2020 FTM Virtual Meeting

Join us for the latest research being conducted in the gear industry.

October 5-19, 2020: Papers and Presentations Available for Viewing

October 20, 2020: LIVE Q&A Sessions & Virtual Networking
A Virtual Experience
*Delivering the same quality and content you’ve come to expect for the past 50 years*

The 2020 Fall Technical Meeting (FTM) is a true testament to the resiliency of the gear industry. Innovation does not stop because of a global pandemic and neither do we. This year, our conference is online, but the quality and content remain the same as they have for the past fifty years.

The FTM provides an incredible opportunity to share ideas, concepts, and real application with others in the gear industry on design, analysis, manufacturing and application of gears, gear drives and related products in the power transmission industry. Attendees, on a global scale, get a chance to be on the cutting edge of gear research and still get to network with peers.

**Pricing**

- **Member Price for individual attendee** ................................................................. $349.00
- **Non-member Price for individual attendee** ......................................................... $499.00
- **Student Rate (with proof of scanned ID and student email)** ..................................... $75.00

*Students must fill out the registration form on the AGMA website.

Please note that each individual person should have their own registration even if you share a work space with a colleague. If your company would like to discuss a group discount, please email lewis@AGMA.org.

**Networking at the Virtual FTM!**

One of the most important aspects of the FTM is the interaction that gear-industry professionals are able to have to discuss the current and future innovations in manufacturing. This year, face-to-face is going to look a little different (as it will be on a screen), but we are dedicated to making sure attendees get to share their knowledge with each other. Join your peers and hop on a virtual video call to talk about industry, share thoughts and ideas and to even play a gear trivia game with some pretty incredible prizes. We look forward to seeing you online October 20th!

**Thank you to our Sponsor!**

*Please contact Leah Lewis at lewis@AGMA.org if you are interested in becoming an FTM sponsor.*
Schedule

OCTOBER 5-19, 2020 – Papers & Presentations Available for Viewing

Two weeks prior to the live Q&A sessions: All recorded presentations and technical papers will be available 24/7 to watch on-demand at your convenience starting on October 5. Catch up on the technical content and prepare your questions to ask our live panelists for Q&A on October 20.

TUESDAY, OCTOBER 20, 2020 – Live Q&A Sessions, Networking, and More

<table>
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<tr>
<th>Time</th>
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| 9:15 am ET – 10:15 am ET | Live Q&A Session               | Aitor Arana, Mechanical and Industrial Production of Mondragon University, Spain  
                             |  | Andreas Beinstingel, Renk AG, Technical University of Munich, Germany  
                             |  | Yi Guo, National Renewable Energy Laboratory, United States  
                             |  | Dominik Kratzer, Gear Research Center (FZG), Technical University of Munich  
                             |  | Parviz Merati, Western Michigan University, United States  
                             |  | Moderator: Todd Praneis |
| 10:30 am ET – 11:15 am ET | Live Q&A Session               | Philipp Norgauer, Gear Research Center (FZG), Technical University of Munich  
                             |  | Robin Olson, Rexnord Industries, United States  
                             |  | Daniel Vietze, Gear Research Center (FZG), Technical University of Munich  
                             |  | Matthew Wagner, Applied Research Lab, Penn State, United States  
                             |  | Christian Westphal, Laboratory for Machine Tools and Production Engineering, RWTH Aachen University, Germany  
                             |  | Moderator: Todd Praneis |
| 11:15 am ET – 12:00 pm ET | Open Discussion and Trivia Game| Attendees will join video networking session for open discussion and a chance to win a free 2021 FTM registration during the trivia game! |
Quasi-Static Transmission Error Behavior Under the Composite Effects of Temperature and Load

Aitor Arana
Mechanical and Industrial Production of Mondragon University, Spain

Current demands for enhanced rotational speed in geared transmissions affect the thermal behavior of mechanical parts by increasing their steady-state temperature. Lubricating film thickness is reduced, increasing the failure probability, and if temperature levels are sufficiently high, thermal distortion can affect mesh behavior. In this work, a custom back-to-back test rig is used to experimentally analyze the composite effect of temperature and load in terms of backlash, mean level of transmission error and its peak-to-peak value. The experimental results are then compared to analytical predictions.

Aitor Arana is a lecturer in the department of Mechanical and Industrial Production of Mondragon University in Spain and a researcher in the Structural Mechanics and Design group of its Faculty of Engineering since 2008. He holds two mechanical engineering degrees from Ecole Centrale de Nantes in France and Mondragon Unibertsitatea in Spain, a Master of Research on Applied Mechanical Sciences and a PhD thesis in thermo-mechanical behavior of gear transmissions. His main research expertise is in the field of mechanical design, tribology and analytical modelling of machine element behaviour (gears, bearings, spline couplings, ball-screws...) regarding performance, durability and/or NVH. He has participated in 17 research projects funded by industry and public administrations and he has published 4 journal papers, 1 patent and 16 conference contributions.
Thermal Lead Correction for High Speed Gears

Andreas Beinstingel
Renk AG, Technical University of Munich, Germany

Temperature distribution in high-speed gears of large dimension and high power density is much different in operation as compared to manufacturing. Therefore, the influence of non-uniform thermal growth should be accounted for with suitable lead modification, as it is demanded by the latest version of API 613. For many years, RENK has been using empiric methods for thermal lead correction based on measurements and experience. This paper compares a complex finite element calculation to the original method and develops a simplified approach for quick and reliable heat analyses for thermal lead correction of high-speed gears.

Andreas Beinstingel is a Computational Engineer for industrial and marine gears with a focus on Structural Dynamics and Acoustics. He has a Bachelor Degree in Mechanical Engineering from Augsburg University of Applied Sciences and a Master Degree in Computational Engineering from Munich University of Applied Sciences. He joined the transmission industry at the beginning of 2015 at RENK AG Augsburg as a Software Developer in the field of Structural Mechanics. Since 2018, he is also been working as an external PhD student at the Chair of Vibroacoustics of Vehicles and Machines (VIB) at the Technical University of Munich (TUM). The research partnership between RENK AG Augsburg and TUM includes the investigation of profile deviations of involute gear teeth under operating conditions within its mathematical implementation in simulation algorithms.
Validation of a Generalized Formulation for Load-Sharing Behavior in Epicyclic Gears for Wind Turbines

Yi Guo
National Renewable Energy Laboratory, United States

In an ideal epicyclic gear set, every parallel gear path transmits the same amount of torque. However, it is well known that certain manufacturing variations result in unequal load sharing between the parallel gear paths. Previous works have developed and validated a general closed-form analytical model of this phenomenon. In this paper the analytical model has been reformulated to include the effects of gravity, carrier bearing clearance, and external applied moments. The model is compared to load measurements collected from two similar wind turbine gearboxes with three-planet epicyclic gear sets, and also compared to the mesh load factor requirements in the ANSI/AGMA 6006 and IEC 61400-4 wind turbine gearbox design standards.

Yi is a senior scientist at National Renewable Energy Laboratory (NREL). At NREL, Yi is dedicated to research and development in dynamic modeling, reliability analysis, vibro-acoustics, data analysis, and design optimization of wind turbine drivetrains and wave energy devices. Prior to NREL, she pursued her Ph.D. research at Ohio State University with specialization in dynamics, vibration, and acoustics of wind turbine and helicopter drivetrains. She received her M.S. and B.S. degrees from Xi’an Jiaotong University in China with the focus on fluid mechanics. Yi has published numerous journal articles, conference papers and technical reports with over 1,000 citation records.
Effects of Different Shot Peening Treatments in Combination with a Superfinishing Process on the Surface Durability of Case-Hardened Gears

Dominik Kratzer
Gear Research Center (FZG), Technical University of Munich

There have been extensive scientific studies in the past on the positive effects of shot peening and superfinishing, however a detailed quantification of a calculation model of these two effects has not been subject to in-depth investigation yet. To address this gap in knowledge, a study was carried out to examine and evaluate different peening processes and the resulting residual stress profiles in combination with a superfinishing process.

By correlating the pitting durability from the experimental investigations with existing calculation methods, it was possible to extend the surface factor ZR from ISO 6336 to a wider range of roughness values as well as to introduce a new factor ZS for different shot peening treatments.

Dominik Kratzer is currently a Research Associate at the FZG Gear Research Centre with the main topic “Gear fatigue life”. He has Bachelor and Master Degrees, both in Mechanical Engineering. This is his first participation at an AGMA Fall Technical Meeting.
Gear Sliding Losses

Parviz Merati
Western Michigan University, United States

Accurately predicting frictional losses is critical for increasing overall gearbox efficiency. This paper documents an approach used to incorporate the effect of lubrication characteristics, gear geometry, surface finish, and operating conditions into an algorithm that accurately predicts sliding losses over a range of operating conditions for a standard set of gears. The methodology developed for simple contacts is used to predict gear sliding losses for much more complicated cases of spur and helical gears, where load and rolling and sliding speed of the contact patch varies at each roll angle during the mesh cycle.

Parviz Merati is a professor of mechanical and aerospace engineering at Western Michigan University (WMU), Kalamazoo, MI. Dr. Merati received his Ph.D. in theoretical and applied mechanics from the University of Illinois at Urbana-Champaign. He was a Post-Doctoral fellow at the School of Aerospace Engineering at Georgia Institute of Technology. Dr. Merati is a registered professional engineer in the state of Michigan. Dr. Merati joined WMU in 1986 and was a Summer Faculty-Fellow at NASA Glen Research Center in 1988. He was the Chair of the Department of Mechanical and Aerospace Engineering at WMU for twenty-one years from 1994-2015. Dr. Merati has won several NSF awards for his work on tribology of mechanical seals and has a large body of journal and conference publications in the area of mechanical seals, experimental fluid mechanics, and heat transfer. He teaches a graduate course in tribology focusing on lubrication hydrodynamics, electrohydrodynamic lubrication, and wear. His current research interests are in the area of measurement and prediction of friction and wear for spur and helical gears.
A New Approach for the Calculation of Worm Shaft Deflection in Worm and Crossed Helical Gear Drives

Philipp Norgauer
Gear Research Center (FZG), Technical University of Munich

According to the current state of the art, worm shaft deflection can be calculated according to ANSI/AGMA 6022, DIN 3996 and ISO/TR 14521. In this paper, the current calculation status for worm shaft deflection is discussed and a new approach for the worm shaft deflection calculation is developed. The new calculation method allows calculation of the bending stiffness of overhung worm shafts as well as worms of reduced tooth thickness, which are usually used in crossed helical gear boxes.

Philipp Norgauer is currently a Research Associate at the Gear Research Centre (FZG) specializing in worm- and crossed helical gears. His research topics are the efficiency, load capacity and simulation of these gear types. He studied at TU Munich and finished his studies with a master’s degree in 2015. Since then, he worked at FZG. He is an active member in the DIN committee of worm gear standardization and worked in the ISO TC60-SC1-WG7.
Case Study of ISO 6336-22 Method

Robin Olson
Rexnord Industries, United States

ISO/TS 6336-22 specifies a method to calculate the risk of micropitting in gear sets through the use of a safety factor. The safety factor is calculated as the minimum specific film thickness in the contact zone divided by a permissible specific film thickness. The permissible specific film thickness is best determined through experience or testing, but there is an option to estimate it based on the lubricant’s failure load stage in FZG testing. In this paper, real cases of micropitting have been identified in gear sets operating in high speed, low speed, and intermediate speed applications. The ISO/TS 6336-22 method has been applied to these cases in order to determine whether the method reliably predicts that micropitting will occur.

Robin Olson is the Director of Applications Engineering for the Material Handling Vertical at Rexnord Industries. Robin started her career at The Falk Corporation in 1995 and has previously worked in the Sustaining Engineering, Computer Aided Engineering, and Engineering Technical Services groups during her career there. She is a member of the AGMA Helical Gear Rating Committee, Chairperson of the AGMA 925 subcommittee, and is honored to act as US delegate to ISO Working Groups 6 (Gear calculations). Previously, Robin has also been a member of the AGMA Computer Programming, Enclosed Drives, and Marine Drive committees. Robin holds a Bachelor of Science in Physics from the University of Wisconsin—LaCrosse and a Master of Science in Physics from the University of Wisconsin—Madison.
Service Life of Cylindrical and Bevel Gears Under Variable Load and Stresses

Daniel Vietze
Gear Research Center (FZG), Technical University of Munich

Transmissions are usually loaded by variable external loads under real operating conditions. Variable loads can be considered in the calculation of the load carrying capacity by using application factors, overload factors or more complex standards like ISO 6336-6. This paper gives a brief overview of currently applied methods to consider variable loads in the design process of cylindrical, bevel and hypoid gears. The scope of application of these methods is shown and critically analyzed for the damage mechanism pitting, tooth root breakage and tooth flank fracture. Furthermore, the influence of locally changing stresses on the pitting load carrying capacity is explained on bevel and hypoid gears. A method to assess such influence is shown for constant external loads.

Daniel Vietze is currently a Research Associate at the Institute of Machine Elements at the Technical University of Munich in Germany. He has Bachelor and Master Degrees, both in Mechanical Engineering form the Technical University of Munich. His research focuses on fatigue life analysis as well as on bevel and hypoid gears. He is presenting for the first time at the AGMA Fall Technical Meeting.
Single Tooth Reversible Bending Fatigue (STRBF) Testing

Matthew Wagner
Applied Research Lab, Penn State, United States

This paper outlines Single Tooth Reversible Bending Fatigue (STRBF) testing, which overcomes previous test limitations by allowing compressive loads to be applied to the test tooth root in any magnitude in conjunction with the typical tensile loads. This test setup involves three teeth of the test gear, with the upper and lower teeth providing the reactions in the up and down load directions and the test tooth being subject to test loads in both directions. Any R-ratio applicable to gear bending fatigue testing up to and including fully reversed loading ($1 > R \geq -1$) is possible. Non-dimensional examples of fatigue data from a recently completed fully reversed testing program are shown.

Matt joined Penn State University’s Applied Research Lab (ARL) in 2015 where he works as a Research and Development Engineer in ARL’s Drivetrain Center and Gear Research Institute. He holds a B.S. in Mechanical Engineering from Penn State University and an M.S. in Mechanical Engineering from Georgia Tech. Prior to joining ARL, Matt worked for 8 years designing and managing implementation of automated production equipment for a wide range of industries. His current research interests include gear health monitoring and prognostics, gear tooth metrology and surface finish evaluation, fully reversed single tooth bending fatigue testing, and loss of lubrication evaluation. He also focuses on development of test methods which allow performance testing of production gears in lieu of representative test specimens. Matt has co-authored two FTM papers and was also a presenter at last year’s FTM.
Analysis of the Operational Behavior of a High-Speed Planetary Gear Stage for Electric Heavy-Duty Trucks in Multi-Body Simulation

Christian Westphal
Laboratory for Machine Tools and Production Engineering, RWTH Aachen University, Germany

In this paper the operational behavior of a high-speed planetary gear stage for electric heavy-duty trucks is analyzed in dynamic multi-body simulation MBS. The tooth contact analysis method developed is extended by the simulation of planetary gears in the MBS. Different bearing strategies for planetary gears are compared and the effects on the operational behavior are evaluated. In addition to the dynamic transmission error, the dynamic tooth flank pressures are analyzed both in their amplitude and their distribution on the tooth flank. Furthermore, bearing forces are evaluated in dynamic operating points. In the simulation, the misalignment of the gears is directly taken into account by means of a penetration calculation in every time step.

Christian Westphal is a research associate in the Gear Department at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University. He studied Industrial Engineering and Management with a major in automotive engineering and corporate development at RWTH Aachen University. After several years as a student research assistant he started his research activities in the field of gear acoustics. Currently he is working on special gearings and the dynamic excitation behavior of planetary gearboxes.
How will the Virtual FTM Work?

AGMA will be hosting the Fall Technical Meeting on an online platform called cadmiumCD. This platform will allow attendees to download all ten papers and watch the presentations that accompany them from October 5-19. Then, on October 20, attendees will be able to sign in for a live Q&A with the presenters directly where they will be able to submit their questions in real time.

Additionally, this platform will allow for attendees to chat with each other to discuss presentations, share industry news and network with one another.

What’s next?

After you have registered for the FTM, and right before the presentations becoming available, all attendees will be sent a link to sign into the online venue allowing you access to all the papers and video presentations. In the meantime, if you have questions or concerns, please feel free to reach out to one of the AGMA team members.

**All Technical Questions:**

Phillip Olson — olson@agma.org
Connor Mallon — mallon@agma.org

**Sponsorship Questions:**

Leah Lewis — lewis@agma.org

**Marketing/AGMA Website Questions:**

Rebecca Brinkley — brinkley@agma.org

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