’s operational fitness,” said Scott Mahrle, SFx Asset Management product manager.

The Lite and PRO versions are now available online. They are compatible with PULSE, PC-DMIS, and any Hexagon CMM that uses DC, RC, or H3C controllers and will support an expanding range of industrial equipment.

MORE INFO  www.hexagon.com

Mahr introduces new high-resolution digital indicators

Mahr Inc., a global manufacturer of precision measurement equipment used for dimensional metrology, has added a new higher-selectable resolution option to MarCator 1086R and 1087R digital indicators making its indicator family one of the most fully featured and versatile available. These digital indicators provide easy operation, a large display, powerful application features, and simple transmission of measurements with their wired or integrated wireless system.

The new option offers six different resolutions, ranging from 0.00001 inches to 0.0005 inches (0.0001 - 0.01 mm). MarCator digital indicators with the selectable high-resolu-
tion option include the 1086 R-HR with large display and the 1087 R-HR analog/digital display and dynamics. These indicators include Mahr's MarConnect data output, allowing for three choices of data output (USB/RS232 or Digimatic) depending on the data cable plugged into the indicators.

Both new digital indicators are available in either 0.5 or 1-inch (12.5 or 25mm) versions. Along with the higher resolutions, these new digital indicators also provide higher performance. Short range performance is better than 20u" (0.5um) and within 70u" (1.8um) for the 0.5-inch (12.5mm) version and 0.0001" (2.2um) for the long range 1-inch (25mm) version.

To switch the indicator's resolution, the user simply enters the main menu of the indicator and scrolls over to the “resolution display.” From there, the up-arrow option can be used to choose the appropriate resolution to accommodate varying gaging applications.

These digital indicators also include standard features such as rotating display, a reference system that remembers the zero location for fast turn on and use, three-year battery life, IP42 protection, and MarConnect Data output controlled by MarCom software. Mahr's MarCom software makes data acquisition simple; users can take a measurement and send data directly into Microsoft Excel or via a keyboard code into any Windows program.

MORE INFO  www.mahr.com

Dillon collet pad jaws and collets grip more varied geometries

Collet pad top jaw systems from Dillon Manufacturing allow more varied geometries to be securely gripped, while also allowing more aggressive machining which shortens cycle times. With systems that can convert thru-hole chucks to hold small bar and tube stock, and full contact of gripping surfaces to provide a more stable grip and allows heavier cuts, these Dillon products allow shops of all sizes to expand their capabilities. Collet pads can be changed quickly, thus maximizing production time. Jaws can be adapted to many styles of chucks, making them ideal for special purpose machining. Dillon collet pads and jaws are ideal for precision boring, high-speed machining, tapping, drilling, and finishing. They are especially suited for small-diameter machining of stems, spools, crimp assemblies, mani-

Dillon collet pads and jaws are ideal for precision boring, high-speed machining, tapping, drilling, and finishing. (Courtesy: Dillon Manufacturing)
accomplished in just minutes with simply a jaw change, which is much faster and easier than changeover of entire chucks. The use of collet pad jaws allows users to maximize their chuck capabilities and more fully amortize their chuck investment by performing both chuck and collet pad projects.

All products are designed and manufactured by skilled and experienced engineers, using an integrated computer system tracks production, in ISO 9001:2015 facilities.

MORE INFO  www.dillonmfg.com

Chiron vertical machining center series for large components

The recently introduced Chiron FZ/DZ 25 vertical machining center series is designed for highly productive machining of complex, large volume structural components for the automotive and aerospace industries.

With a spindle distance of 800 millimeters and spindle speeds to 20,000 rpm, the two-spindle DZ 25 P 5-axis introduced at EMO 2019 is designed for double-spindle machining of large aluminum structural components with a work area up to 799mm diameter per position.

The series of twin spindle machines is designed for machining high-value components with a combination of productivity, accuracy and flexibility unrivaled in this class, according to a company spokesman. Pallet size under each spindle is 630 x 630 mm. Up to 60 HSK63 tools can be assigned to each spindle with chip to chip time of 3.5 seconds.

Spindles travel independently of each other in the X and Z direction, cooperating smoothly with user-selected automation options. Travel in X, Y, and Z are 800mm, 1,100mm, and 800mm. The highly dynamic machine offers rapid travel speeds of 120/75/75 m/mi, and acceleration of 10/10/15 m/s².

Operation and loading take place on separate sides of the machine, which is a major advantage for processing large workpieces. This allows optimum access to the working area and a good view of the process — even if the machining center is supplemented by a pallet changer for workpiece changes during machining. Automation options available from Chiron for the machine include a robot, pallet changer, and pallet changer plus robot. The machine can also be direct loaded by gantry in high-production systems.

The machining centers are operated via the Chiron TouchLine control system in conjunction with Siemens or Fanuc controls and the large panel on which the machine status can be monitored at any time. The 25 series is prepared for the Chiron SmartLine modules RemoteLine, DataLine, and ProcessLine, ensuring an additional productivity boost.

The 25 series also requires only a small amount of floor space, thanks to its compact design. Its optimal dynamics make it a compelling offering in this competitive environment, the company said.

The Chiron Group, headquartered in Tuttlingen, is a global company specializing in CNC vertical milling and turning machining centers, as well as turnkey manufacturing solutions. The Group has a global presence, with production and development sites, sales, and service subsidiaries, and sales agencies worldwide.

MORE INFO  www.chironamerica.us

New GPT planetary gearbox family has numerous gear ratios

The new metal GPT planetary gearbox family is characterized by its compact dimensions, high torque, and very fine graduations of the numerous gear ratios. It is robust and tolerates both frequent as well as sudden load changes. The gearheads operate with high efficiency, can be combined with many different motors, and enable various shaft configurations.

The pure metal GPT gearheads achieve performance values comparable to more expensive technologies on the market such as ceramic components. The gearheads are available with diameters of 22, 32, and 42 millimeters. The gearheads achieve top values for torque as well as for speed. Compared to the predecessor models, the continuous input speed was more than doubled above 10,000 rpm, and can support input speeds up to 20,000 rpm in intermittent mode. The 42GPT Series can sustain an intermittent torque up to 25 Nm while its length is squeezed down to 71 millimeters. The GPT gearheads are designed to be robust and tolerate both continuous as well as very abrupt and sudden load changes. At the same time, they are significantly shorter than other models in the same diameter.

The gearheads can be equipped with up to four reduction stages. Each stage is individually optimized to achieve the highest power in terms of torque and speed. An important feature of the product family is the high number of available gear ratios and their very uniform distribution. As a result, the motor power can be used optimally: A higher torque can be achieved with the same input speed, and a higher speed can be achieved with the same torque. In addition, power consumption is significantly reduced through a much higher efficiency. Compared
to previous product generation, the new GPT family is also particularly suited for accurate positioning applications granted by a very low backlash characteristic.

With high performance values and the great robustness, the gearheads of this new product family are suitable for various demanding applications. The compact design fits particularly well with the new BXT brushless flat motor family when size is a key constraint integrating actuators inside applications. A large selection of DC motors is also available in combination with the new GPT gearhead family. They are ideal for different types of robots — inspection, assembly, rehabilitation, or exoskeletons — as well as for production and laboratory automation, packaging machines, measurement and testing equipment, or for semiconductor handling.

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Optomec delivers 500th industrial 3D printer for additive manufacturing

Optomec, Inc., a privately-held supplier of proprietary additive manufacturing equipment and software, has delivered its 500th industrial 3D printer. The machine is installed at a division of General Electric, which now counts more than 20 Optomec systems in use across GE business units including aviation, healthcare, power, and oil and gas.

For 20 years, Optomec has been at the forefront in delivering additive manufacturing (AM) solutions targeted at industry’s most challenging needs. The company has invested more than $50 million developing its proprietary solutions for 3D-printed metal and 3D-printed electronics, resulting in a comprehensive intellectual property portfolio that includes more than 60 patents issued and a wealth of enabling materials and process knowledge.

Optomec’s installed base of 500 Industrial 3D printers includes more than 200 LENS® machines for 3D-printed metal, where Optomec was first to market with a DED (directed energy deposition) based solution. These metal printers are used for a range of high ROI production applications including short-run manufacturing, upfront wear coatings and rebuild of worn or damaged components. The solution compares favorably versus other metal printing solutions such as powder bed fusion and binder jetting.

Additionally, Optomec has fielded almost 300 of its patented Aerosol Jet® systems for 3D-printed electronics. These machines are used in production for applications including high-density 3D semiconductor packaging and directly integrated 3D antenna and sensors, for industry leaders in consumer elec-
In addition to GE, Optomec customers include Samsung, Lockheed, Panasonic, Siemens, Honeywell, United Technologies, Northrop, NASA, and the U.S. Navy, Army, and Air Force. The company has users in more than two dozen countries across North America, Europe, and Asia.

“We are proud to have delivered our 500th Industrial 3D printer, and appreciate the confidence that our customers have shown in our products as we have now surpassed more than $250 million in cumulative sales,” said Dave Ramahi, Optomec CEO. “We are seeing increased industrial adoption across target applications in both metals and electronics, which will lead to a continued acceleration in growth.”

Optomec is a privately held, technology-rich supplier of industrialized additive manufacturing solutions that include equipment, software, and digital products.

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Frenco Gmbh offers a new horizontal slide option for spline inspections. (Courtesy: Frenco Gmbh)

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Schunk updates slim hydraulic expansion toolholder

Three years ago, Schunk launched the slim hydraulic expansion toolholder Tendo Slim 4ax. Schunk now launches a version with cool-flow technology.

The precision mounting of the original Tendo Slim 4ax combines the outside geometry of heat shrinking mountings according to DIN 69882-8 with the proven qualities of Schunk hydraulic expansion technology. The new version with cool-flow technology allows for highly effective cooling via tool mountings.

The Tendo Slim 4ax cool-flow toolholder offers various advantages when it comes to machining of steel, aluminum, and plastic.

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The coolant or water jet does not depend on the unclamped length and always optimally adapts to the metal-cutting process. In contrast to heat shrinking mountings, the jet of the Tendo does not bounce back along the whole unclamped length of the tool shank, but instead fully surrounds the tool shank up to the cutting edge. This is a benefit for cooling the cutting edge, improving the chip removal, and increasing efficiency of the overall process. Pilot applications in the field of tool making show that the vibration-absorbing mounting cool-flow technology particularly pays off in the form of an excellent surface quality when roughing, pre-finishing and finishing. Moreover, reworking measures and tool costs are reduced.

In contrast to heat shrinking toolholders, the Tendo Slim 4ax seamlessly fits into the proven program of hydraulic expansion technology from Schunk with its permanently precise run-out accuracy of < 0.003 mm at an unclamped length of 2.5 x D, and a balancing grade of G 2.5 at 25,000 rpm. Moreover, the shape and positional tolerances can be met precisely. Like all Schunk Tendo hydraulic expansion toolholders, the Tendo Slim 4ax is also proven in terms of perfect vibration damping and a rapid tool change by using an Allen key. Investments into expensive peripheral equipment are not required. Since the precision mounting of conventional heat-shrinking toolholders can be easily replaced by Plug- & Work without having to reprogram the outside contour, their advantages can be directly tested or permanently used. The slim mounting with cool-flow technology will be available in the lengths of 90 mm and 120 mm for the interfaces HSK-A63 between Ø 6 mm up to Ø 32 mm. The interfaces for SK 40 with Ø 6 mm up to Ø 32 mm will be available in mid-2020. Further interfaces such as BT 40 and length variants with 160 mm are being planned.

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“Staying on top of the latest trends and giving customers the tools they need to effectively do their job is a motivating factor for us.”

What’s a typical day like for you at BIG KAISER?
As the engineering manager, I help guide the engineering department. I’m also hands-on as we do a lot of application support. Whether that’s traveling around the country to visit customers or provide support over the phone, our goal is to make sure our tools work out in the field.

What does BIG KAISER do for the gear manufacturing industry?
BIG KAISER is a combination of things. We have many types of tool holders and get into special arbors and things for the gear-manufacturing industry. We have angle heads, which are used a lot to cut internal keyways or splines.

We also have boring tools, and while they’re not used a whole lot in the gear-manufacturing industry, the need for boring tools arises from time to time.

You've recently enhanced your online access to BIG KAISER’s 2D and 3D tooling data. What was the reason for that?
Our customers are requesting 2D and 3D data on a daily basis, and we’ve added the data to our website to make their jobs easier.

The industry has gone through a transformation. When I first started 20 years ago, we were working on 2D applications; 3D was just emerging. To see the industry progress to where you can do all the simulations and verifications before you even attempt to run a part really requires a lot of digital data that wasn’t necessarily fully available or interchangeable.

The hardest thing was always getting a file from a company. When you finally got the files and brought them together, you had to reconcile layers and how things were put together in each metric, among other challenges, before you had data you could use.

Using the DXF standard allows customers to combine products from multiple companies with unified layer structures and eliminates some of those challenges. Now, multiple files from multiple vendors should work interchangeably with each other. You don't have to do all that translation on your own.

How will this enhancement further aid your clients and customers?
Getting consistent file formats will ease or eliminate some of the responsibility for the operator. The files also are being used by most of the CAD/CAM systems out there. Whether using tool management software such as our own Intelligo for our tool presetters or TDM; verification software such as Vericut; or CAD/CAM software such as Mastercam, ISPRE, or one of the other systems, the same file can be used across all platforms interchangeably. You're working from the same dataset in your CAD program and your verification software. It really makes things a lot simpler.

Could you give an example of how this worked for one of your customers?
I find that just about every one of our customers these days is using these files in their planning or in their CAD systems, their verification systems, and their programming systems. It’s giving them that availability to integrate our products into it. Pretty much everyone is using this type of technology, and it’s getting to a point where it’s easier to use now that there’s a standard.

You mentioned that growing standard, could you go into more detail about what that means?
There was an ISO standard developed that gives you a template to follow to be able to exchange data with all these different systems. Part of that was with the DXF files, which define everything about the layer structure — from names and colors to line weights — so when you put multiple components together, they’re on the same layer system and match up exactly. It’s very easy to take single components and turn them into a full assembly.

They also include layers for the cut and no-cut boundaries, specifically for verification software. So, I’d be able to generate a profile of what will be happening if that tool holder is spinning. The second part of it is into the 3D graphics. There’s the 2D, but the standard also covers 3D step files to take them directly into verification software without having to translate it in any way. And then the third part is that the data file helps the software identify what it is and gives it specific information such as what type of tool and some of the dimensions in a data file. Within those three parts, they should have enough information to use it in a variety of software applications.

Can you give an idea of how much time is saved with these standards in play now?
It’s going to be hard to put a number on it. Preparing data for input into your own system was a large investment in time and manpower. Just a simple step of getting most of the files on the same layer setting eliminates that entire job or most of that job, instead of changing layers and copying and pasting. The data manipulation part of it is a huge time savings.

What does BIG KAISER hope to achieve by transitioning to this drawing standard?
We hope to give the customers the tools to be able to implement our products as this industry progresses into Industry 4.0. If you don’t have digital documents available for your customers, the customers are going to go somewhere else. Staying on top of the latest trends and giving customers the tools they need to effectively do their job is a motivating factor for us.
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