TORSIONAL VIBRATION SYMPOSIUM

PROGRAM SALZBURG 2025

Content

TORSIONAL VIBRATION SYMPOSIUM

Dear Colleagues,

Welcome to the fourth Torsional Vibration Symposium from May 14th to May 16th 2025.

Eleven years ago we organised the first meeting of this kind and we are pleased to see that the number of participants has been increasing ever since.

Thank you, esteemed torsional vibration experts, for preparing your papers, which most of you have to do in addition to your other daily tasks. We hope that you will be rewarded with a lot of positive response to your presentations.

During this event we will have the unique opportunity to interact with leading experts, including the two keynote speakers, Prof. Dr. Robert Schlögl and Alexander Knafl. We will be able to share ground-breaking research and discuss innovative solutions to the complex problems associated with torsional vibration.

Our meeting reflects the importance of understanding the impact of torsional vibration on system performance, reliability and lifetime. As such, our work has a far-reaching impact on industry and society.

On behalf of the organising committee, we would like to thank you all for your participation. Your commitment to torsional vibration is truly inspiring and we look forward to the productive and insightful discussions that await us.

Sincerely yours,
Uwe Merl and Lothar Kurtze

VIBRATION ASSOCIATION
Schwingungstechnischer Verein

General Information

Wifi Congress Salzburg
Name: TVS2025
Password: Vibration25

Photography and Video Recording
Photography and video recording of any lecture are not permitted.

Congress proceedings
All papers of the contributions will be available online.

Paper Download

All papers are available online

Information for Speakers

Oral Presentations are scheduled as follows:

- 20 minutes lecture
- 3 minutes discussion
- 2 minutes break (possibility to change rooms)

This schedule should be strictly observed. It is not possible to exceed 20 minutes for a presentation. In each room, a laptop, a beamer, and an audio loudspeaker are available. The laptops are equipped with actual Windows, MS-Office and Acrobat Reader. Please store your presentation on a USB flash drive, bring it to the conference and make sure to transfer it to the laptop of your technical room well before your session starts. It is not allowed to use personal laptop computers for presentations. Please perform a virus check on your data storage device. For PowerPoint presentations, we recommend to create an additional file, which is system-independent. Please choose "pack and go" in the file menu. Since we don't assure the compatibility of your presentation with the installed power point version, a preview corner will be available to check your slides during the conference.

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Organization

The organizer of the event is the Vibration Association.

VIBRATION ASSOCIATION
Schwingungstechnischer Verein

Schwingungstechnischer Verein
(Vibration Association)
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Program

Wednesday: May 14, 2025

18:00	Welcome Reception, Restaurant M32

Thursday: May 15, 2025

Sessions A: Karajan Hall
Sessions B: Wolf-Dietrich Hall

07:30	Registration Desk Opens
09:00	Official Opening
09:15	Keynote: Prof. Dr. Robert Schlögl President Alexander von Humboldt Foundation, Germany **Green Molecules**
10:00	Coffee Break, Exhibition Opens

	Session 1A: Engine Development	Session 1B: Noise, Vibration, Harshness (NVH)
10:30	**Torsional Vibration Aspects of Variable Compression Ratio on 2-Stroke Engines** R. Rusch, S. Virta WinGD Ltd.	**Acoustically Optimized Rubber Misalignment Couplings for Yachts and Marine Applications** T. Andogho VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG
10:55	**Enhanced Time-Domain Torsional Vibration Model Verification by Means of Cylinder Pressure Measurements** S. Persson MAN Energy Solutions SE	**Model-Assisted Experimental Determination of Elastomer Coupling Properties for Torsional Vibration Calculations** T. Rapp, D. Hilbk, H. B. Alaya VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG
11:20	**Influence of Large-Bore Gas Engine Gensets on Grid Stability - Challenge or Storm in a Teacup?** J. Wolter, P. Böhm MAN Energy Solutions SE	**Full System Integrated Lateral Vibration Analysis for Marine Applications** M. Müller VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG

11:45	**Torsional Vibration Analysis of an Opposed-Piston Engine Architecture** B. B. Mahanta Cummins Inc.	**Proven Solutions to Reduce the Transfer of Structure Borne Sound in Couplings** N. Yazdandoost Geislinger GmbH
12:10	Lunch Break	

	Session 2A: Power System Simulation I	Session 2B: System Reliability – Case Studies I
13:10	**From Diesel to Modern Fuels - The Changes in Crankshaft Torsional Vibration** K. Buczek, M. Bartosik, B. Jagodzinski, S. Shah FEV Polska Sp. z o.o., FEV Europe GmbH, ENORISE GmbH	**An Investigation into Engine Damage Using Torsional Shear Strain as a Means of Characterising Load Acceptance** J. Stainsby Lloyd's Register EMEA
13:35	**Coupled Simulations of Torsional Vibration and Elastic Mounting Systems** D. Hochlenert, M. Schuchardt Rolls-Royce Power Systems AG	**Study of OD Shaft (Oil Distribution Shaft) Damage Cases in CPP Marine Propulsion Plants** H. Amini, Ø. Alnes, E. Brodin Det Norske Veritas
14:00	**Visco-Elastic Finite Element Approach on Thermo-Mechanical Coupled Simulation and Validation in Rubber Coupling** M. Hasan, R. I. Zadoks REXNORD CENTA, Independent Consultant	**Validation of Fatigue Theory for a Propulsion Shaft Subject to Torsional Vibrations** G. Dahler, J. E. Kjær, G. M. Bakken DNV AS
14:25	Coffee Break	

	Session 3A: Powertrain Components I - Elastic Couplings and Dampers	Session 3B: Power System Simulation II
14:50	**Skip Firing as Challenge on Modern Powertrain Configuration** H.G. Flesch, M. Mehrgou, C. Mühlberger, et. al. AVL, Geislinger GmbH	**System-Modeling Marine Drivetrains: A Glimpse at the MBSE Approach at IME Aachen GmbH** B. Juretzki, M. Körber, T. Möller, et. al. IME Aachen GmbH

15:15	**Sustainable Solution by Reducing Idle Speed and Fuel Consumption in Crane Application with Super-Soft Rubber Coupling** M. Hasan REXNORD CENTA	**Temperature Effects on the Dynamic Stiffness and Damping of Carbon-Filled Elastomer Couplings** S. Bahr, G. Jacobs, G. Höpfner, S. Akbulut Institute for Machine Elements and Systems Engineering, RWTH Aachen
15:40	**Vibration Aspects of Different Power Take-Off Units for 2-Stroke Marine Propulsion Systems** R. Wilkie, D. Richter-Trummer, A. Thalhammer Geislinger GmbH	**Open-Source Software for Torsional Vibration Analysis** S. Laine Aalto University
16:05	Coffee Break	

	Session 4A: System Reliability - Case Studies II	Session 4B: Active and Passive Dampers
16:30	**Development of a Damage Model for the Lifetime Prediction of a Viscous Torsional Vibration Damper** A. Leib, B. Mokdad, Y. Peterschmitt Liebherr-Components Colmar SAS	**Active Damping of Torsional Vibrations** U. Ubaid Lloyd's Register EMEA
16:55	**Marine Propulsion Shafting Excessive Torsional Vibration: Case Study Revisited** B. Cowper, Z. Schramm LamaLo USA, LLP	**Improved Prediction of the Nonlinear Behavior of Silicone Oil in Viscous Dampers** M. Steidl, R. I. Zadoks, S. Willeke Hasse und Wrede GmbH, Independent Consultant
17:20	End of Thursday's Sessions	
18:00	Aperitif, Salzburg Residence Palace	
19:00	Gala Dinner, Salzburg Residence Palace	

Friday: May 16, 2025

08:00	Registration Desk Opens
09:00	Keynote: Alexander Knafl, PhD Senior Vice President MAN Energy Solutions SE, Germany **Decarbonising Large Bore Internal Combustion Engines**

	Session 5A: Marine Propulsion	Session 5B: Measurement and Monitoring
09:50	**Impact of Propeller Retrofits in the Torsional Vibrations of Marine Propulsion Shafting – Case Studies** K. Lal, J. Klüss Mecklenburger Metallguss GmbH	**MEMS Gyroscope in Torsional Vibration Measurements** J. Köykkä, J. Määttä, P. Sundström, et. al. Wärtsilä Finland Oy
10:15	**Unveiling the Truth Behind First Order Dynamics and Alignment** M. Zeid BERG Propulsion	**Early Fault Detection Applied to Turbines, Pistons Engines, and Torque Evaluation** H. Saiah dataVIB Impédance
10:40	Coffee Break	

	Session 6A: Vibrations of Powertrains	Session 6B: Compressors
11:05	**Shudder in Wet Brakes and Clutches Caused by the Performance Loss of E-Drive Lubricants** J. Wirkner, A. Lebel, C. Besser, et. al. Technical University of Munich, Austrian Centre of Competence for Tribology	**Electrical System Interaction Induced Torsional-Lateral Coupled Vibration at an Integrally Geared Compressor** R. Chumai Machinosis Company Limited
11:30	**Designing Synchronous Motor-Driven Trains Against Torsional Vibration** M. A. Corbo No Bull Engineering, PLLC	**Variable Inertia Effects on Torsional Vibration of Reciprocating Compressors** M. Thorn, T. Stephens Ariel Corporation

11:55	**Torsional Vibration Challenges in Parallel Hybrid Systems** M. Dylla, H. B. Alaya VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG	**High Vibration Of Integrally Geared Compressor Due to Variable Frequency Drive** T. Robertson, T. Feese Eagle LNG Partners, Engineering Dynamics Incorporated
12:20	**A Digital Twin for Torsional Vibrations of Power Plant Turbogenerators** S. Herold, H. Holzmann, R. Nordmann, P. Smeekes Fraunhofer Institute for Structural Durability and System Reliability LBF, Technical University Darmstadt, Teollisuuden Voima Oyj (TVO)	**Simulation Based Dimensioning of Drivetrain Components in Motor-Driven Reciprocating Compressors** T. P. Holopainen, T. Ryyppö, M. Lyly ABB Oy
12:45	Lunch	

	Session 7A: Powertrain Components II	Session 7B: Rules and Regulations
13:45	**Reciprocating Compressor Coupling Revamp: Advantages of Highly Flexible Elastomeric Couplings and Disadvantages of Steel Disc Couplings for Torsional Vibration Aspects** K. Kloos Neuman & Esser GmbH & Co. KG	**CIMAC Working Group 4 Crankshaft Rules – Current Activities** P. Böhm, T. Frondelius, J. Dowell, D. Bell, et. al. MAN Energy Solutions SE, Wärtsilä,Wabtec Corporation, Ricardo UK Ltd, Kobe Steel Ltd.
14:10	**Reduction of Torsional Vibration through Power Take-In System in Marine Shaft Generators** J. Kim, J. Choi HD Hyundai Heavy Industries	

	Session 8: Closing Session
14:35	**TVA Modelling Beyond the Deterministic Theory** A. Thalhammer, K. Bergmann Geislinger GmbH
15:00	Closing
15:10	Farewell Coffee
15:30	End

Saturday: May 17, 2025

08:15	Social Program: Hallstatt Tour (not included in the Symposium fee / Participation fee: EUR 150,- (excl. 20% VAT))

Keynote Speaker I

The first keynote speech will be held by
Prof. Dr. Robert Schlögl

President Alexander von Humboldt Foundation
Germany

Born in Munich in 1954, Robert Schlögl is a chemist who completed both studies and doctorate at LMU Munich. Following this, he achieved habilitation at the Fritz Haber Institute in Berlin. Currently he stays in Basel and Cambridge.

Robert Schlögl is the President of the Alexander von Humboldt Foundation and Vice President of the National Academy of Science Leopoldina. From 1994 to 2023, he served as Director at the Fritz Haber Institute of the Max Planck Society in Berlin and was also the Founding Director of the Max Planck Institute for Chemical Energy Conversion in Mülheim an der Ruhr.

Robert Schlögl's main research interests include inorganic chemistry, heterogeneous catalysis, nanostructures, materials research for chemical energy conversion, and the development of innovative concepts for sustainable energy supply and storage.

Keynote Speaker II

The second keynote speech will be held by
Alexander Knafl, PhD

Senior Vice President of R&D Engineering Four-Stroke
MAN Energy Solutions SE, Germany

After completing a master's degree at the Technical University of Graz, Knafl pursued a PhD at the University of Michigan, Ann Arbor.

This was followed by a role as a researcher at General Motors R&D in Detroit. Subsequently, he worked as a Senior Development Engineer at PACCAR Inc. in Washington before taking on several key positions with MAN Energy Solutions in Augsburg.

Currently, Alexander Knafl serves as Senior Vice President for R&D Engineering in the Four-Stroke division at MAN Energy Solutions SE in Augsburg.

Abstracts

Thu 09:15 Karajan Hall Keynote speech

Green Molecules
Prof. Dr. Robert Schlögl
President Alexander Humboldt Foundation, Germany

Future energy systems will be sustainable and thus largely free from fossil energy carriers. Mobility comprises a large fraction of present and future energy consumption. The present idea of electrifying mobility completely is unsuitable for heavy-duty applications such as maritime, special terrestrial or airborne transport. In addition, many areas in the world will for long time not provide sufficient infrastructure for charging BEV in the required abundance. Hence it is likely that also terrestrial passenger vehicles will be using power trains fueled with green molecules as energy carriers.
These green molecules will be needed in all sectors of sustainable energy systems and are thus available for use in the mobility sector without re-conversion into electricity. The chemical nature of green molecules can be chosen according to their final use. As of today, the availability of free hydrogen from international trade will be limited or even unlikely on the expense of derivatives which are denser in hydrogen than the pure cryogenic liquid that is technically demanding to handle in global quantities. Whereas for airborne traffic SAF with kerosene-like molecular mixtures will dominate for long times, the maritime transport may largely use methanol as a suitable and easy-to-handle fuel. C1 molecules are suitable transportation fuels as their local emissions are free from particulates and modified diesel engines or direct converters from chemical to electrical energy can be used.
From a chemical viewpoint we will use either electrons or electron pairs as energy carriers bound to storage systems with limited (electrochemical batteries) or unlimited (molecular liquids) capacities. The presentation will emphasize systemic and global aspects of the use and choice of green molecules and suggest that co-existence of pure electrical and serial hybrid power trains may be a universal cost-effective strategy for defossilizing the mobility part of energy systems.

Thu 10:30 Karajan Hall Engine Development (1A)

Torsional Vibration Aspects of Variable Compression Ratio on 2-Stroke Engines

R. Rusch, S. Virta
WinGD Ltd.

WinGD's low-pressure dual-fuel technology requires lower compression ratio in gas mode operation than applicable on corresponding diesel engines. With fixed compression ratio, this consequently means that the engine is operated at suboptimal conditions when running on diesel. Variable Compression Ratio (VCR) technology allows compression to be adapted in operation, improving fuel consumption and reducing emissions. VCR opens a new field of optimized load points in the whole engine operation range. However, changes influencing the cylinder pressure curves have an impact on the harmonic excitations and consequently torsional vibrations. This study investigates the effect of VCR on different fuel modes on torsional vibrations. Simulation results are compared with a conventional diesel engine. At low loads, the effect of VCR is compared with LowTV tuning, a standard feature in WinGD engines to minimize excessive vibrations at low loads. Furthermore, the simulation accuracy of the VCR operation is validated by means of a comparison between torsional vibration calculation and measurement. The results show that VCR influences torsional vibration characteristics of a low-pressure dual-fuel engine. This research highlights the importance of compression ratio management in dual-fuel engines with VCR to optimize performance and mitigate vibration related challenges.

Thu 10:55 Karajan Hall Engine Development (1A)

Enhanced Time-Domain Torsional Vibration Model Verification by Means of Cylinder Pressure Measurements

S. Persson
MAN Energy Solution

Torsional vibration measurement is crucial for validating Torsional Vibration Calculations (TVC) on 2-stroke direct driven propulsion systems. Traditionally, TVC is performed in the frequency domain for open-water conditions, making it valid only for steady-state scenarios. This limitation complicates troubleshooting and evaluation of transient events. Previous studies have demonstrated that normalizing measured torsional vibration amplitudes using recorded cylinder pressure data is an effective method to refine TVC models for a better match with measurements. However, these methods are restricted to steady-state conditions.
In this paper, the author explores the application of time-domain TVC for analyzing transient events such as barred speed range passages or situations with speed instability at the main critical natural frequency during intended steady-state conditions. By employing a time-domain model in a local rotating reference frame, and incorporating measured cylinder pressures, it is possible to accurately simulate the fore-end vibration amplitude under transient conditions. This approach allows for tuning of mass-elastic parameters to achieve an improved correlation between model and measurement, ultimately leading to more precise stress estimations in the shafting system under transient conditions. Finally, a comparison between measurement and simulation results for various transient events is presented.

Thu 11:20 Karajan Hall Engine Development (1A)

Influence of Large-Bore Gas Engine Gensets on Grid Stability - Challenge or Storm in a Teacup?

J. Wolter, P. Böhm
MAN Energy Solutions SE

The use of large-bore gas, dual-fuel as well as alternative fuel engines for stationary power applications has become an important market in Europe. Compared to classical genset-setups with large turbines, these engines show an interesting phenomenon: The operation in gas mode increases the resultant power fluctuation of the generator. The main reason is obvious. Inner combustion engines have different excitation patterns compared to turbines and the moment of inertia properties and stiffnesses of the powertrains differ significantly. The power fluctuation increases compared to the same genset running in diesel mode, an effect easily detectable for dual fuel engines. This phenomenon might have a potential to lead to future challenges with grid stability. Thus, this phenomenon has been further investigated at MAN ES. The investigation included an in-depth investigation of the combination of drivetrain-setup and governor setting. It also contained investigations regarding the cylinder individual pressure curves. Furthermore, a simulative approach to calculate the power fluctuations has been implemented. Cylinder pressure measurements for every cylinder have been performed for some hundred working cycles. These cylinder pressure curves were then used in a classical frequency domain TVC tool, utilizing a new multi working cycle approach which will be further explained. With this approach, the simulated power fluctuations correlate very well with the measurements. The increased power fluctuation of engines running in gas mode are explainable. But it remains an unanswered question which influence the resultant power fluctuation on the grid stability has. Even for small grids (island mode), rather large power fluctuations show no significant influence on frequency and voltage stability. Correspondingly, this contribution should also stimulate the discussion with relevant parties.

Thu 11:45 Karajan Hall Engine Development (1A)

Torsional Vibration Analysis of an Opposed-Piston Engine Architecture

B. B. Mahanta
Cummins Inc.

Cummins is developing an opposed-piston engine for military and future commercial applications. It is a four-cylinder, eight-piston, two-stroke design with higher power density, high fuel efficiency and low heat rejection. This compact 14.3L engine produces 1,000 HP and a peak torque of 2424 lb-ft. There are two crankshafts, and the torque output from the crankshafts is combined via a gear train. The gear train also drives the accessories along with a high-speed supercharger.
This paper documents the procedure followed to formulate the torsional model of this complex architecture and analytically study the torsional vibration characteristics of the engine. Based on the torsional analysis results, design decisions were made related to gear train, vibration damper, flywheel and torsional coupling which will be discussed in this paper. Torsional measurements were conducted, and model correlation was carried out. There were some challenges in model correlation due to gear train back-lash and compliance effects and these aspects will also be discussed in this paper.

Thu 10:30 Wolf-Dietrich Hall Noise, Vibration, Harshness (1B)

Acoustically Optimized Rubber Misalignment Couplings for Yachts and Marine Applications

T. Andogho
VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG

In modern yachts and naval vessels, structure-borne noise (SBN) requirements are increasingly stringent due to comfort, stealth, and regulatory factors. While resilient mount solutions effectively address the primary noise path through the foundation, the propulsion coupling can serve as a critical secondary path. In some scenarios, the coupling can even be the dominant (flanking) path if its dynamic stiffness is high at relevant frequencies. This paper introduces acoustically optimized rubber couplings designed for low-to-moderate-speed (<~750 rpm), high-torque marine applications, as well as options for higher speed (up to 2100 rpm), lower torque applications. It highlights simulation-based evaluations of dynamic stiffness, sound transfer function, and overall NVH performance. Focus is placed on VULKAN's coupling solutions - from double-cardanic Integrated Shaft Coupling (ISC) concepts with specialized rubber elements and lightweight intermediate shafts, to economically competitive options using conventional coupling designs. The trade-offs in stiffness, damping, and reaction forces when balancing noise attenuation with operational stability are examined. The approach combines vibro-acoustic finite element analysis (FEA), an in-house Transfer Matrix Method (TMM) for radial SBN, and initial experimental work using VULKAN's acoustic test bench. A simulation-based case study demonstrates how a conventional ISC compares with an acoustically optimized ISC in a hybrid marine propulsion scenario. Results confirm that a carefully engineered rubber coupling can significantly reduce SBN while still fulfilling the torque, torsional vibration tuning and misalignment requirements demanded by yacht and naval vessels.

Thu 10:55 Wolf-Dietrich Hall Noise, Vibration, Harshness (1B)

Model-Assisted Experimental Determination of Elastomer Coupling Properties for Torsional Vibration Calculations

T. Rapp, D. Hilbk, H. B. Alaya
VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG

The Noise, Vibration, and Harshness (NVH) characteristics of pleasure boats are key to ensuring customer satisfaction. To optimize NVH performance, torsional vibration calculations (TVC) are conducted during development. TVC enable identification of unwanted vibrations and their mitigation through precisely tuned, highly flexible elastomer couplings. Until now, TVC usually utilize a linearization of the non-linear, operating-point-dependent properties of the elastomer. However, in high-end applications such as superyachts, operating points exist where linearization leads to unacceptable errors. Here, experimental determination of coupling properties becomes indispensable. Yet, wide ranges of operating points and limited effectiveness of interpolation and extrapolation methods, which tend to amplify measurement errors, result in significant measurement efforts and reduced accuracy. This contribution therefore introduces a method developed at VULKAN, which enables determining coupling properties at various operating points with only a limited number of measurements, while also minimizing measurement errors. The method comprises an analytical model representing the relationship of coupling properties and operating point. It is parameterized using an optimization procedure that matches the model to measurements. A comparison between classical TVC, TVC using the model, and measurements taken from a real drivetrain highlights the model's improved accuracy.


Design
Whirling
SBN
Consulting
Production
Engineering
Part of our DNA
6/12 DOF
Shock
Compound Research
Vibration
LVC
FE Analysis
Acoustic
TVC
VULKAN

Thu 11:20 Wolf-Dietrich Hall Noise, Vibration, Harshness (1B)

Full System Integrated Lateral Vibration Analysis for Marine Applications
M. Müller
VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG

To harmonize the handling and COG of modern ships, the trend goes to long, light weight shaft and coupling systems. This introduces new challenges for the specialists in the connection between two potentially highly exciting aggregates, such as combustion engines and gearboxes. In the presence of high vibrations, these long composite shafts and coupling components can experience lateral excitation, reducing the overall system's lifetime. A case study will be presented to illustrate how system boundaries are defined to encompass the entire propulsion system. We will demonstrate the workflow used to identify excitations and system responses, using a real-world example from marine applications. Additionally, we will highlight key considerations for the future design of propulsion system couplings. Attendees will gain insights into the latest advancements in modal analysis of fully integrated system models, using modern finite element analysis (FEA) tools and measurement systems to compare virtual simulations with real conditions on board of a lightweight shaft propulsion system ship.

Thu 11:45 Wolf-Dietrich Hall Noise, Vibration, Harshness (1B)

Proven Solutions to Reduce the Transfer of Structure Borne Sound in Couplings
N. Yazdandoost
Geislinger GmbH

Today's powertrains for marine applications are characterized by their high-power density in combination with the requirements for a light construction and the lowest possible acoustic transmission.
The primary structure-borne sound path is transmitted from the engine over the engine mounts into the ship's hull. This obvious path is currently already well attenuated. Therefore, the secondary path from the engine via the coupling into the gearbox or the first main bearing and then into the ship's hull becomes more and more important. For this reason, torsionally flexible couplings and misalignment couplings are required, which can also minimize the transfer of structure borne sound while transmitting high torque levels. To fulfill all these partly contradictory demands, innovative approaches are essential. In this lecture, the development of a lightweight misalignment coupling made of a combination of glass and carbon fibers and elastomer layers will be presented. The unique design leads to a significant reduction of the structure-borne sound. This has been proven in measurements on the Geislinger test beds as well as in the installed state for the end application. Results of the dynamic stiffness of application with and without the Geislinger coupling will be shown.

Thu 13:10 Karajan Hall Power System Simulation I (2A)

From Diesel to Modern Fuels - The Changes in Crankshaft Torsional Vibration
K. Buczek, M. Bartosik, B. Jagodzinski, S. Shah
FEV Polska Sp. z o.o., FEV Europe GmbH, ENORISE GmbH

Although diesel fuel has dominated the world of commercial engines for decades, there is currently an increased interest in development of natural gas, methanol, ammonia and hydrogen engines operated with premixed combustion. All these fuels have a great potential for emission reduction including carbon dioxide, but their combustion process is also substantially different from that of the diesel engines. Due to the risk of engine knocking, a reduction in the peak firing pressures is necessary, which generally results in a lower crankshaft load compared to the diesel engine. At the same time, the premixed combustion process in combination with modern fuels is significantly less stable, which leads to increased cycle-to-cycle pressure variations. In this paper, the excitation of crankshaft torsional vibration by gas forces, which is produced during the combustion of above mentioned fuels, is investigated using Fourier analysis and compared with the excitation in state-of-the-art diesel engines. The results obtained show the potential for optimization of crankshafts designed for diesel and used for operation with alternative fuels. Using the simulation software Virtual Dynamics, the influence of increased cycle-to-cycle combustion variations on crankshaft torsional vibration is analyzed. The results are compared with those obtained using a typical simulation approach in which an averaged pressure curve is applied to each cylinder of an engine.

Thu 13:35 Karajan Hall Power System Simulation I (2A)

Coupled Simulations of Torsional Vibration and Elastic Mounting Systems
D. Hochlenert, M. Schuchardt
Rolls-Royce Power Systems AG

In technical applications, the torsional vibration system is always part of a larger power or drive system. In the context of the present study, this is typically a drive system consisting of a diesel engine and other components such as base frames, gearboxes and electric machines, each on corresponding elastic mounting. Many of the applications, especially in the marine sector, have high and constantly increasing acoustic requirements. To meet these requirements, coupled simulations of the torsional vibration and elastic mounting system are becoming more and more necessary to predict vibrations of the coupled system with sufficient accuracy during the design process. Based on a marine propulsion unit consisting of a diesel engine and a gearbox on a common base frame such a coupled simulation is investigated. The classical torsional vibration system is extended to include the structures of engine, gearbox and base frame, whereas the base frame is modeled using finite elements and the gear stage is detailed to represent its interaction with the base frame.

Thu 14:00 Karajan Hall Power System Simulation I (2A)

Visco Elastic Finite Element Approach on Thermo-Mechanical Coupled Simulation and Validation in Rubber Coupling

M. Hasan, R. I. Zadoks
REGAL REXNORD, Independent Consultant

Torsional Vibration Analysis is commonly used to select couplings, with heat loss being a key response for rubber couplings. Coupling heat loss is derived from the area of the hysteresis loop, which represents dissipated energy. However, it is the resulting temperature that influences material degradation, and so accurate predictions of the temperature distribution and its development over time is essential for estimating the lifetime of rubber couplings. Previously, the authors reported on a multibody simulation which was employed to predict coupling heat loss. In the current study, this analysis is enhanced by utilizing a viscoelastic model with user-defined material properties. This advanced approach allows for more accurate simultaneous prediction of temperature development and deformation behavior. The method provides improved insights into power loss and enables more precise temperature predictions in complex operational conditions. These new simulation results are validated with experimental data from a dynamic test bench, showing a strong correlation between simulated and measured temperatures. Moreover, an excellent match between the dynamic stiffness of rubber couplings from simulation and test is achieved. This refined approach offers a deeper understanding of rubber coupling lifetime under operational conditions, leading to more optimized coupling selections for driveline applications.

Thu 13:10 Wolf-Dietrich Hall System Reliability – Case Studies I (2B)

An Investigation into Engine Damage Using Torsional Shear Strain as a Means of Characterising Load Acceptance

J. Stainsby
Lloyd's Register EMEA

Using torsional shear strain, Lloyd's Register's Technical and Failure Investigation Department (TFI) was able to characterise the load acceptance response rate of a pair of diesel engines installed in a RoPax ferry. The measurements were taken over a range of different operating conditions in order to substantiate the findings of a materials investigation into damaged components, which suggested the engine was experiencing overload conditions. Each engine drives a controllable pitch propeller through single reduction gearing and conventional shafting. The damage to both engines consisted of light scuffing to one piston, scuffing, chipping and uneven wear of piston rings, scoring and pitting damage to main bearings, and extensive fretting damage to all cylinder liners. The conclusion from the torsional strain measurements and other additional data collected, was that for the range of operational conditions assessed, the engine builders power limit curves for normal operation were exceeded and that transient dynamic overload was occurring. Recommendations were made to adjust the relationship between propeller pitch angle and main engine speed so that the engine was no longer at risk of being overloaded.

Thu 13:35 Wolf-Dietrich Hall System Reliability – Case Studies I (2B)

Study of OD Shaft (Oil Distribution Shaft) Damage Cases in CPP Marine Propulsion Plants
H. Amini, Ø. Alnes, E. Brodin
Det Norske Veritas

Fatigue damages related to torsional stress in oil distribution shaft (OD shaft) are presented. All cases are from marine propulsion plants with controllable pitch propeller (CPP) driven by a two-stroke engine. Various factors contributing to OD shaft damage referencing recent incidents are discussed. Based on these identified contributing factors, the paper provides insights to mitigate the risk of shaft failure and address potential weaknesses in today's design requirements.

Thu 14:00 Wolf-Dietrich Hall System Reliability – Case Studies I (2B)

Validation of Fatigue Theory for a Propulsion Shaft Subject to Torsional Vibrations
G. Dahler, J. E. Kjær, G. M. Bakken
DNV AS

In 2019 a 44 kDWT bulk carrier was put idle and off hire at a lay by berth in USA. The vessel had experienced damage of the intermediate shaft in the form of surface cracks in vicinity of the intermediate bearing. DNV was engaged to investigate the damage and to assess the likelihood for safe sailing to the desired repair yard in China. A combination of material investigations and ultrasonic testing (UT) were made three times, in the US, prior to crossing the Panama Canal and in China. The first crack depths observed in the US were measured to be approx. 2 mm, whereas at the destination 3 months later cracks had grown beyond 32 mm. This paper highlights fatigue theory in combination with torsional vibration calculations and ship sailing data to guide for safest possible voyage to the repair yard. The propulsion system passing the barred speed range during the ship maneuvring is assumed to be the main source for shaft fatigue, hence followed thoroughly. The quantitative approach was assisted by validation by means of UT. The paper presents major results and the correlation between fatigue theory and observed torsional crack propagation.

Thu 14:50 Karajan Hall Powertrain Components I (3A)

Skip Firing as Challenge on Modern Powertrain Configuration
H-G. Flesch, M. Mehrgou, C. Mühlberger, A. Thalhammer
AVL List GmbH, Geislinger GmbH

With the need to reduce fuel consumption, engine manufacturers are exploring a variety of solutions for their engines and powertrains. One way to achieve this is through increasing the efficiency of the system while simultaneously decreasing the thermal losses. The challenge for the engine operator is to run the engine at the most thermodynamically efficient operating condition throughout the entire service life of the engine. In order to run the engine at this optimal operating condition in relation to the power output, it is necessary to introduce various skip firing scenarios. In these scenarios, it is not enough to simply rely on one cylinder not firing. Dedicated scenarios must be created and thermodynamically analyzed, to reduce the wall heat losses so that each cylinder is kept warm. It should be noted, however, that the implementation of such scenarios will lead to torsional vibration issues due to the irregular excitations. These will subsequently need to be considered in the design of such powertrain configurations. Torsional vibration dampers (TVD) then need to account for these additional loads. Additionally, the crankshaft and power take-off components, such as couplings, become highly stressed by the presence of additional torsional vibrations. This can lead to potential damage of the couplings or drive shaft. Simulation models representing these physical aspects, can provide valuable insight to address the issues caused by these torsional vibrations. Firstly, the vibrations can be optimized/reduced through proper component selection including the analysis of dedicated skip firing scenarios. Secondly, the increased loads can be accounted for to ensure that the components can withstand the additional irregular vibration patterns that occur between the engine and the propeller or gearbox. And finally, a proper TVD and coupling tuning is needed.

Thu 15:15 Karajan Hall Powertrain Components I (3A)

Sustainable Solution by Reducing Idle Speed and Fuel Consumption in Crane Application with Super-Soft Rubber Coupling
M. Hasan
REGAL REXNORD

In the quest to reduce CO2 emissions in crane operations, this study explores the effectiveness of reducing idle speed in systems where a combustion engine drives gearbox pumps through an elastic soft rubber coupling. By optimizing idle speed, significant reductions in fuel consumption and associated carbon emissions can be achieved without compromising operational efficiency. The soft rubber coupling plays a critical role in absorbing vibrations and minimizing wear, thus enhancing the longevity and reliability of the system. This approach offers a practical and sustainable solution for minimizing the environmental impact of cranes applications, aligning with broader efforts to reduce greenhouse gas emissions in industrial applications. The measurements indicate a reduction in engine idle speed at lower levels, with no resonance observed at these reduced speeds. Real-time measurements were conducted in a crane application, confirming a decrease in idle speed.

Thu 15:40 Karajan Hall Powertrain Components I (3A)

Vibration Aspects of Different Power Take-Off Units for 2-Stroke Marine Propulsion Systems
R. Wilkie, D. Richter-Trummer, A. Thalhammer
Geislinger GmbH

With the ever-increasing need to lower emissions, shipyards are looking at all the components along the powertrain to find new areas where efficiency can be increased. This increase in efficiency is often directly correlated with a decrease in fuel consumption, which in turn lowers operating costs and ensures better compliance with environmental legislation.
One of the key areas of interest along the powertrain are the diverse types of power take-off units. These units all have a direct impact on fuel consumption, maintenance costs and onboard noise levels. Power take-off units can be divided into three distinct categories: shaft, tunnel gearbox-driven and front-end generators. Each category has its own distinct set of advantages and disadvantages, particularly when it comes to torsional vibration effects along the powertrain.
This paper looks to analyze the torsional vibration effects of the diverse types of power take-off units in 2-stroke marine propulsion applications. Each type of power take-off unit creates a unique change in the torsional vibration system. The additional loads from these units often place additional stresses on other components along the powertrain. Thus, special attention is required when dimensioning torsional vibration dampers or flexible couplings to combat issues associated with these additional stresses.

Thu 14:50 Wolf-Dietrich Hall Power System Simulation II (3B)

System-Modelling Marine Drivetrains: A Glimpse at the MBSE Approach at IME Aachen GmbH
B. Juretzki, M. Körber, T. Möller, F. Andary, J. Marheineke
IME Aachen GmbH

Model-Based Systems Engineering (MBSE) aims towards an improvement of complexity-handling, agility, and efficiency in engineering processes by transforming the product development process from a document-centric approach to a model-based approach. In this context, the IME Aachen GmbH pursues the implementation of a MBSE methodology which follows approaches of modularization of the system (sub) components and generalizable and automatable Validation Workflows to check the fulfillment of requirements for actual state of the development. This paper presents the motego Entities method as an extension of the motego method from MSE institute of RWTH Aachen University. This method uses the abstract-defined System Solutions and Structure Set from motego in order to create a library of concrete implementations for Solution Entities, such as bearings or shafts, in the mechanical system. Higher levels of detail can be achieved through recursive nesting of the System Solution model structure. The method is applied to the example of a marine drivetrain consisting of an ICE and electrical motor, elastic coupling, transmission, and propeller. The validation of requirements in such System Model is demonstrated on the dynamic behavior of the drivetrain. In addition, the set-up of Validation Workflows for requirements is shown, which automatize the usage of Torsional Vibration Simulation utilizing IME's concept of Smart Model Units (SMU®).

Thu 15:15 Wolf-Dietrich Hall Power System Simulation II (3B)

Temperature Effects on the Dynamic Stiffness and Damping of Carbon-Filled Elastomer Couplings

S. Bahr, G. Jacobs, S. Akbulut, T. Rapp, S. Wischmann
Institute for Machine Elements and Systems Engineering, RWTH Aachen, 2VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG.

Widely used in automotive and industrial drivetrain applications, elastomer couplings dynamically isolate drivetrain components and dissipate vibrational energy. The stiffness and damping of the coupling are determined by the nonlinear material effects of the elastomer, which are dependent on both dynamic load and temperature. This research examines the impact of temperature on stiffness and damping of the coupling under torsional load, focusing on hyperelasticity, viscoelasticity, and the PAYNE effect. Dynamic mechanical thermal analyses were conducted on a servo-hydraulic torsional test bench with a climatic chamber, evaluating the coupling's stiffness and damping across a temperature range of 20 °C to +80 °C. The investigation allows for an attribution of temperature effects to material effects of elastomers and thereby an influence analysis on the stiffness and damping of the coupling. The procedure is demonstrated on two different coupling sizes both manufactured from the same batch of elastomer compound with a Shore A hardness of 65. The findings provide valuable insights into elastomer material behavior of the coupling to improve torsional vibration characteristics of drivetrains in temperature-variable environments. Within the observed temperature range, stiffness varies by factors of up to 50 %, and damping by up to 100 %, compared to room temperature.

Thu 15:40 Wolf-Dietrich Hall Power System Simulation II (3B)

Open-Source Software for Torsional Vibration Analysis

S. Laine
Aalto University

Commercial codes are typically used in torsional analyses, leaving two options: either settle for the features provided by the commercial code or develop an in-house code. The latter is often chosen by companies to allow for modifications and the implementation of novel or application-specific methods. Recent developments in open-source tools for torsional vibration analysis have introduced a new possibility, as both industry and academia can now develop in-house codes using open-source libraries as a foundation. In this study, two open-source libraries are considered: OpenTorsion, a library for creating and analyzing lumped-element torsional vibration models, and Motulator, an electric drive simulation code. These software tools can be interconnected to simulate torsional vibrations in electric powertrains, including the electrical system and control of the electric drive. Both libraries are developed in Python, an open-source programming language widely used in the academia and the industry. The study demonstrates that VFD-driven electric motor systems can be effectively simulated using these freely available tools, which feature permissive licenses for commercial use. Case examples of two VFD applications are presented and discussed.

Thu 16:30 Karajan Hall System Reliability - Case Studies II (4A)

Development of a Damage Model for the Lifetime Prediction of a Viscous Torsional Vibration Damper

A. Leib, B. Mokdad, Y. Peterschmitt
Liebherr-Components Colmar SAS

Uneven cylinder pressures in reciprocating internal combustion engines result in oscillating and twisting forces in the crankshaft, known as torsional vibrations. Viscous-type torsional vibration dampers (TVDs) are commonly used in modern engines to absorb and dissipates these vibrations into heat to prevent crankshaft fatigue failure. The ambient temperature surrounding the TVD also contributes to the increase of the temperature inside the TVD. This heat can cause premature thermal ageing of the silicone oil, potentially leading to critical crankshaft failures. Estimating the temperature of a TVD's silicone oil under specific operating conditions is crucial for evaluating its degradation level. To address this, a Design of Experiments (DoE) approach based on an existing TVD thermal model was employed to determine the silicone oil temperature. Additionally, thermal ageing measurements were conducted to assess the viscosity drop of the silicone oil when subjected to sustained temperatures over a given amount of time. The results of these measurements and the DoE enabled the creation of a model to estimate the degradation of viscous-type TVDs, considering the engine configuration, running hours at given speeds and surrounding ambient temperatures.

Thu 16:55 Karajan Hall System Reliability - Case Studies II (4A)

Marine Propulsion Shafting Excessive Torsional Vibration: Case Study Revisited

B. Cowper, Z. Schramm
LamaLo USA, LLP

At the 2022 Torsional Vibration Symposium (TVS) two case studies were presented by the Authors. One of the cases described excessive torsional vibrations on the propulsion shaft of a Bulk Cargo vessel. The vessel is powered by two V16-cylinder, four-stroke diesel engines through a double-input/single output reversible reduction gearbox to a fixed-pitch propeller. Numerous failures had occurred to the propulsion engines and the shaft couplings between the gearbox and main engine. This including two connecting-rod failures. Excessive resonant torsional vibrations were measured and barred speed ranges were determined in 2019. A re-design of the shafting system was developed to provide for a system without excessive torsional vibrations throughout the shaft speed operating range. A new shaft connecting the gearbox to the main engines was fitted, complete with a support bearing and a flexible torsional coupling at the engine end. To determine the effectiveness of this new arrangement, torsional vibrations and power measurements were taken during a voyage in July 2022. This paper provides the results of the measurements with the modified system and compares the results to the previous measurements.

Thu 16:30 Wolf-Dietrich Hall Active and Passive Dampers (4B)

Active Damping of Torsional Vibrations
U. Ubaid
Lloyd's Register EMEA

A conceptual design of a modal state feedback controller to attenuate torsional vibrations at resonance with the engine excitations is presented in this paper. Using this method, a dynamic state feedback controller can be designed to increase the damping of the problematic mode at the desired speeds. The control design methodology is developed and illustrated through simulations using a model of a 2-stroke direct drive marine propulsion shafting system. Steady state frequency domain simulation results show that the control actuation torque applied at only a single inertia station can reduce the vibratory torques at all shaft sections and thus reduce the stresses to below the permissible limits for continuous operation. The maximum actuating torque required to reduce the vibratory stress by 20 MPa, to below the limit for continuous operation at the critical speed of first mode engine firing frequency, which occurred at 55% of MCR speed, is 59% of the propeller load torque.

Thu 16:55 Wolf-Dietrich Active and Passive Dampers (4B)

Improved Prediction of the Nonlinear Behavior of Silicon Oil in Viscous Dampers
M. Steidl, R. Zadoks, S. Willeke
Hasse und Wrede GmbH, Independent Consultant

Starting in the late 2000's, Hasse & Wrede found that simulation methods used to predict the behavior of viscous dampers sometimes led to results which deviated from the measured torsional vibration levels. To address this gap, an extensive research program was undertaken to improve viscous damper simulation methods. This work included the development of a rheometer that could duplicate the conditions that silicone oil is subjected to during operation in a viscous damper and then using measured results to develop a new empirical model of the mechanical properties of silicone oil depending on the base viscosity, temperature, frequency, and shear. Application of this advanced silicone oil model improves the accuracy of the prediction of torsional vibrations of viscous dampers during operation of reciprocating machinery. The application of this nonlinear silicone oil model will be illustrated with two examples: one where there is relatively little difference between the linear and nonlinear model results, and another where there are significant differences between these two sets of results.

PREDICTING COMPLEXITY WITH PRECISION

- In-depth development of an in-house silicone oil model
- Enhanced Simulation Accuracy
- From Case Study Insights to Industry Applications

We wish all participants a successful and
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HASSE & WREDE

Fri 09:00 Karajan Hall Keynote Speech

Decarbonising Large Bore Internal Combustion Engines

Alexander Knafl, PhD
Senior Vice President of R&D Engineering Four-Stroke MAN Energy Solutions SE, Germany

Energy availability and security are at the heart of global stability. As demand for energy surges in an increasingly interconnected world, and the race for renewable dominance will define the fate of nations, competition over resources has fueled tensions, trade disputes, and even conflicts. The quest for stable, sustainable, and equitable energy solutions has never been more urgent.
While some sectors such as electricity or heating are relatively easy to de-carbonize, some other sectors heavily rely on energy-dense hydrocarbon fuels. Among those are aviation and deep-sea shipping with each of them accounting for approximately 1.8% of total annual GHG emissions Within the shipping sector, liquid, diesel-like fuel oils are the predominant source of energy. The International Maritime Organization (IMO)—the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships—has put forward the ambitious goal to reduce GHG emissions intensity by at least 40% by 2030 compared to 2008 and reach net-zero GHG by or around 2050. Similar ambitious targets are put forward by the EU through the European Green Deal and are adopted in the European Climate Law.
Internal combustion engines continue to play important roles particularly in propulsion and electricity production for the foreseeable future. Operational measures and technical improvements to increase overall efficiency are able to reduce GHG emissions. Reaching net-zero GHG emissions, however, requires carbon-neutral or carbon-free fuels wherever electrification or carbon capture is not viable. Biogenic—liquid or gaseous fuels with properties similar to today's fossil based-fuels can be used as blends or straight run. These fuels are likely to be limited in quantity. Renewable hydrogen (H2), methanol (CH3OH) and ammonia (NH3) are promising fuel candidates for achieving reach net-zero emissions. While all three fuel candidates have been demonstrated for use in internal combustion engines, several technical, regulatory and economic challenges remain and few engines have made their way into commercial applications.

Fri 09:50 Karajan Hall Marine Propulsion (5A)

Impact of Propeller Retrofits in the Torsional Vibrations of Marine Propulsion Shafting – Case Studies

K. Lal, J. Klüss
Mecklenburger Metallguss GmbH

The objective of this paper is to provide an overview of the impact of propeller retrofits in the Torsional Vibration Calculation (TVC) analysis of marine propulsion shafting for the sea-going vessels. In the first part of this paper, a background on the increasing demand for propeller retrofitting in marine vessels is presented. Nowadays, most of the existing fleet of vessels are forced to reduce their maximum engine load and vessel speed due to the rising IMO regulations on Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII). This requires shipping companies to modify or upgrade their current propulsion systems by some measures such as engine modifications, including (engine de-rating, re-tuning, turbocharger cut-off, and exhaust gas by-pass), which often necessitates propeller retrofitting in ships. In the main part of this paper, the influence of propeller retrofits on the torsional vibration in the ship propulsion drive is explained. The main propeller parameters, such as propeller mass and blade number, that can directly affect the torsional vibration characteristics are described, along with some relevant studies. The torsional vibration analysis with these propeller parameters indicates that propeller designs with an optimised geometry and reduced mass will often have a positive impact on torsional vibration behaviour in the propulsion line, resulting in higher propulsion efficiency and reduced Specific Fuel Oil Consumption (SFOC) on vessels.

Fri 10:15 Karajan Hall Marine Propulsion (5A)

Unveiling the Truth Behind First Order Dynamics and Alignment

M. Zeid
BERG Propulsion

The widely accepted notion that "dynamic response measurement shows first order response" often shifts the focus to "alignment." However, how accurate is this common understanding? What exactly is "alignment," and how do different inducers affect first-order dynamics? This paper delves into the most prevalent first-order dynamics, tracing the journey from excitation to dynamic responses. It explores various types of alignment, identifying when alignment is connected to first-order dynamics and when it is not. Additionally, the paper highlights efficient tools for each addressed case, providing insights into their effectiveness and application. By dissecting these elements, the paper aims to clarify misconceptions and offer a comprehensive understanding of first-order dynamics and alignment.

Fri 09:50 Wolf-Dietrich Hall Measurement and Monitoring (5B)

MEMS Gyroscope in Torsional Vibration Measurements
J. Köykkä, J. Määttä, P. Sundström, A. Roveredo, M. Martin
Wärtsilä Finland Oy

Torsional vibration measurements are crucial in assessing the mechanical integrity of rotating machinery. Multirow flexible couplings present a unique challenge in torsional vibration measurements. Each rubber element row has its own mode shapes, which may coincide with the main excitation frequencies from the engine, potentially leading to resonance, coupling failure, and reduced lifespan. Traditional measurement techniques using pulse train, strain gauges, or magnetic field-based applications often face challenges when applied to multirow flexible couplings. Due to low inertia and stiffness compared to other components in the system, responses from flexible couplings should be measured directly from individual rows. MEMS Gyroscope sensors offer a promising solution by directly measuring angular velocity. These sensors can be placed at any point on a rotating disc or shaft. The voltage output from the sensor provides the rate of angular velocity, and with adequate post-processing, torsional vibration data can be accurately extracted. Importantly, these sensors exhibit low sensitivity to linear vibrations, making them suitable for this application.

Fri 10:15 Wolf-Dietrich Hall Measurement and Monitoring (5B)

Early Fault Detection Applied to Turbines, Piston Engines, and Torque Evaluation
H. Saiah
dataVIB Impédance

Continuous monitoring of turbines (steam or gas) and piston engines (diesel or gas) performance is critical for early detection of fault developments in an engine or turbine before it goes into a functional failure. Torsional vibrations based on extraction instantaneous angular speed (IAS) analysis is one of a few non-intrusive condition monitoring techniques that could be applied for such tasks. This method is more powerful than traditional methods and needs only a non-intrusive speed sensor (existing/or added magnetic or optical) signal to assess in details the mechanical behavior of an engine or turbine and diagnose in case of turbine such regularity/deviation, combustion-kit status, bearings, blades for gas turbine; and also wear, bearings, blades, regulation for steam turbine. Also in case of piston engine: fuel injection performance, compression in cylinders, condition of cylinder parts, and damage to bearings/moving parts can be monitored, even pinpointing the exact cylinder that is defective. The technique is more suitable and efficient for mass industry deployment than other non-intrusive methods such as vibration and acoustic emissions. A combination of instantaneous angular speed analysis based on Hilbert transform associated with order analysis and statistical moments is used and give detailed and robust diagnosis. The systems are used and deployed in certain industries like waste to energy conversion, fleet locomotives, military/ferry boats, oil/gas, energy, etc.

Fri 11:05 Karajan Hall Vibrations of Powertrains (6A)

Shudder in Wet Brakes and Clutches Caused by the Performance Loss of E-Drive Lubricants J. Wirkner, A. Lebel, C. Besser, H. Pflaum, K. Voelkel, K. Stahl
Technical University of Munich, Austrian Centre of Competence for Tribology

The driving comfort and safety of electric vehicles are significantly related to the performance, aging, and functionality of the e-drive transmission fluid (ETF). The presented study focuses on investigating the performance loss of the ETF due to water influx resulting from environmental influences and iron particles originating from the wear of different gear unit components. The performance loss can lead to adverse NVH (Noise, Vibration, Harshness) behavior, perceptible as shudder noise, and is evaluated by the changes in the friction behavior of wet clutches.
Furthermore, a deep understanding of the correlation between shudder and friction behavior is inevitable to prevent damage to distinct machine elements or entire subsystems within the transmission. Hence, a method was developed that indicates the performance loss by correlating the gradient of the coefficient of friction with water and iron content as well as mechanical energy input.
The presentation will provide insights into associated test methods for component test rigs to determine the performance loss of the ETF in an application-related test environment. Results are shown from investigations with wet clutch parts from a transfer case used in serial auto-motive applications, considering the influence of water contamination and iron particles as well as their mutual interactions.

Fri 11:30 Karajan Hall Vibrations of Powertrains (6A)

Designing Synchronous Motor-Driven Trains Against Torsional Vibration
M. A. Corbo
No Bull Engineering, PLLC

In turbomachinery, electric motor-driven trains suffer far more torsional vibration problems than those driven by steam or gas turbines. The problem is compounded if the motor is a synchronous motor because of the pulsating torques such motors generate during starting. When the excitation frequency of those torques coincide with the first torsional mode, the resulting stresses almost always exceed the shaft endurance limit somewhere in the train. As a result, these trains almost always have a limit on the number of starts they can withstand. The paper begins with a brief description of synchronous motors, their construction, and why they need to be started as an induction machine. It then describes why this start-up method can be hazardous and how to perform the needed transient torsional analysis of their start-up. The paper then addresses the aspect that befuddles most engineers – the use of the transient results to predict the number of starts the train is good for. A highly rigorous fatigue analysis procedure is presented for doing this. Most importantly, readers are given a number of remedies that can be made to both the analysis and the design to make an unacceptable train acceptable without having to go to an expensive "band-aid" such as an elastomeric or torque-limiting coupling.

Fri 11:55 Karajan Hall Vibrations of Powertrains (6A)

Torsional Vibration Challenges in Parallel Hybrid Systems

M. Dylla, H. B. Alaya
VULKAN Kupplungs- und Getriebebau Bernhard Hackforth GmbH & Co. KG

The use of hybrid propulsion systems is becoming increasingly important with the introduction of new emission standards for ships. In this context, the electric machine is of key importance for the economy, manoeuvrability, safety and reliability of ship operation. The torsional vibrations of the ship's drive shaft have a direct impact on the performance and safety of the ship's operation. At present, two concepts can be identified as favourites. One is the so-called inline electric machine, which is integrated into the main drive train. The second possibility is the parallel-connected electric machine, which is coupled to the main drive train via a gearbox, like the PTO/PTI concepts known from the past. In the past, it was relatively easy to ensure resonance-free operation with PTO/PTI concepts operating at constant speeds, even with inexpensive elastic couplings. Today's drive concepts are based on frequency controlled electric motors or generators, which should be available without restriction for all required operating conditions over the entire operating speed range. However, compliance with the permissible loads in the gear mesh and the necessary flexible couplings, as well as proof to the classification society, is a challenge that is often recognised too late by the project engineer. This paper presents studies that highlight the main challenges associated with torsional vibration loading in parallel hybrid applications. General solutions will also be presented. Another objective is to increase the understanding of the need for torsional vibration calculations and their early consideration in the project. This is particularly important as it is easier to find a solution at the beginning of a project than at a later stage when extensive specifications and design decisions have already been made.

Fri 12:20 Karajan Hall Vibrations of Powertrains (6A)

A Digital Twin for Torsional Vibrations of Power Plant Turbogenerators

S. Herold, H. Holzmann, R. Nordmann, P. Smeekes
Fraunhofer Institute for Structural Durability and System Reliability LBF, Technical University Darmstadt, Teollisuuden Voima Oyj (TVO)

Turbogenerators are important mechanical and electrical components in power plants. The steam turbines convert thermal energy into mechanical energy causing the rotor to spin. And the generator produces electrical energy by electromechanical interactions. The total energy is transferred via the air gap torque of the generator. For a safe and reliable operation, the mechanical-electrical interactions in the air gap of the generator and the resulting torsional vibrations of the shaft train must be observed very carefully. In case of disturbances in the electrical system, the excited transient torsional vibrations may become very large due to the low system damping.
In such cases it is important to control the torsional vibration behaviour to guarantee acceptable vibration and stress levels. A Digital Twin is a suitable monitoring tool to solve this task. With a Finite Element Model (FEM) as part of the Digital Twin torsional vibrations can be calculated. And the real torsional vibrations are measured at selected locations of the shaft train with sensors. By comparison of measured and calculated torsional vibrations, the vibration difference is introduced into a calibration loop of the Digital Twin, in which the system parameters as well as the air gap torque are continuously identified and adjusted. The Digital Twin can be used online, running permanently parallel to the real system as a monitoring system and as a detection system in case of system failures.

Fri 11:05 Wolf-Dietrich Hall Compressors (6B)

Electrical System Interaction Induced Torsional-Lateral Coupled Vibration at Integrally Geared Compressor

R. Chumai
Machinosis Company Limited

A motor-driven integrally geared compressor experienced intermittent subsynchronous vibration (SSV), primarily affecting stages 1 and 2 pinion. Noticed vibration frequency was close to first torsional natural frequency (TNF) documented in the machine's datasheet, prompting suspicion of torsional vibration excitation. Subsequent torsional vibration analysis was conducted utilizing high-sampling rate key-phaser data for torsional vibration extraction based on wavelet decomposition. This analysis revealed torsional vibration frequency closely resembling the SSV observed, confirming torsional-lateral coupled vibration. To find the possible excitation source, motor dynamic current was measured using a current transformer. The dynamic current spectrum revealed sidebands of the same subsynchronous frequency around the power supply line frequency of 50 Hz during torsional vibration occurrences. This observation suggested that fluctuating air gap torque caused by noisy current supply was the root cause of the torsional vibration. Further investigation revealed a correlation between vibration amplitudes in stages 1 and 2 and the power consumption of the gas heater within the same power supply loop as the motor. This correlation indicated that SSV manifested at specific levels of gas heater power consumption. As a temporary solution, the gas heater was operated at power levels that eliminated the SSV.

Fri 11:30 Wolf-Dietrich Hall Compressors (6B)

Variable Inertia Effects on Torsional Vibration of Reciprocating Compressors

M. Thorn, T. Stephens
Ariel Corporation

A torsional analysis will generally assume that reciprocating masses of a reciprocating compressor package can be treated as constant moment of inertia elements. This simplification linearizes the differential equations governing the drivetrain's rotational motion, making them easier to solve. However, this approach neglects torque produced by torsional vibrations that accelerate and decelerate reciprocating masses, which can have a significant impact. As a compressor crankshaft rotates, the distance from the crankshaft axis to the center of mass of the piston assembly, crosshead, and conrod changes. This results in a moment of inertia that changes as a function of crank angle. The varying inertia leads to fluctuating torsional natural frequencies, which makes frequency domain predictions difficult. A time domain model, with variable inertia included, will show the presence of secondary responses, principally at two orders above and below a resonant harmonic. These secondary responses are usually low in amplitude but have the potential to excite other torsional modes. This paper will present a method for calculating variable throw inertia and demonstrate how torque at ±2 harmonics of the excitation frequency is manifested. Case studies will show measurements and predictions of the secondary responses and how modal response interactions can occur.

Fri 11:55 Wolf-Dietrich Hall Compressors (6B)

High Vibration of Integrally Geared Compressor Due to Variable Frequency Drive

T. Robertson, T. Feese
Eagle LNG Partners, Engineering Dynamics Incorporated

High vibration levels were occurring on the integrally geared compressor causing the unit to trip. The compressor manufacturer verified the vibration readings, replaced the bearings, and found evidence of backlashing on the gear teeth. There is a variable frequency drive (VFD) that is primarily utilized for electrical soft-starting but remains engaged at full operating speed of the induction motor (3583 RPM, 60 Hz). A strain gage telemetry system was installed on the motor shaft and used to measure alternating torque of more than ±120% of the full load torque (FLT), which is an abnormal condition for centrifugal machinery. The predominant frequency of the torque fluctuation was the first torsional natural frequency (TNF) of the system. The excitation source was the VFD when operating at any speed above the TNF even though there was sufficient separation margin (SM) from torsional resonance.
The medium voltage drive was found to be in Volts/Hz (scalar) mode, which is typical for equipment not requiring precise speed or torque control. Correlation was made between the torque fluctuation and sidebands in the electrical current at the motor junction box, also indicating the VFD was the source of the excitation. Several attempts were made to tune the VFD parameters with no significant improvement. The VFD was changed from scalar mode to sensorless vector mode, which is better able to control the torque and magnetizing portions of the current. The motor had to be decoupled from the compressor and operated solo so that the drive parameters could be tuned. Upon restart of the compressor unit, the alternating torque was dramatically reduced to an acceptable level. If this torsional vibration problem had not been detected and corrected, the high alternating torque levels could have damaged the motor shaft, coupling components, and gearing in the compressor.

Fri 12:20 Wolf-Dietrich Hall Compressors (6B)

Simulation Based Dimensioning of Drivetrain Components in Motor-Driven Reciprocating Compressors

T. P. Holopainen T. Ryyppö, M. Lyly
ABB Oy

The calculation procedures for torsional powertrain analyses in industrial applications are well-established. Typically, a powertrain is modelled as a linear one-dimensional system, with electromechanical interactions neglected and electromagnetic torque treated as an external load. However, it has been observed that when the load inertia is large and the shaft coupling is flexible, these electromechanical interactions can significantly alter the lowest critical speeds and their damping. A common example of this is a motor-driven reciprocating compressor with a soft coupling.
This paper introduces a novel approach for industrial powertrain analyses, employing time-domain simulations for all industrial load cases using a consistent non-linear electromechanical model. To illustrate this approach, a calculation example involving a motor-driven reciprocating compressor is provided. While this approach increases computational time, the total time and required resources are reduced due to the automation of model generation, solution procedures, and post-processing of results.

Fri 13:45 Karajan Hall Powertrain Components II (7A)

Reciprocating Compressor Coupling Revamp: Advantages of Highly Flexible Elastomeric Couplings and Disadvantages of Steel Disc Couplings for Torsional Vibration Aspects

K. Kloos
Neuman & Esser GmbH & Co. KG

In the early past, common coupling types for reciprocating compressor applications have been elastomeric rubber-in-compression or steel disc couplings. Due to their dynamic torsional stiffness the natural frequency of these coupling types is always in a range of low harmonics (1st to 6th) with high excitation torque. Therefore, rubber-in-compression couplings often suffer a high wear and steel disc couplings can even fail if they are not properly designed considering the inaccuracy in torsional stiffness and a high safety factor. For twenty years Neuman & Esser has used highly flexible elastomeric couplings as standard coupling type. Especially the combination with an electric motor has proved itself as a very robust system without any failures. Due to much lower coupling stiffness the natural frequency is usually below the 1st harmonic. But even more important is the reaction of the motor air gap torque on the compressor torque dynamics, which has a significant effect on the torsional vibration behavior of the elastic shafting system and coupling. This paper will show the advantages of highly flexible couplings by comparison of torsional vibration simulation results for a revamp of a compressor drive train, at which the original steel disc coupling failed several times.

Fri 14:10 Karajan Hall Powertrain Components II (7A)

Reduction of Torsional Vibration through Power Take-In System in Marine Shaft Generators

J. Kim, J. Choi
HD Hyundai Heavy Industries

As international environmental regulations for ships are progressively tightened, marine diesel engines are increasingly required to comply with environmental regulations (Energy Efficiency Design Index (EEDI)) while offering good environmental performance and fuel efficiency. In particular, shipowners are increasingly requiring the use of shaft generators to improve energy efficiency and reduce carbon emissions on both newbuildings and existing vessels. Shaft generators (generators driven by the rotating shaft of another machine) are environmentally friendly products that use the rotating power of the shaft of the propulsion engine to generate the electricity needed by the ship when it is in operation, and the electricity is generated by a large engine with a higher fuel efficiency than a generating generator engine, which can reduce fuel costs and improve the ship's EEDI (Energy Efficiency Design Index), which is gradually being strengthened according to IMO environmental regulations. The shaft generator has three modes for use with the main propulsion engine. The first, Power Take Out (PTO) mode, provides the main power to the ship's grid and optimises the use of the larger engines, reducing the need for auxiliary generators, thus reducing fuel costs and emissions. Secondly, in Power Take In (PTI) mode, it acts as a synchronous motor for an additional power boost when the shaft generator is propelling. Finally, in Power Take Home (PTH) mode, the shaft generator provides emergency propulsion when the main engine is not running. This study investigates the effectiveness of reducing torsional vibration in propulsion shafts using the Power Take In (PTI) mode. Torsional vibration is a significant challenge in marine propulsion systems, sometimes leading to mechanical failure. Experiments were carried out under various phase conditions in PTI mode to measure changes in torsional vibration in the propulsion shafting. The test results showed a reduction in the amplitude of torsional vibrations in the PTI mode. In particular, certain phase conditions showed that the PTI system was effective in reducing torsional vibrations. This could be one of the solutions to the torsional vibrations.

Fri 13:45 Wolf-Dietrich Hall Rules and Regulations (7B)

CIMAC Working Group 4 Crankshaft Rules – Current Activities

P. Böhm, T. Frondelius, J. Dowell, D. Bell, Y. Hanawa
MAN Energy Solutions SE, Wärtsilä, Wabtec Corporation, Realis Simulation Ltd., Kobe Steel Ltd.

In 2022, the CIMAC Working Group 4 (WG4) Crankshaft Rules gave a short introduction to itself and its fields of activities and an outlook on what should be achieved in the near future. Three main topics have been addressed:

- Working out a technical base for taking the cleanliness of steel into account for the fatigue strength assessment of crankshafts.
- Creating a white paper giving best practice guidance for the multi-body simulation of crankshafts. This includes recommendations for the usage of multi-body dynamics for load and stress determination in engine crankshafts.
- Working in the field of multi-axial fatigue, creating a recommendation for the multi-axial fatigue assessment for infinite life design of engine crankshafts and setting up an algorithm challenge.

In this contribution, we will give an overview of the current activities and current achievements within WG4 and inform about some significant progress.
The clean steel subgroup gives new guidance to handling the property cleanliness within the context of the Unified Requirement M53, leading to new proposals for Appendix IV "Guidance for Evaluation of Fatigue Tests" and Appendix VII "Guidance for the Application of Clean Steel". The multi-axial fatigue subgroup informs about the current status of the new CIMAC Guideline "Multiaxial Fatigue Assessment of Crankshaft Design", including results from a series of fatigue tests on single crank throw specimens and from a fatigue challenge. Furthermore, a new testing phase has been started to extend the investigation to induction hardened crankshafts. Finally, an update is given about the CIMAC Guideline "Multi-Body Simulation to Assess Crankshaft Designs".

Fri 14:35 Karajan Hall Closing Session (8)

TVA Modelling Beyond the Deterministic Theory

A. Thalhammer, K. Bergmann
Geislinger GmbH

In propulsion systems with internal combustion engines, torsional vibration analysis traditionally relies on deterministic models. However, real-world factors - such as component wear, combustion stability or environmental conditions - introduce variability that can significantly affect system performance. This paper highlights the benefits of moving beyond deterministic approaches by incorporating stochastic modelling to better capture these influences. Key input factors are analyzed based on their statistical properties across different time scales. These time scales range from long-term effects including wear, hull fouling, and related maintenance activities, towards mid-term variations such as weather conditions and thermal effects, to finally transient behaviors, such as engine start-ups and load changes. These factors can have a substantial impact on the dynamic response of the system and are critical for consideration when designing or retrofitting propulsion systems. By incorporating stochastic modelling, this study offers a more robust framework for evaluating and optimizing the reliability and performance of drive trains, accounting for real-world variability that is often overlooked in traditional approaches.

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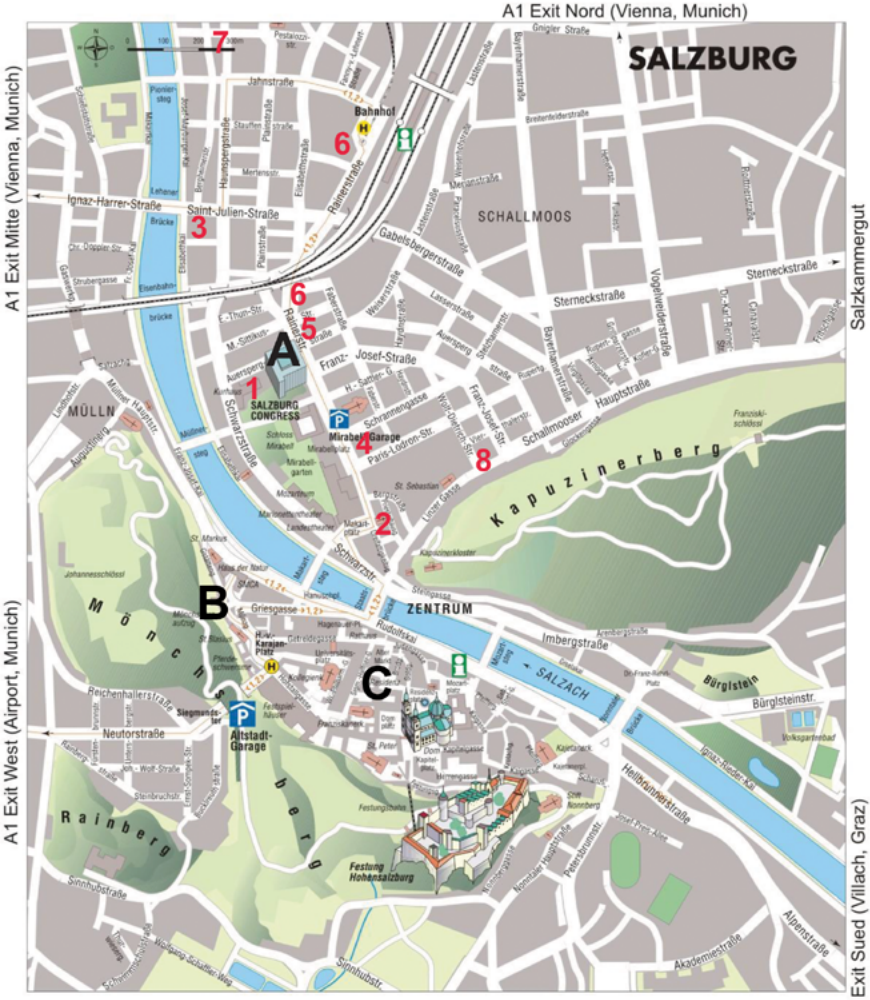
Map – City of Salzburg



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7 Hotel Mayburg
8 Hotel Hofwirt

A Salzburg Congress
B Welcome Reception, Restaurant M32
C Gala Dinner, Residenz

Symposium Location

The Salzburg Congress is within walking distance of the historical city centre and most hotels can easily be reached by bus. It is also located right next to the famous Mirabell Garden. The Symposium will be held on the first floor of the Salzburg Congress, in the Karajan Hall and the Wolf-Dietrich Hall.

Salzburg Congress
Auerspergstrasse 6
5020 Salzburg / Austria

Website: www.salzburgcongress.at

Symposium Location: Salzburg Congress / Photos: Tourismus Salzburg GmbH

Salzburg Congress Floor Plan

Exhibitors

Geislinger GmbH (1)
VULKAN (2)
Hasse & Wrede GmbH (4)
Intellectual Maritime Technologies (5)
Torquemeters Ltd. (6)
Dewesoft GmbH (7)
OROS Digital S.A.S (8)
Impédance DataVIB (9)
Telemetrie Elektronik GmbH (10)
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Manner Sensortelemetrie GmbH (13)
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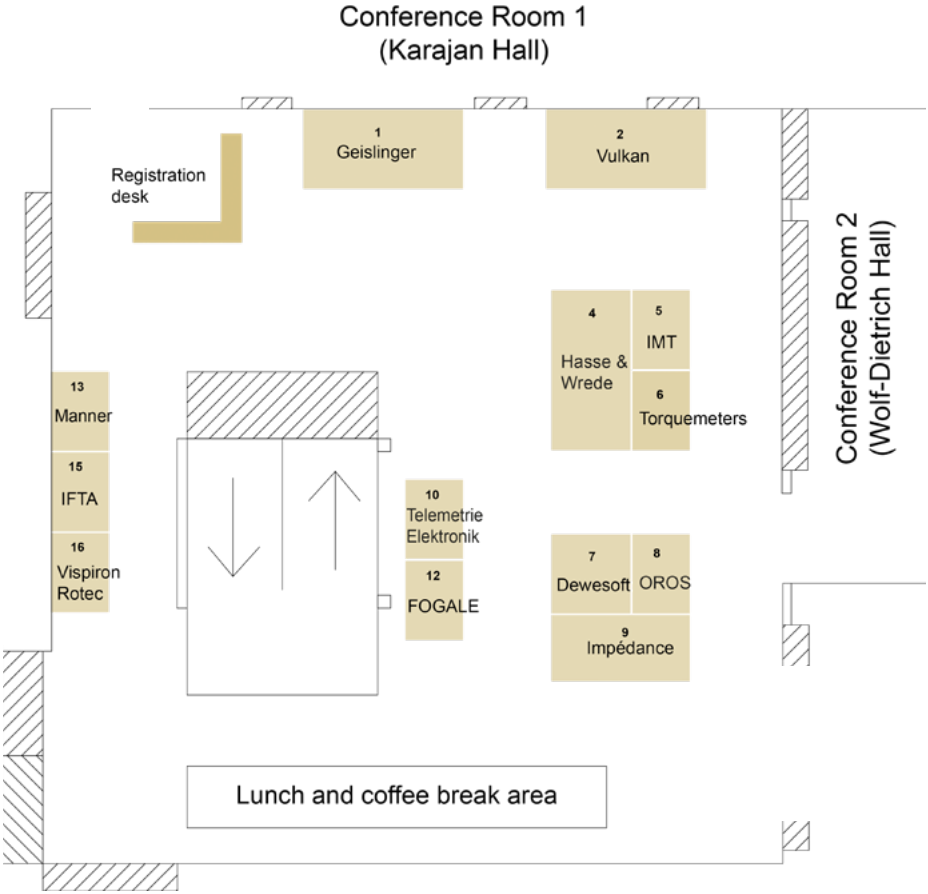

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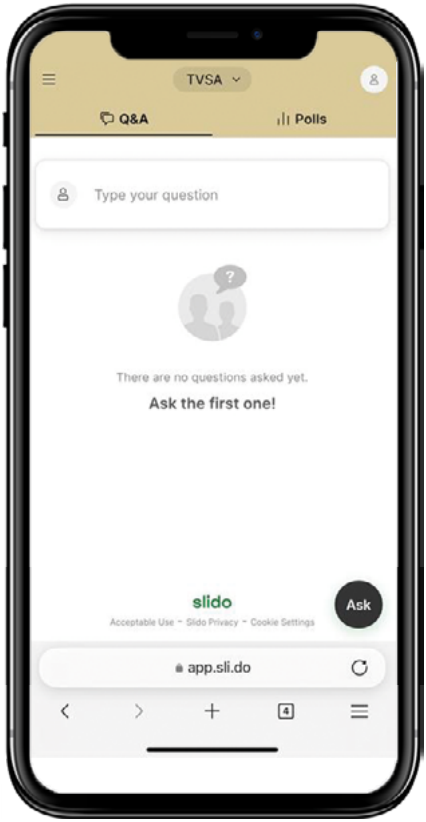

Welcome Reception

Welcome Reception*, Restaurant "M32"
Wednesday, May 14, 2025, 18:00

Please use the elevator called "Mönchsberg Aufzug" to reach the restaurant on top of the city hill Mönchsberg. Our staff will welcome you there and show you the way up to the restaurant M32.

Address: Mönchsbergaufzug, Gstättengasse 13, 5020 Salzburg

Restaurant M32

View of Salzburg's Old Town

The M32 is located on one of the city hills of Salzburg. Matteo Thun's design combines naked concrete and vivid colors and is dominated by the 390 stag antlers adorning its walls. Due to the restaurant's top location, the entire city can be admired from the dinner table while enjoying traditional Austrian or simple Mediterranean cuisine. The M32 offers a modern and creative, yet delightful and natural atmosphere combined with a stunning view and excellent food.

*The "Welcome Reception" is included in the Symposium Participation Fee.

Gala Dinner

Gala Dinner*, Salzburg Residence Palace
Thursday, May 15, 2025

18:00 Aperitif
19:00 Gala Dinner

Address: Residenzplatz 1, 5020 Salzburg

Residence Palace

The old residence palace is the Prince Archbishop's palace complex. It is surrounded by the cathedral square (Domplatz), the residence square (Residenzplatz) and the Sigmund-Haffner alley, which spans from our city hall to the Franciscan church (one of the oldest churches in Salzburg). It was first built in 1120, but completely demolished and rebuilt in 1597 in the style of the late renaissance on the order of Archbishop Wolf Dietrich. In the residence, there is a total of 180 rooms, containing 15 pompous baroque rooms, which never fail to fascinate and impress visitors.

*The "Gala Dinner" is included in the Symposium Participation Fee.

Social and Cultural Program

Hallstatt Tour
Saturday, May 17, 2025
Participation Rate*: EUR 150,- / Person, Pre-registration required, takes place in all weather conditions.

This Hallstatt Tour from Salzburg takes you to the picturesque world-famous town between Lake Hallstatt and the steep slopes of the Dachstein Massif.
Located right on the shores of Lake Hallstatt, this small town is considered one of the most beautiful lake side villages in the world. Not only does it captivate with its fabulous idyllic & fairytale-like atmosphere, Hallstatt also has a rich history that dates back to the Neolithic Age.

View of Hallstatt

*The "Social and Cultural Program" is not included in the Symposium Participation Fee.

Contact

The organizer of the event is the Vibration Association.

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(Vibration Association)
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