# Synopsis 2023 AGM Technical Papers

Key Speaker

**Vasilios Bakolas**
Schaeffler Technologies AG & Co. KG

**VDMA Guideline on Product Carbon Footprint: Challenges, Status and Next Steps**

*Dr. Vasilios Bakolas was born in Thessaloniki, Greece. He studied Mechanical Engineering at the Aristotle University of Thessaloniki, where he also wrote his Ph.D. thesis. In 2000 he started working as an analytical engineer for the Schaeffler Group. For more than 10 years he was responsible for contact modelling and lubrication analysis of contacts. From 2011-2017 he was responsible for the Advanced Bearing Analysis Department where he continued to deal with tribology questions, but he was also heavily involved in innovation projects in the field of bearings. In 2017 he was appointed to Principal Expert for Bearings R&D. He is also an Associate Editor for Tribology Transactions since 2009. He has been a member of the STLE Board of Directors from 2012-2018 and was named STLE Fellow in 2020. Dr. Bakolas has written more than 60 articles and conference papers. He also holds more than 10 patents related to various aspects of rolling element bearings.* *vasilios.bakolas@schaeffler.com*

**Frank Berens**
Co-author: Piet M. Lugt
SKF

*Frank Berens has studied Production Techniques at the University of Iserlohn (1990). He started his career for SKF in Germany, working in different positions over the years focusing on material & process development. In 2000 he moved to SKF France starting in the product development area and growing his knowledge in lubrication. Since 2018 he works as a Senior Technologist and is the chairman of the SKF Lubrication Specification Group, responsible globally for lubricant related activities within SKF.* ***frank.berens@skf.com***

**Sustainability and grease lubrication in rolling bearings**

The largest contribution of the rolling bearing industry to the transformation of society to become carbon free, circular and clean is to provide more efficient bearing solutions. With respect to grease this means extending grease life, reducing friction, collect used grease and use clean grease. In this paper we will show the $CO_2$ emission results for different bearing applications, which will provide guidelines on how the grease industry can support this transformation.

**Johan Leckner**
Axel Christiernssion International AB

*Johan has an MS and PhD in chemical engineering from Chalmers University of Technology in Gothenburg, Sweden. He worked for six years as a researcher, first at the Pasteur Institute in Paris and then at Chalmers University of Technology. In 2009 he joined Axel Christiernsson International as Senior Development engineer and since 2016 he is working as Group Technical Manager. Since 2021, Johan is also part-time Professor in Lubricant Design at KTH Royal Institute of Technology in Stockholm.* *johan.leckner@axelch.com*

## Bevel gear grease – a sustainability case study.

This paper summarises two recent studies which together highlight both the importance and the complexity of including in-service performance when assessing the environmental footprint of a lubricant.
The first study focuses on the development of a new grease for nutrunner bevel gears. Here we show that the durability and energy efficiency of both the gear and the grease can be significantly enhanced when modern grease formulation solutions are applied. More specifically, the benefits of switching from a mineral oil-based, lithium soap thickened grease to a polypropylene thickener system with synthetic oil is presented.
The second study compares the greases using two different Life Cycle Assessment approaches that highlight the importance of a more holistic, cradle-to-grave approach, incorporating data from bench and field tests, versus a more limited cradle-to-gate approach. The outcome from this study is that including the in-service data reverses the outcome from the cradle-to-gate assessment, demonstrating that a fully synthetic grease is a much more sustainable alternative when the usage phase is included.
In essence, the core message of this paper is that the performance of lubricated machine elements can have a very significant impact on sustainability assessments and that a grease providing better performance can, even if it requires more resources to produce, be the superior solution

**Marika Rangstedt**
Co-author Gaia Franzolin
Nynas

*Marika has more than 20 years of experience in specialty oil products and their applications. With an MSc in Chemical Engineering from the Royal Institute of Technology in Stockholm, Marika joined Nynas in 1999. She has over the years held various positions within R&D, product and development, technical marketing, advisory and management. Most recently Marika has in her role as Manager Sustainable Development been working with projects and other initiatives in the area of sustainability, including the development of Nynas' sustainability ambition and strategy. She is based at the Nynas headquarters in Stockholm, Sweden.* ***marika.rangstedt@nynas.com***

## Navigating among the developments in the area of sustainability

Sustainability has been a key topic for some time now and, in particular, climate change is the driver for many industrial roadmaps and investment decisions. With the increased focus come new learnings. As many industry sectors develop own guidelines, and new standards and certifications become more popular, there is quite a variety of aspects to understand and take into account. We review some of these developments and look at how they relate to the grease industry and its suppliers

**Matthias Stammler**
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Co-Authors: Rihard Pasaribu – Shell Netherlands
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*Matthias works as a Senior Engineer with IWES. He has more than 10 years of experience in the wind industry and specialised in rolling bearings for wind turbines. Matthias did his PhD on test strategies for wind turbine pitch bearings.**matthias.stammler@iwes.fraunhofer.de*

**Scaled Line Contact Tests of Wind Turbine Pitch Bearings**

This paper will review both of these properties in the context of grease and grease for EV. The well-established efficacy of phosphonium ionic liquids for anti-wear improvements (2-4) will be evaluated by 4-ball, MTM and SRV. The synthesis of ionic liquids such as [P4444][DEHP] (2) and [P8888][DEHP] (4), Figure 1 will be discussed.. The synthesis of phosphonium ionic liquids and their ability to be tailored (5,6) by swapping out anions to alter lubricant, anti-wear, and solubility properties will also be discussed. Furthermore, the obtained results will be coupled with electrical/thermal conductivity analysis.

**Eamonn Conrad**
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*Eamonn completed his Ph.D. in 2014 in phosphorus chemistry at Dalhousie University (Canada) and followed this with a post-doctoral fellowship at the University of British Columbia (Canada). After completing this he joined Cytec which was later acquired by Solvay. He has been with the company for 8 years first in research, and is currently a Global Business Development Leader managing the team globally in the Phosphorus Specialties GBU. With other 15 years' experience in phosphorus chemistry He supports topics of lubrication, catalysis, thermosets and many others* *eamonn.conrad@solvay.com*

**The Response of Phosphonium Ionic Liquids in Lubricating Greases with Respect to various Tribological contacts**

There are many challenges facing today's electric vehicle (EV) manufacturers. When selecting EV lubricants and greases, companies often rely on iterative improvements to formulations designed for internal combustion engines. These lubrication systems present challenges and fail to substantially improve system efficiency. Engines running with conventional or modified lubricants in EV lose as much as 30% of efficiency due to losses directly related to lubrication. This presentation demonstrates the responses of phosphonium ionic liquids as metal free/ashless additives to deliver AW/EP properties and thermal/electrical conductivity improvements, beneficial to this application with specific focus on lubricating greases .

**Gareth Fish**
The Lubrizol Corporation USA

*BSc in Chemistry and PhD in Tribology from Imperial College of Science, Technology and Medicine, London. Currently Technical Fellow at the Lubrizol Corporation, Wickliffe, Ohio, USA, with more than 30 years of grease industry experience. Author of more than 70 technical papers and 80 teaching classes on Tribology and lubricating greases and winner of 14 industry awards.* ***Gareth.fish@lubrizol.com***

**Formulating Challenges in an Increasingly Regulated World**

The European Chemicals Agency, ECHA, has moved on from the Evaluation phase and into the Authorization (and restriction) stages of REACH. As outlined by their presentation at the 2017 ELGI Meeting in Helsinki, ECHA are advanced in their reviews of chemical data test results in the areas of human health and toxicity and environmental hazards. These reviews have looked at many common chemicals and additives used in the manufacturing and formulation of lubricating greases.
The use of common copper corrosion inhibitors based on triazole chemistry have had their allowable limits reduced. Substituted diphenylamine antioxidants are currently under regulatory review from which initial reports suggest that their use in greases will be restricted. Other basic components and formulations such as zinc compounds and ashless dithiophosphate esters, amines and amides are now under scrutiny.
More recently it has been proposed that lithium hydroxide and hexylene glycol be categorised as reproductive toxins. Alternative thickener systems such as ureas based on MDI or TDI are not immune from these events. The new preformed polyurea powders have to go through full REACH testing protocols.
This paper will describe potential pathways for grease developers to move forward with formulations that both comply with current legislation and offer the desired performance.

**Solveig Scholl**
Fuchs Lubricants Germany

*Solveig obtained a PhD in Metal Organic Chemistry and Catalysis at the University of Heidelberg in 2013. Since 2015 she worked at FUCHS Lubricants Germany GmbH. From 2015 to 2019: REACH Compliance Manager; since 2019: Global Regulatory Affairs Manager and since 04/2022 Co-chair of ERGTC*

**REACH: Achievements and challenges (ERGTC)**

**Manfred Jungk**
MJ-Tribology
ELGI Director

*Manfred is Chemist with doctorate degree and has 34 years' experience in the lubricant industry. Recognized (STLE fellow) contributor to the tribology community worldwide through presentations at conferences, journal articles, book chapters and society's board membership. He is the Editor in Chief of Tribologie und Schmierungstechnik, the leading German peer reviewed Journal on Tribologie, available online, English articles possible, Open Access possible and is the Initiator and Co-Editor of Schmierstoff und Schmierung, quarterly German language publication for the lubricant industry.*

**Report on the ELGI Sustainability Technical Consortium**

**Anoop Kumar**
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*Anoop has a Ph. D (Chemistry) from India's Premier IIT Roorkee & Post Graduate Diploma (Marketing Mgmt.) and has over 30 years' global experience in product & process development, manufacturing, and applications of lubricating greases & Industrial Oils.*
*He started his career with Indian Oil Corporation Ltd in 1991 and worked there for about 17 years in different capacities in the field of lubricating greases. In 2008 he moved to the USA. During his tenure with Indian Oil R&D Centre, he was instrumental in the formation and running of NLGI India Chapter from 1997 till 2008. From 2008 till 2018, we worked with Royal Mfg Co, now Axel Royal LLC as Director R&D and Business development. He Joined NLGI Board in 2012. He is currently working with Chevron Corporation at Richmond Technology Center, California as Senior Staff Scientist ( Grease - SME) He has 29 worldwide patents ; over 90 worldwide technical publications, presentations in conference and journals of international repute. He is Co-Founder of NLGI-India's Greasetech India. He has contributed several technical articles in STLE's TLT, Lubes'n'Greases, Lubes, Noria' Machinery Lubrication. He is the inventor of Titanium Complex Grease Technology. He is currently TLT's Technical Editor, ASTM D0G0.02 Sub-Committee Chair and President NLGI. He received many awards and recognitions:*

## The Effect of Thickener Microstructure on Physicochemical and Tribological Properties of Overbased Ca-Sulfonate Complex Greases.

Conventionally, Ca-sulfonate greases specially overbased Ca-sulfonate complex are known for their superior inherent extreme pressure, antiwear, water resistance, rust, and corrosion resistance properties. These properties can be attributed due to the microstructure of Ca-sulfonate thickener which is quite different compared to other type of soap thickeners. The physicochemical characteristics of a fully formulated grease are greatly influenced by its composition, processing parameters and thickener microstructure. The overbased Ca-sulfonate complex greases are generally prepared by suitably converting newtonian overbased Ca-sulfonate detergent containing amorphous calcium carbonate to crystalline calcite particles which are associated with rheological change by virtue of great degree of association between wafer-like calcite particles.

In this paper, the overbased Ca-sulfonate complex grease is prepared in lab using conventional mineral oils by carefully selecting ingredients and proprietary manufacturing process. The resultant grease exhibited outstanding extreme pressure and antiwear , excellent high temperature life, and excellent water resistance and rust protection properties. To investigate these key performance differences, efforts have been made in this paper to comparatively study the microstructure of these two greases: one prepared in our lab and other commercial Ca-sulfonate grease by TEM, STEM, EDX coupled with other analytical techniques. The details of these comparative tribological, physicochemical and their microstructures investigations will be covered in this paper.

**Sevda Şahan**
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*Sevda Şahan, her MsC in synthesis and evaluation polymeric nanoparticles in drug delivery systems at Hacettepe University in 2018. She has over 6 years' experience in lubricant industry- R&D studies and formulations of different types of lubricating oils and greases. Since 2020, she has the role of managing quality control and R&D laboratory at Petrol Ofisi Technology Centre.* *sevda.sahan@petrolofisi.com.tr*

*Ece Korkut, graduated from Yıldız Technical University with a bachelors' degree. She has the role of R&D Engineer at Petrol Ofisi Technology Center. Her main product portfolio basis on greases and industrial lubricants*

## Development of e-grease with carbon nanotubes

Lubricant industry has an increasing need for grease products to use in electric vehicles. In this study we have been investigated the development of electrically conductive grease products with using carbon nanotubes. Base oil types, soap types and different types of performance additives have been evaluated to use in e-grease. Different types of performance characteristics of carbon nanotube e-grease have been reported and also a new test method to measure the conductivity of e-grease has been developed

**Solvay**
Gaetano Calvaruso
Co-author: Christine Hamon - Solvay

*Gaetano Calvaruso has a PhD in Customer Technical Development and is an Engineer at Solvay Specialty Polymers, since April 2019. Italy/Germany Postdoctoral Researcher RWTH Aachen University, from 01 mar, 2017 to 01 Feb, 2019 Germany. Doctorate/PhD in Chemistry Max-Planck-Institut für Kohlenforschung, from 01 lug, 2013 to 01 dic, 2016 Germany* *gaetano.calvaruso@solvay.com*

## Greases based on Fomblin® perfluoropolyether oils for E-mobility high speed bearing

The shift towards electric vehicles plays an important role in the transition to a more sustainable mobility. Electrical powertrains are pushed to higher rotational speed in order to efficiently improve the power density. This brings new challenging requirements for the rolling bearings, in which advanced EV grease formulations are needed to reduce friction, wear and NVH on long run while preventing electrical erosion. To address these challenges we have tested different grease compositions based on Fomblin® M PFPE. The Fomblin® Z/M fluids are synthetic lubricants largely used for highly demanding applications thanks to their outstanding thermal and oxidative stability, chemical inertness and hydrolytic stability. In this presentation, we will report the influence of the characteristics of the grease components on the bearing performance at high speed: the viscosity of the Fomblin® M base oil, the type of thickener as well as the additives. We will also discuss the optimisation of the electrical properties of the PFPE based lubricating grease for EV bearing application.

**Piet Lugt**
SKF
Co-author – Frank Berens

*Senior Scientist at SKF Research and Technology Development. Full Professor and Scientific lead of the SKF University Technology Centre for Grease Lubrication at the University of Twente. Piet Lugt studied mechanical engineering and tribology at the University of Twente in The Netherlands (MSc. 1988, PhD. 1992). He worked at the Technical University of Delft until 1995 when he joined SKF Research where he has fulfilled several positions in Tribology and Lubrication, presently as a Senior Scientist. He has been a part-time Professor at Luleå Technical University, Sweden, from 2005-2008 and is (part-time) full professor at the University of Twente since 2011. Piet has written the book "Grease Lubrication in Rolling Bearings* *Piet.lugt@skf.com*

**The Grease Life Factor (GLF) concept for ball bearings**

Bearing fatigue life is a function of the bearing load capacity C, a parameter that is given for any bearing by the bearing manufacturer. Bearing grease life is not quantified by such a number. In grease specifications grease life is given by a number of hours that the grease survived on some (standardised) test rig (FE9/ASTM/ROF etc.). This paper describes a proposal to change this. Grease life can be quantified by a so-called 'Grease Life Factor' (GLF). This makes it possible, similar to bearing life, to quantify the life properties of a grease using 'any' grease life test rig. So there is no longer a need to specify grease life for standardised test rigs. The validity of this concept is illustrated with test data obtained from the most widely used test methodologies: FE9 and R0F.

**Joe Kaperick**
Technical Advisor, Afton Chemical Corp

*Joe Kaperick is a Technical R&D Advisor for Greases at Afton Chemical Corporation and has been in Afton's Industrial R&D area with a primary focus on Grease since 1999. Joe received a Master's Degree in Analytical Chemistry from St. Louis University as well as undergraduate degrees in Chemistry, Fine Arts and Classical Humanities. He is a member of STLE, Chair of the joint WG on Grease Particle Evaluation, and Chair of Section G.01 for ASTM. Joe is a past President of NLGI and has served on their Board of Directors since 2007.*
*Joe.Kaperick@AftonChemical.com*

**The Matrix Revisited: Exploration of Additive Choice with Different Thickener Types**

The predominant matrix of choice for grease manufacturers has been lithium for several decades now. However, its position as the default for cost-effective, multipurpose grease formulations is beginning to show signs of weakening. The increasing imbalance in the supply/demand position of LiOH has inspired many grease manufacturers to evaluate alternate thickener types as options for a variety of applications. Unlike most lubricating oil formulations, additive interaction with the grease thickener matrix is a critical element that needs to be carefully considered to create an optimised grease formulation in an efficient and cost-effective manner. This paper looks at the impact of grease thickener type on additive selection by presenting the results of several studies and discussing theoretical aspects of the interactions in question.

**Ronald Hoogendoorn**
Patech Fine Chemicals Co. Ltd.

*Ronald has a Chemical degree and worked for more than 35 years in the lubricant and Oleochemical Industry in Research formulating lubricants and Sales & marketing and Business management positions. Ronald worked for Cimcool, a Metalworking fluid supplier, Unichem (nowadays Cargill a synthetic Ester producer and Vollenhoven Olie a lubricant distributor. Ronald did spend a couple years in both Taiwan and the USA looking after the American and Asian Lubricant market. Ronald has since 2004 his own lubricant consultancy company consulting in lubricant formulation development and marketing and trade of lubricant ingredients. Currently Ronald is as General Manager for Patech Europe, responsible for their Ester business in Europe.* *ronald@patechfc.com.tw*

### Overcoming the High Viscosity Limitation of Readily Biodegradable EAL Base Fluid.

As the demand for Environmentally Acceptable Lubricants (EAL) significantly grows, industries that required heavy loading operation are no longer satisfied with the current EAL base fluids viscosity range. They need higher viscosity EAL for better Elastohydrodynamic Lubrication (EHL) and Boundary Lubrication properties to improve wear protection. However, to achieve higher viscosity, base fluids need to have higher molecular weight (MW) or highly complex structure. To meet the physical demand of Oxidation and Hydrolytic stability in the field, these molecules must also be fully saturated. Previous assumptions are that these properties are counter to a readily biodegradable molecule. In this presentation, we will show how, by using different modelling techniques, we overcame these assumptions and broke the viscosity limitation in successfully developing several extreme high viscosity readily biodegradable base fluids. We will demonstrate the hydrolytic stability, lubricity, oxidation stability of these fluids. Since these types of fluids are sometimes used as viscosity modifiers, we will also show their compatibility with PAO and natural base oils

**Erik Willett**
Functional Products Inc.

*Erik Willett is the technical director at Functional Products Inc. in Macedonia, Ohio. His key research interest is the role of polymers and their structure in advancing lubricant performance. He has received the 2018 NLGI Development Author Award and the P.P.C. Gonsalves Memorial Award. Erik earned his PhD in polymer science from the University of Akron.* ewillett@functionalproducts.comn

### Viscosity Modifiers Enable Re-Refined Base Oils for Grease

Petroleum oil is a vital component for most lubricating greases but also a major concern for how sustainable grease can be with respect to carbon footprint and life cycle analysis. Global lubricating oil product reaches almost 100 billion litres/yr while production of synthetics is on the order of 1 billion litres/yr. Creating a closed loop on oil through re-refining may be the only solution that provides a more sustainable option for good economics on the scale needed. However, re-refined oils may be unsuitable for grease applications due to a few key challenges. Most re-refined oil cuts are light (ISO 10 to 46) and targeted toward multigrade engine oils but greases tend to use heavy (ISO 100 to 500) cuts of Group I, Group II, and bright stock. Re-refining also removes cyclic components, molecular weight, and sulphur which are important components to the load carrying performance.

Synthetic polymers (ideally from emerging renewable monomers) provide a path toward building proper viscosity grades out of light re-refined oils. This work screens the capability of different shear stable polymer chemistries in contributing to both the base oil viscosity and load carrying performance of EP greases. These polymer-modified and re-refined EP greases will be compared against conventional heavy Group I and bright stock cuts in a range of test methods from the NLGI HPM-HL specification.