TORSIONAL VIBRATION SYMPOSIUM

SALZBURG 2017

PROGRAM SALZBURG 2017

Content

Dear Colleagues,

Time flies: It is already three years since the first Torsional Vibration Symposium was held here in Salzburg. Now we are very pleased to welcome you to the second Torsional Vibration Symposium from May 17th to 19th, 2017.

We are again looking forward to welcoming torsional vibration experts from all around the globe, and to hearing lectures on a wide array of topics. In 2014 this specific meeting for torsional vibration experts attracted 186 participants from more than 20 countries. At that time 36 papers were presented and we are glad that during this second Torsional Vibration Symposium even more participants will be able to listen to an extended number of the latest technologies and technical trends.

Being responsible for the conference, we would like to thank all the authors for their contributions to the event and for their efforts to make the program so complete. The exchange of knowledge and information between torsional vibration experts from universities, research institutes, consulting companies, software- and measurement companies and from the industry are of major significance to all of us. However, the conference does not only aim at contributing to the technical and scientific progress in the field of torsional vibrations, but it also aims at improving the cooperation between people with the same interests.

We are looking forward to this second Torsional Vibration Symposium and we hope that you will enjoy it!

Sincerely yours,
Uwe Merl and Lothar Kurtze

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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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Website: www.torsional-vibration-symposium.com

Program

Wednesday: May 17th, 2017

16:00	Salzburg City Tour (not included in the Symposium fee / Price: EUR 18,-)
18:00	**Welcome Reception**, Restaurant M32

Thursday: May 18th, 2017

8:00	Registration opens
8:45	Briefing speaker
9:30	**Official opening**
9:45	**Keynote: Prof. Stefan Pischinger, FEV** President & CEO, FEV Group Holding GmbH Head of VKA – Institute for Combustion Engines, RWTH Aachen University, Germany **Torsional vibration in powertrains as a challenge for performance and a driver for innovation**
10:30	Coffee break

	Session 1A: Marine Propulsion - Responding to the latest Challenges	**Session 1B: Simulation based System Design**
10:45	**Passing time through the barred speed range and fatigue life time of propulsion shafting** S. Persson MAN Diesel & Turbo	**Firing order selection for commercial engines with FEV Virtual Engine** K. Buczek, S. Lauer FEV Polska Sp. z o.o., FEV Europe GmbH
11:10	**Aspects of simulation, estimation and evaluation of torsional loads from BSR passages** H. Keller Winterthur Gas & Diesel Ltd.	**Effect of engine ignition timing on crankshaft torsional vibrations** F. Bianciardi, K. Janssens, L. Britte Siemens Industry Software NV
11:35	**Comparison of measured torsional stress and excitation for steady state condition and transient condition** A. Yamada Mitsui Engineering & Shipbuilding Co., Ltd.	**Real time & system simulation of large engine applications as a valuable contribution to CAE tasks concerning vibrations and durability** R. Strasser, H.G. Flesch, C. Huber AVL List GmbH
12:00	Lunch	

Thursday: May 18th, 2017

	Session 2A: Marine Propulsion - Design and Development	Session 2B: Noise and Vibration
13:00	**Application of high strength steel to intermediate shaft and its effect on torsional vibration characteristic of shafting** M. Ota, Y. Iguchi, T. Ikegami, T. Arikawa, H. Takaoka, F. Tamura, Y. Hanawa, N. Fujitsuna Kobe Steel, LTD.	**Transient closed loop simulations as tool for analyzing noise in drive trains** H. Brandtstädter, L. Hübner, A. Sirucic Siemens AG
13:25	**Consequence of bearing support stiffness modelling into shaft performance prediction and system understanding in lateral** M. Zeid Caterpillar Propulsion	**Vibration isolation of large machinery** M. Heger, L. Kurtze, B. Pinnekamp, M. Heider Renk AG, Geislinger GmbH
13:50	**Engine X-mode vibration due to 2nd node torsional vibration on two stroke low speed diesel engines** D. Lee, J. S. Kim, J. H. Kim, R. D. Barro Mokpo National Maritime University	**Torsional vibrations of inequidistant gears** P. Neubauer, J. Bös, T. Melz SAM, Technische Universität Darmstadt
14:15	Coffee break	

	Session 3A: Simulation	Session 3B: Marine Propulsion - Navigating in Ice Conditions
14:40	**Simulation and measurement of turbo-generator low pressure stage torsional vibration mode assembled by disc shrink fits** L. Gaul Technische Universität Stuttgart	**Ice induced propulsion shafting torsional vibration analysis issues and case studies** Y. Batrak Intellectual Maritime Technologies
15:05	**Equivalent modeling of torsional vibration dampers in frequency and in time domain for a smooth transition between concept and design phases** T. Parikyan, T. Resch, O. Knaus, T. Philipp, AVL List GmbH and AVL Deutschland GmbH	**Proposal for the assessment of ice loads based on IACS/FSICR on the highly flexible rubber coupling** D. Hilbk, M. Dylla, R. Bauermeister VULKAN Couplings
15:30	**Transient and steady state torsional vibration analysis of large bore diesel engines** M. Taubert, M. Donderer, P. Böhm, U. Waldenmaier MAN Diesel & Turbo SE, Augsburg	**Simulation of ice induced torsional vibrations on azimuth thruster** M. Kostial, B. Schlecht, F. Mieth, T. Rosenlöcher Technische Universität Dresden (TUD)
15:55	**Efficient workflows for transient and steady-state analyses of powertrains in the time and frequency domain** C. Penndorf, S. Grützner, T. Hofmann ESI ITI GmbH	
16:20	Coffee break	

Thursday: May 18th, 2017

	Session 4A: System Parameter Identification	Session 4B: Noise and Vibration - Active and passive Reduction
16:45	**Measurement of hydrodynamic moment of inertia and damping of propellers** P. Orthmann MAN Diesel & Turbo	**A concept design of a rotational energy harvesting vibration absorber** S. Perfetto, F. Infante, S. Herold, D. Mayer Fraunhofer Institute LBF, Darmstadt
17:10	**Determination of model parameters for torsional vibration models of drivetrains by system measurements** B. Juretzki, F. Andary, M. Wegerhoff, G. Jacobs IME Aachen GmbH, RWTH Aachen University	**Torsional vibration isolation for automotive clutch dampers using anti-resonance** G. W. Kim, J. H. Yun, H. Lee, S. C. Shin Inha University Incheon, Kyungpook National University, Korean Powertrain Co.
17:35	End of Thursday's sessions	

18:15	First transfer from Salzburg Congress to Gala Dinner
18:30	Last transfer from Salzburg Congress to Gala Dinner
20:00	**Gala Dinner,** Kavalierhaus Klessheim / Salzburg

Friday: May 19th, 2017

8:30	Registration opens
8:45	Briefing speaker

	Session 5A: Powertrain Components - Elastic Couplings	Session 5B: Measurement and Monitoring
9:00	**Dynamic torsional stiffness of natural rubber in shear couplings under the influence of preload, amplitude, frequency, and rotational speed** M. Hasan, R. Zadoks Centa Antriebe Kirschey GmbH, Caterpillar Inc.	**Torsional vibration measurement and model-based monitoring in todays reality of power generation business** M. Golebiowski, E. Knopf, T. Krueger GE Power, Steam Power Systems
9:25	**Torsional vibration calculations of rubber couplings by a master curve model** D. Hochlenert, M. Schuchardt MTU Friedrichshafen GmbH	**Torsional vibration excitation using axial shaker to determine dynamic properties of elastomeric flexible couplings** J. Matitschka, A. Albers, S. Ott IPEK, Karlsruhe Institute of Technology
9:50	**How to provide customer benefit by selecting the "best fit" product for a specific application** G. Gödecke, R. Seiler VULKAN Couplings	**Torsional vibration measurement of an angle grinder in real life applications** T. Gwosch, S. Matthiesen, A. Wettstein IPEK, Karlsruhe Institute of Technology
10:15	**Influence of damping factors on coupling applications** C. Mühlberger, K. Prenninger, J. Krah, M. Geislinger Geislinger GmbH	**Field measurement techniques and instrumentation for torsional vibrations determination** C. Grislin, N. Péton, G. Cousin, N. Denisot GE Oil & Gas, OROS
10:40	Coffee break	

	Session 6A: Rules and Regulations	Session 6B: Compressors Applications
11:05	**Marine propulsion – Barred speed passing and shaft fatigue life assessments – A classification society's perspective** E. Brodin, G. M. Bakken, G. Dahler, S. Avanesov, D. Sideris, O. Deinboll DNV GL	**Electro-mechanical modelling of a reciprocating compression train driven by induction motor** A. Fusi, F. Grasso, A. Sambataro, A. Baylon, L. Pugi CST - Compression Service Technology, University of Florence
11:30	**New german grid code regulations and their relation to torsional vibrations** P. Böhm, P. Stolze MAN Diesel & Turbo SE, Augsburg	**Real time torsional vibration measurement on VFD Emotor driven compressors in the oil and gas sector** C. Sleath, M. Cooper, C. Holmes Torquemeters Ltd.
11:55	Lunch	

Friday: May 19th, 2017

	Session 7A: Engine Development - Managing Vibrations at the Source	Session 7B: System Reliability - Case Studies
13:00	**Not only torsional vibrations in the crank-shaft of 2-stroke installations** W. Schiffer Winterthur Gas & Diesel Ltd.	**Coupling failures in VFD motor / Fan systems due to high torsional vibration** T. Feese Engineering Dynamics Inc.
13:25	**Irregularity instead of harmony – Ways to improve torsional performance of a V20 engine** B. Mokdad, C. Henninger Liebherr Components Colmar SAS, Liebherr Machines Bulle SA	**Coupling failure in engine driven pipeline compressor system** T. Feese Engineering Dynamics Inc.
13:50	**Review of the dimensing calculation process in torsional vibration and evaluation of possible development directions** C. Pestelli, P. Sundström, M. Almerigogna, A. Pettirosso Wärtsilä Corporation	
14:15	Coffee break	

	Session 8A: Engine Development - Future Concepts	Session 8B: System Evaluation
14:40	**A procedure for calculaction of the maximum allowed engine power under misfire conditions: Application to 14 and 16 V medium speed four stroke stationary engines.** F. Jiménez-Espadafor, A. López Lora, D. Palomo Guerrero, F. Fernández Vacas Seville University, Endesa Generación	**Propulsion shafting alignment from analysis report to practice in the field, how to read and apply** M. Zeid Caterpillar Propulsion
15:05	**Future concepts and development trends related to medium speed engines** M. Bierl MA-C-S Engineering	**Performance mapping of tuned type torsional vibration damper for automotive on-highway engine application** A. Khule, R. Channapattan, H. J. Raja Hodek Vibration Technologies Pvt Ltd.

	Session 9: Closing Session
15:30	**Effects of engine and vessel operating conditions on torsional vibration dampers** K. Prenninger, S. Lange, D. Richter-Trummer Geislinger GmbH
15:55	**Closing**
16:00	**End**

Keynote speaker

The keynote speech will be held by
Prof. Dr.-Ing. Stefan Pischinger

President & CEO, FEV Group Holding GmbH
Head of VKA – Institute for Combustion Engines,
RWTH Aachen University, Germany

Professor Stefan Pischinger studied Mechanical Engineering at Aachen Technical University. From 1985 until 1989 he worked as a research assistant at the Sloan Automotive Laboratory at M.I.T. until he received his PhD for his work on Spark Ignition in modern combustion engines. From 1989 until 1997 he was in various positions at Daimler-Benz (today: Daimler) working on diesel and gasoline engine development. In his last position he was department leader of advanced engineering diesel engines and project leader for the new common rail V8-diesel engine. Since 1997 he is Professor at Aachen Technical University and Director of the Institute for Combustion Engines. At the same time he is President and Chief Executive Officer of the FEV Group, a worldwide leading company for engineering services and test systems in the field of combustion engines and powertrain. Since 2010 he is member of the North Rhine-Westphalian Academy of Sciences, Humanities and Arts; since 2006, he has the Fellow Grade of Membership of SAE.

Abstracts

Thursday sessions

Thu	09:45	Karajan Hall	Keynote speach

Torsional vibration in powertrains as a challenge for performance and a driver for innovation.

S. Pischinger
President & CEO, FEV Group Holding GmbH
Head of VKA – Institute for Combustion Engines, RWTH Aachen University, Germany

The continuing trend towards higher break mean effective pressures and also peak firing pressures has resulted in crankshaft designs with ever growing coefficients of material utilization. While a peak cylinder pressure of 175 bar marked a first class benchmark value 25 years ago, the current trend tends towards 300 bar for the peak firing pressure. Against this background the determination and control of torsional vibrations in the cranktrain becomes even more important to assure a safe and reliable engine operation.The steadily increased loading of the crankshaft has been addressed with the application of improved crankshaft materials in combination with the development of new surface treatment technologies. For example, with fillet surface treatments like rolling, the bending fatigue strength of the crankshaft base material can be increased by 150% up to 200%. Functional testing of crankshaft dynamics has been in the past and will be in future an integral part of an engine development program. The appropriate strain and torsional deflection measurement technology is well established and has reached a high level of confidence. Nevertheless, there is a need for further development of advanced measurement techniques on the one hand and simplification of measurement principles and sensor applications on the other hand. The numerical analysis of torsional cranktrain vibrations has been performed for more than four decades. Initially, the torsional vibration analysis procedure was based on a phase-vector sum approach in order to determine single harmonic vibration orders. Today, 1D as well as 3D Multi-Body-Simulation (MBS) tools are being used for the analysis of torsional vibrations and their influence on the material stresses. In future, the 1D crank train analysis approach will be utilized for a more sophisticated multi-criteria optimization in order to find a common optimum for several design parameters like crank star layout, bank angle, firing order, counterweight size and number and torsional vibration damper layout. Since the beginning of this century, the analysis of the coupled axial, bending and torsional vibrations in crankshafts using 3D MBS software tools by means of so-called flexible bodies has been established as a standard in the development procedures of many manufacturers. Using this MBS approach, the complete virtual validation of a cranktrain is possible even before the first prototype engine is being built. With increasing computational power, the consideration of additional boundaries like external loads due to earthquake excitation or the integration of e.g. the surrounding ship structure in the simulation model will be possible.

Thu 10:45 Karajan Hall Marine Propulsion - Responding to the latest Challenges (1A – 1)

Passing time through the barred speed range and fatigue life time of propulsion shafting

S. Persson
MAN Diesel & Turbo

The general focus on fuel economy and the introduction of the energy efficiency design index (EEDI) requirement, has over the last decade resulted in a general trend of longer stroke, lower engine rpm, larger propellers and derating of engine power. During the same period of time, the number of reports that the passage time of the barred speed range (BSR) is unacceptably long - has increased. Even though countermeasures such as increased dynamic engine torque and the BSR power margin recommendations have solved the problem with long passage time, the reports have resulted in an increasing interest for fatigue life time of propulsion shafting within the industry. Predicting the fatigue life time at the design stage is a complex task, generally involving many uncertain parameters. The fatigue life time is not only influenced by the number of BSR passages, but also the procedure for passing the barred speed range is important due to the impact on passage time and the stress amplitudes. This paper aims to give an overview of the BSR acceleration topic. Based on statistics, simulations and experience from measurements, the tendencies of the governing factors for evaluating the fatigue life time as well as suggested countermeasures are presented.

Thu 10:45 Wolf-Dietrich Hall Simulation based System Design (1B – 1)

Firing order selection for commercial engines with FEV Virtual Engine

K. Buczek, S. Lauer
FEV Polska Sp. z o.o., FEV Europe GmbH

The continuously increasing mechanical and thermal loads of modern engines require optimization of the designs with incorporation of a wide range of different aspects. Application of advanced computer simulations in the development process for most engine components is well established, leading to the creation of well optimized products. However, the optimization of such design variables like the firing order, which influences engine operation in several disciplines, is still challenging. Considering the ever increasing peak firing pressure requirements, the layout of the firing order in multi-cylinder commercial engines is an efficient way to reduce crank train/overall engine vibration and main bearing loads, whilst controlling engine balancing and preserving adequate gas exchange dynamics. The proposed general firing order selection process for four-stroke engines and, in particular, its first part being the optimization of the firing order based on crank train torsional vibration, is the main topic of this paper. The exemplary study for a V16 high speed commercial Diesel engine regarding the influence of the firing sequence on crank train torsional vibration has been conducted with the multibody dynamics simulation software "FEV Virtual Engine". It addresses various engine crankshaft layouts and engine applications.

Thu 11:10 Karajan Hall Marine Propulsion - Responding to the latest Challenges (1A – 2)

Aspects of simulation, estimation and evaluation of torsional loads from BSR passages

H. Keller
Winterthur Gas & Diesel Ltd.

Barred speed ranges due to a strong torsional resonance are very common in the direct-coupled 2-stroke propulsion installations with the popular five and six cylinder engines. Since long time, the Classification Societies' rules (IACS UR M68) defined a continuous torsional stress limit vs. relative shaft speed, and additionally a transient stress limit for application within a barred speed range of well-defined position and width. The passage itself was always assumed to be quick enough (i.e. some seconds) in order to have a limited number of cycles with high dynamic shaft stress. In the recent past, unusual extremely long passage times were experienced in some single cases. Some ship owners started to discuss the fatigue aspect of the higher accumulated cycle numbers and to ask for reliable passage time estimations prior to the sea trials. At a first glance, simulations of the dynamic torsional behaviour of a propulsion shafting could provide individual and reliable passage time figures and related shaft stress cycles, based on extended models of the torsional system used for the standard TVC, allowing an assessment by fatigue calculations. In this paper, the practical issues, challenges and limitations of this approach shall be highlighted, like essential model components, parametrization, parameter sensitivity and meaningful evaluation of results.

Thu 11:10 Wolf-Dietrich Hall Simulation based System Design (1B – 2)

Effect of engine ignition timing on crankshaft torsional vibrations

F. Bianciardi, K. Janssens, L. Britte
Siemens Industry Software NV

Internal combustion engines by nature do not generate a constant torque. The torque varies within an engine cycle as a consequence of the non-uniform combustion and inertia forces, leading to a varying engine rotational speed, named torsional vibrations. Torsional vibration can negatively impact the engine performance, and potentially leading to fatigue failure of the crankshaft, or to important NVH problems. Nowadays noise and vibration problems are becoming even more important with the advent of downsized engines and the evolution towards a combination of mechanics, electronics and controls. A thorough understanding of the impact of the engine control parameters on the NVH performance represents a great challenge. This paper presents an example of how different ECU (Engine Control Unit) parameters influence crankshaft torsional vibrations by means of 1D simulation. Different ignition timing settings have been simulated. Finally the simulated torsional vibration results have been compared with experimental data acquired on a Ford 1.6L Ecoboost engine. The good correlation between the simulated and measured data proves the reliability of the proposed solution. The paper shows how simulation techniques (1D, 3D) and advanced testing methodologies are complementary during the engine development phase.

Thu 11:35 Karajan Hall Marine Propulsion - Responding to the latest Challenges (1A – 3)

Comparison of measured torsional stress and excitation for steady state condition and transient condition

A. Yamada
Mitsui Engineering & Shipbuilding Co., Ltd.

Recently, the acceleration performance is getting worse for vessels installed with 2 stroke low speed diesel engine. As a result, the passing time through Barred Speed Range (BSR) is longer and ship crews complain the poor maneuverability. Further, fatigue damages for the shaft line are worried in the long term. However, the general Torsional Vibration Calculations (TVC) and Torsional Vibration Measurements (TVM) are performed as steady state condition and it seems that TVM in the transient (acceleration) condition is not performed and evaluated so often. Therefore, TVM and cylinder pressure measurement in case of both steady state and transient condition have been performed and in this paper, the comparison of measured torsional stress and excitation (torque harmonics) are presented.

Thu 11:35 Wolf-Dietrich Hall Simulation based System Design (1B – 3)

Real time & system simulation of large engine applications as a valuable contribution to CAE tasks concerning vibrations and durability

R. Strasser, H. G. Flesch, C. Huber
AVL List GmbH

System simulation of large engine applications is a valuable approach in order to find the overall performance and efficiency optimum. System complexity is growing, not least because of the increasing importance of hybridization and the higher number of components. In the virtual world models are indispensable components to investigate and optimize the complex interactions between subsystems (engine, control system, electric components, batteries, transmission, driver/operator, information technology, traffic etc.). Physics-based real time engine models are of special interest as the modeling approach with crank-angle resolved simulation of the cylinders and the gas path allows the detailed description of in-cylinder conditions, torque pulsations and pulsations of mass flow and pressure in the gas path in real time. Hence, numerous engine phenomena such as scavenging effects, reverse mass flow, cycle-to-cycle variations, cylinder-to-cylinder variances, knock, misfiring, skip firing etc. can be simulated. Model-based pre-calibration of injection system parameters for given emission scenarios can be performed in an early project phase when no prototype engine is available yet. It allows the prediction of in-cylinder pressure traces and, consequently, the excitation of engine components concerning vibrations. This opens up new possibilities as the results of the global system simulations of real-life operating profiles can be used for unerring definition of boundary conditions and input for CAE tasks concerning torsional vibrations, durability and acoustics. Detailed component simulation as part of the global system simulation leads to a more complete view in order to detect weaknesses of the system as the knowledge of the actual operational behavior in an early design stage is of high importance. The detection of resonance issues is a major task to ensure the long-term durability of the engine and auxiliaries. Only with detailed component models which are linked to the global system in terms of vibration and performance a CAE based engine development can lead to success. The establishment of integrated and seamless simulation approaches is therefore an important and promising aspect for the successful development of large engine applications.

Thu 13:00 Karajan Hall Marine Propulsion – Design and Development (2A – 1)

Application of high strength steel to intermediate shaft and its effects on torsional vibration characteristics of shafting

M. Ota, Y. Iguchi, T. Ikegami, T. Arikawa, H. Takaoka, F. Tamura, Y. Hanawa, N. Fujitsuna
Kobe Steel, LTD.

High energy efficiency is required for newly built ships to reduce greenhouse gas. Thus, the stroke of main engine becomes longer to generate higher output with lower speed. Accordingly, torsional vibration of shafting especially of intermediate shaft becomes more severe. The minimum specified tensile strength for low-alloy steel which is applied to propulsion shaft was prescribed not exceeding 800MPa in the IACS rule. Kobe Steel, Ltd. developed high strength intermediate shaft of low-alloy clean steel. Torsional fatigue test results show that developed material has the same fatigue characteristic as the extension of conventional material. As a result, the requirements of special approval of low-alloy steel which has minimum specified tensile strength from 800MPa to 950MPa for intermediate shaft was newly stipulated in APPENDIX. In this study, the fatigue characteristic of shaft material is explained first. Then the calculation of torsional vibration of shafting in case of applying high strength intermediate shaft is conducted. It is shown that its safety margin can be taken higher. Consequently shafting components (e.g. flywheel and tuning wheel) can be designed smaller. Moreover, it is found to be utilized for shafting designs, for example, lowered critical speed range by reducing its diameter without significant stress increase.

Thu 13:00 Wolf-Dietrich Hall Noise and Vibration (2B – 1)

Transient closed loop simulations as tool for analysing noise in drive trains

H. Brandtstädter, L. Hübner, A. Sirucic
Siemens AG

The balancing bunker in the Dynamowerk represents a complex electromechanical drive train system. In operation, during the start-up-process, noise arises. Usually, noise is produced by unwanted vibrations which may lead to increased waste and even destruction of the system. This paper describes the investigations of reasons for the observed noise respective-lyand underlying vibrations based on numerical transient simulations of the complete drive train. Neither the electrical nor the mechanical system are adapted and approximated in steady state. In fact, a closed loop simulation of the electromechanical drive train system is realized, that takes into account the interaction between both subsystems. Based on numerical simulations, reasons for the noise can be located and explained.

Thu 13:25 Karajan Hall Marine Propulsion – Design and Development (2A – 2)

Consequence of bearing support stiffness modelling into shaft performance prediction and system understanding in lateral

M. Zeid
Caterpillar Propulsion

The marine propulsion shafting lateral simulation is a process which is used to be carried out by different parties in marine industry. This type of simulation developed along the years, however still a lot of simulations representing a several assumptions. The traditional assumptions [3], [4] in a lot of cases don't suite the current development in the industry. On the other hand the simulation tools has been developed significantly, thus Caterpillar Propulsion decided to be more principle and move from traditional assumption modelling concepts into specific desired domains. One of the most significant assumptions in this type of simulation is the shafting system bearings support stiffness. If the stiffness values used in the analysis not in line with the stiffness values in reality, the system performance expectation is very far from expectations presented in the analysis report. In order to do that, the analysis tools has been used to study the variation of stiffness variation between bearings supports toward each other in same shafting system. The study shall represent a specific domain of bearing support stiffness where practically applicable as well as study the practical possibility to check the applied stiffness range in real life.

Thu 13:25 Wolf-Dietrich Hall Noise and Vibration (2B – 2)

Vibration isolation of large machinery

M. Heger, L. Kurtze, B. Pinnekamp, M. Heider
Renk AG, Geislinger GmbH

Machinery generating or transmitting torque can contribute significantly to noise emissions of a mechanical system. This can be shown using the general equation for machine acoustics with the focus on the engine mounts and the coupling. To assess potentials for reducing acoustic signatures in marine propulsion systems, Renk and Geislinger have conducted tests on an Advanced Electric Drive and a Silenco coupling. The system was tested at the Renk test facility using techniques including laser vibrometry and classic acceleration sensors. As validation, the test lab results have been compared with on board measurements of a coupling during a sea trial.

Thu 13:50 Karajan Hall Marine Propulsion – Design and Development (2A – 3)

Engine x-mode vibration due to 2nd node torsional vibration on two stroke low speed diesel engines

D. Lee, J. S. Kim, J.H. Kim, R. D. Barro
Mokpo National Maritime University

For the past years, higher power rating two-stroke super long stroke diesel engines having more than 8 cylinders and larger cylinder bore are installed on very large containerships to save on fuel consumption. However, these engines are prone to X-mode vibration due to 2nd node torsional vibration or the X-type guide force moment, particularly because of the increase in total length and height. Recently, cases of excessive X-mode vibration often occurred on engine's major components. This vibration is manifested also as secondary vibration causing failure in large engine mounting structures. This study investigated the excitations caused by the 2nd node propulsion shafting torsional vibration that influence X-mode vibration of the main engine and practical countermeasures are proposed. An 8RT-flex82T 8-cylinder engine and 11S90ME-C 11-cylinder engines for a container ship were used as research model.

Thu 13:50 Wolf-Dietrich Hall Noise and vibration (2B – 3)

Torsional vibrations of inequidistant gears

P. Neubauer, J. Bös, T. Melz
SAM, Technische Universität Darmstadt

The research group SAM at Technische Universität Darmstadt investigates the inequidistant gearing, which is a new approach to reduce whining noise of gears. By positioning the teeth of a gear wheel with irregular spacings, a less periodic excitation of vibrations can be achieved. Therefore, with this kind of gearing, tonal components of the radiated gear noise can be decreased, hence whining noise is decreased. Besides analytical and numerical investigations, experiments on a back-to-back gear test rig are carried out. In the past, only airborne and structure-borne sound have been considered. In this paper, the results of recently performed investigations of torsional vibrations are presented. A set of conventional spur gears is compared to a set of inequidistant gears. The measurements are conducted by using a rotational laser vibrometer. The results give new insights to the excitation characteristics of the inequidistant gearing. The research objective to reduce tonal components of the excitation signal, and therefore the whining noise, can also be confirmed with respect to torsional vibrations.

Thu 14:40 Karajan Hall Simulation (3A – 1)

Simulation and measurement of turbo-generator low pressure stage torsional vibration mode assembled by disc shrink fits

L. Gaul
Technische Universität Stuttgart

The paper at hand shows how structural damping and stiffness parameters in shrunk joints can be determined by a generic joint experiment. With thin-layer elements these parameters from the joint experiment are coupled to the structures finite element model. Equivalent modal damping factors can be determined by performing a complex numerical modal analysis, by which the stability of the rotor can be tested. The two-disc rotor is examined as an application sample. This rotor consists of a shaft with two shrunk-on discs. With the above mentioned approach, and by considering structural damping added to material damping, the modal damping of the first torsional eigenfrequency is calculated and then compared to the results of an experimental modal analysis. The paper shows that the presented approach leads to a reliable approximation of the examined structure's dissipation properties. It serves as a prediction tool for the response behavior of a turbo-generator.

Thu 14:40 Wolf-Dietrich Hall Marine Propulsion – Navigating in Ice Conditions (3B – 1)

Ice induced propulsion shafting torsional vibration analysis issues and case studies

Y. Batrak
Intellectual Maritime Technologies

Since analysis of shafting transient torsional vibrations caused by ice impacts became mandatory, numerous modelling-based calculations have been carried out for ships sailing under ice class. However, the calculation results still do not allow to obtain general conclusions from the shafting response in ice conditions. The main reasons for this could be summarized as follows. First of all, the different tools in use for the prediction of transient vibrations make the comparison of analysis results rather difficult. Secondly, some simplifications about the response of the propulsion system in ice conditions are to be made because the consideration and addressing of the complex nature of a propulsion system in practical design are impossible for many reasons. Thirdly, various underlying uncertainties in the input data put a shaft designer in a situation in which he needs to make a decision. This paper is an attempt to make some contributions to the presentation and analysis of the propulsion shafting torsional vibration induced by propeller-ice interaction. Two practical examples are considered: for a polar class ship with a direct coupled diesel engine and another one for the case of a geared propulsion unit. Some uncertainties in data setting concerning of the design torques are considered and assessed.

Thu 15:05 Karajan Hall Simulation (3A – 2)

Equivalent modeling of torsional vibration dampers in frequency and in time domain for a smooth transition between concept and design phases

T. Parikyan, T. Resch, O. Knaus, T. Philipp
AVL List GmbH and AVL Deutschland GmbH

To be time-efficient while fulfilling the quality standards, a powertrain dynamics calculation project is carried out in two phases – concept phase and design phase. In the concept phase, torsional vibrations of a linearized system are analyzed in frequency domain. In design phase, non-linear system is simulated in time domain (mainly 3D dynamics). Most torsional vibration damper (TVD) types are often described by frequency dependent stiffness and/or damping characteristics. These can be readily used as input data for the analysis in frequency domain. In time domain, however, they cannot be used directly, but need to be transformed to some equivalent form first. The present paper describes a methodology to transform the frequency dependent stiffness and damping parameters from frequency domain into time domain. Such transformation is based on the consideration of stored energy as well as dissipated power of TVD, resulting in equivalent speed-dependent stiffness and damping. Two application cases are discussed: a) in-line 4-cylinder passenger car diesel engine with rubber damper and b) V6 passenger car gasoline engine with a viscous damper. For the viscous damper the initial parametrization from measurements on test rig is explained. Torsional vibration results are compared between frequency and time domain solutions.

Thu 15:05 Wolf-Dietrich Hall Marine Propulsion – Navigating in Ice Conditions (3B – 2)

Proposal for the assessment of ice loads based on IACS/FSICR on the highly flexible rubber coupling

D. Hilbk, M. Dylla, R. Bauermeister
VULKAN Couplings

In recent years the regulations for the propulsion system of ice-going vessels have been changed fundamentally. While in former times it was feasible to consider ice amplification factors for the shaft line components of a propulsion system, it is nowadays required to evaluate a class defined ice load spectrum. For this purpose cumulative damage calculations are recommended. A flexible coupling, however, is substantially made of rubber, for which the fatigue behaviour is not fully understood yet. In addition, highly flexible couplings are also made of metallic parts that need to be assessed as well. Therefore, it is evidently difficult to apply damage accumulation on rubber-made couplings. This paper makes a suggestion how an assessment could be carried out to guarantee a safe and cost-effective coupling solution. The idea is to calculate a damage equivalent ice torque amplitude that can be compared with coupling limits given in the catalogue.

Thu 15:30 Karajan Hall Simulation (3A – 3)

Transient and steady state torsional vibration analysis of large bore diesel engines

M. Taubert, M. Donderer, P. Böhm, U. Waldenmaier
MAN Diesel & Turbo SE, Augsburg

This article describes a part of the simulation based drive train development process of large bore diesel engines for marine and stationary applications within MAN Diesel & Turbo (MDT). The classical approach for torsional vibration analysis is the steady state method, which is well established over many years. However, some basically transient phenomena cannot be adequately addressed by the use of the steady state simulation approach. The development process of the new MDT 175D engine became the starting point for the use of a Modelica based simulation platform, where both domains can be handled. This article presents the integration of the simulation platform into the MDT workflow focused on efficient automated simulation, parameter variation and optimization. For the area of steady state simulation examples for firing sequence variation and cylinder deactivation is shown. For the transient simulation a diesel engine model, including a 1D torsional mechanical model, a 0D empirical combustion model and a speed governor model, is demonstrated.

Thu 15:30 Wolf-Dietrich Hall Marine Propulsion – Navigating in Ice Conditions (3B – 3)

Simulation of ice induced torsional vibrations on azimuth thruster

M. Kostial, B. Schlecht, F. Mieth, T. Rosenlöcher
Technische Universität Dresden (TUD)

Drive trains of icebreakers in arctic conditions are subjected to high stress levels. Due to collisions between ice and propeller, overloads and torsional vibrations occur. The main objective of the "Arctic Thruster Ecosystem" (ArTEco) project is to increase the reliability of vessels in arctic conditions. In order to achieve this goal different load scenarios are analyzed with multi-body-system (MBS) simulation tools complemented by a test rig facility located in Tuusula (Finland). It is operated by the technical research center of Finland (VTT) and Wärtsilä. On the test rig, various loads can be applied to different azimuth thrusters, which are equipped with diagnostic instruments. For further analysis a simulation model is assembled and verified by several time-based data sets and modal analysis of the test rig. Thereby, overloads and high dynamic loads that are unobtainable at the test rig become accessible in simulations. To reduce torsional vibrations, different damping systems, designed at the department of intelligent hydraulics and automation (IHA) Tampere and the VTT, can be analyzed with the MBS model. Besides torsional vibrations, one objective is the displacement of the bevel gears leading to different stress situations. Using simulation-based displacement data and the software BECAL [1], a precise contact pattern can be determined, which allows conclusions regarding the required safety factors.

Thu 15:55 Karajan Hall Simulation (3A – 4)

Efficient workflows for transient and steady-state analyses of powertrains in the time and frequency domain

C. Penndorf, S. Grützner, T. Hofmann
ESI ITI GmbH

Substantial knowledge of torsional vibrations in powertrains for vessels, vehicles and heavy machinery is essential to ensure functional reliability, safety and comfort. Depending on the application and specifications – for example in certification processes –, transient simulations in the time domain and steady-state simulations in the frequency domain are proven methods to analyze the torsional vibration behavior of powertrains with combustion engines. What are the benefits and limitations of each method? How are effects analyzed best (most accurately, efficiently etc.) using steady-state or transient analyses? How to integrate these kinds of simulations in the development process, from data import and model creation to simulation and automated reports? Case studies from daily work experience in different industries will help to illustrate the spectrum of torsional vibration simulations and the integration into an efficient workflow.

Thu 16:45 Karajan Hall System Parameter Identification (4A – 1)

Measurement of hydrodynamic moment of inertia and damping of propellers

P. Orthmann
MAN Diesel & Turbo

The vast majority of low-speed two-stroke diesel engines used for propulsion have a barred speed range due to 1-node torsional vibrations excited by the combustion at the firing frequency. The large torsional amplitude in the barred speed range is controlled by the propeller damping. Propeller damping is generally considered to be an uncertain parameter and of high importance in the 1-node torsional vibration layout, but unfortunately it is not well-documented by the propeller designers. Instead, many engine builders and shipyards use different propeller damping models based on individual empirical experience. The recent trend of using an increased propeller size and reduced engine speed has, however, resulted in new interest in propeller damping. This paper describes a method for determining both propeller inertia and damping on ships based on measurements of torque and angular vibration at the aft end of the intermediate shaft. The method is applicable in a large speed range and shows the differences between various propellers, which are demonstrated with results from several measurements. The conclusion is that the described method is a direct way to verify theoretical hydrodynamic models, gain experimental knowledge with specific propeller designs and document the choice of propeller model in torsional vibration calculations.

Thu 16:45 Wolf-Dietrich Halle Noise and Vibration – Active and passive Reduction (4B – 1)

A concept design of a rotational energy harvesting vibration absorber

S. Perfetto, F. Infante, S. Herold, D. Mayer
Fraunhofer Institute LBF, Darmstadt

Vibration in rotating machinery is often responsible for deterioration of the performances or decrease of the life time. For instance in power-trains, undesirable torsional vibrations can result from the fluctuating torque caused by firing processes, unbalanced forces and other phenomena. Thus, the introduction of vibration absorbers in such systems is often necessary. On the other hand, when a structure is vibrating, mechanisms for mechanical-to-electrical energy conversion (e.g. piezoelectric transducers) can be employed, suggesting that vibration absorbers have potential for energy harvesting capabilities. Thus, small sensors can be supplied when and where they operate by energy harvesting systems. This can be of particular interest in rotating machineries, where the problem of energy transfer between rotating and stationary parts is remarkable. However, the design of an integrated device (i.e. for both vibration reduction and energy conversion) needs to be investigated carefully. In this work a rotational energy harvesting vibration absorber is proposed. For the purpose of energy conversion, piezoelectric transducers are employed. A simulation model is implemented and numerical results are presented. Furthermore, a concept design is proposed and experimental results are shown, to support the feasibility of the rotational energy harvesting vibration absorber as integrated device.

Thu 17:10 Karajan Hall System Parameter Identification (4A – 2)

Determination of model parameters for torsional vibration models of drivetrains by system measurements

B. Juretzki, F. Andary, M. Wegerhoff, G. Jacobs
IME Aachen GmbH, RWTH Aachen University

The validation of simulation models is essential for the further use of the models. In Torsional Vibration Simulation the validation of models sometimes fails due to various reasons like inadequate system boundaries or insufficient accuracy of the critical model parameters. While some of these reasons can be compensated by the experience of the user, others are in practice unavoidable due to required high efforts in modelling or parameter estimation. Significant differences require further effort for the optimization of the model or remodelling of the model. An alternative approach for modelling and its validation, which will be presented in the paper, is to generate automatically a Torsional Vibration Simulation model with its parameters based on data derived by system measurements. The proposed approach follows a two stepped process. In a first step a modal model will be identified from revolution speed measurements in the rotating system by application of Operational Modal Analysis (OMA). In the second step the physical model parameters will be extracted from the modal model by Inverse Eigenvalue Calculation. The presented approach has two important benefits: Firstly, a model directly fitted to measurement data is implicitly validated. Secondly, a model generated from measurement data can be used to validate existing models by the comparison of the model parameters instead of the simulation results. Deviations in parameters can be identified directly. Challenges are in particular measurement and excitation techniques for the stiff rotating system. Especially the application of OMA techniques to systems with significant deterministic excitations as well as the application of the Inverse Eigenvalue Calculation in general must be mentioned.

Thu 17:10 Wolf-Dietrich Hall Noise and Vibration – Active and passive Reduction (4B – 2)

Torsional vibration isolation for automotive clutch dampers using anti-resonance

G. W. Kim, J. H. Yun, H. Lee, S. C. Shin
Inha University Incheon, Kyungpook National University, Korean Powertrain Co.

This paper presents the preliminary study on the new type of passive torsional vibration isolator used for automotive clutch dampers. In this study, the proposed working principle for vibration isolation is to take advantage of anti-resonance. The new way of isolating torsional vibrations is to insert a planetary gear (PG) set between two main inertia elements (impeller, and turbine). The PG set is designed based on a conventional coil spring dampers. This study provides a state-of-the-art technology for passive torsional vibration isolators for suppressing the torsional vibration induced by an internal combustion engine.

Fri 09:00 Karajan Hall Powertrain Components – Elastic Couplings (5A – 1)

Dynamic torsional stiffness of natural rubber in shear couplings under the influence of preload, amplitude, frequency, and rotational speed

M. Hasan, R. Zadoks
Centa Antriebe Kirschey GmbH, Caterpillar Inc.

Flexible couplings are used to reduce torsional vibration and noise in drivelines, effectively isolating the prime mover from the driven equipment. The critical dynamic behavior is characterized by the first torsional mode of the system and the dynamic stiffness of the coupling is the primary control for adjusting this natural frequency. The work presented here was undertaken to capture the dynamic torsional stiffness of natural rubber in shear couplings as a function of amplitude, preload, frequency, and rotational speed. This work included physical testing and the development of an analytical model. The analytical model was used to predict the hysteresis response, since the slope along the long axis of a hysteresis loop provides the dynamic torsional stiffness of a coupling. There was a close match between the simulation and measured results. The amplitude has a remarkable influence of the dynamic stiffness of natural rubber in shear couplings. In particular, it was found that stiffness decreases with increasing amplitude. In addition, the influence of varying dynamic stiffness of a flexible coupling on the torsional response of a system under variable loading conditions was investigated. The results of a torsional vibration simulation were compared to measured data, and reasonably good agreement was obtained.

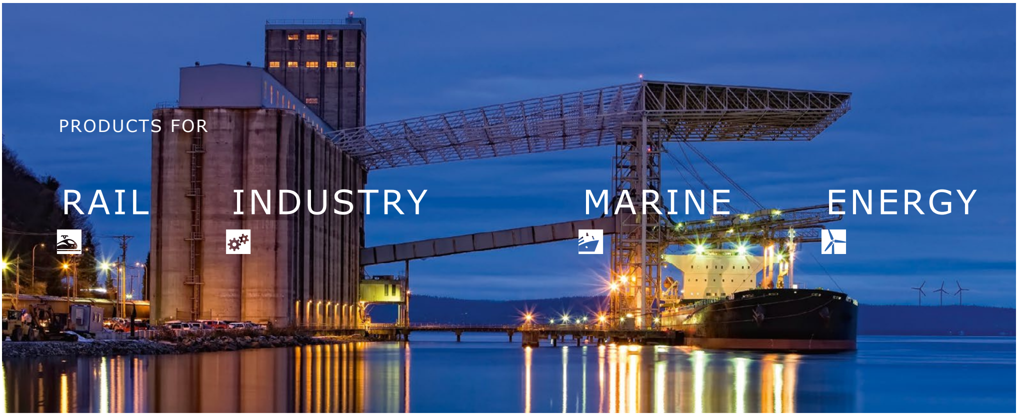
Fri 09:00 Wolf-Dietrich Hall Measurement and Monitoring (5B – 1)

Torsional vibration measurement and model-based monitoring in todays reality of power generation business

M. Golebiowski, E. Knopf, T. Krueger
GE Power, Steam Power Systems

Growing share of renewables and consequently increasing risk of sub-synchronous torsional interactions between electrical grid and power plant machinery, constitute a demand for a robust, reliable and accurate torsional vibration monitoring approach. In addition, the torsional vibration measurements are frequently required by customers to validate rotor dynamic models and to prove sufficient separation between shaft-line's torsional modes and the excitation frequencies (in case of rotor retrofits). This paper presents various case studies of torsional vibration measurements starting from component level validation tests to full shaft train operational measurements. It describes also application of a model-based torsional vibration monitoring, where numerical rotor dynamic models were used to predict stresses and vibration amplitudes in non-observable locations along the rotor (including stress estimation in subcomponents like blades or retaining rings of turbo-generators).

CENTA POWER TRANSMISSION



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A broad range of flexible couplings and drive shafts with performance ranging from 10 Nm to 20 million Nm have already been put to use in millions of applications. Decades of experience and close cooperation with renowned engine manufacturers contributed significantly to this success.

WORLDWIDE COMPETENCE

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Moreover, CENTA demonstrates its commitment to ISO 14001 and 50001. All environmental laws and regulations as well as additional recommendations are met and firmly integrated into the company's decision-making and implementation structures.

Fri	09:25	Karajan Hall	Powertrain Components – Elastic Couplings (5A –2)

Torsional vibration calculations of rubber couplings by a master curve model

D. Hochlenert, M. Schuchardt
MTU Friedrichshafen GmbH

For many applications rubber couplings are used to reduce torsional vibrations in the drive train and to achieve increasingly high acoustic requirements. The selection of appropriate couplings and the evaluation of stresses in the drive train are based on torsional vibration calculations. It is well known that the dynamic behavior of rubber couplings depends on several parameters including effective torque, temperature as well as frequency and amplitude of loading. Nevertheless, the rubber couplings are usually modelled as a dissipative and elastic element with constant coefficients. In some cases this results in rather insufficient predictions of the torsional vibration behavior of the drive train. The present contribution shows the application of a master curve model for rubber couplings considering the dependence of the dynamic behavior on effective torque as well as amplitude and frequency of loading in a factorized fashion. The torsional vibration calculations are compared to engine test rig measurements to show potentials and limits of the procedure.

Fri	09:25	Wolf-Dietrich Hall	Measurement and Monitoring (5B – 2)

Torsional vibration excitation using axial shaker to determine dynamic properties of elastomeric flexible couplings

J. Matitschka, A. Albers, , S. Ott
IPEK, Karlsruhe Institute of Technology

Shaft couplings are often implemented in the powertrain of machines or vehicles for isolating and damping of undesired torsional vibrations. The necessary calculations of the powertrain's dynamics, however, impose high demands on accurate modelling of the couplings dynamic properties. Aim of the investigation is obtaining dynamic properties of elastomeric flexible couplings on a broad frequency range up to 1000 Hz. Tests at lower frequencies are conventionally carried out using electric or hydraulic motors. However, testing the influence of high frequency torsional vibrations that may be caused by meshing gears, for example, are difficult to achieve due to the dynamic range of the motor and inevitable inertia of the test setup. A new test rig is introduced, based on a methodical design and validation approach, in order to extend the frequency range of torsional vibration excitation. Oscillating torque is generated by applying the force of an axial shaker tangentially on a shaft connected to the flexible coupling. Finite element analysis is used to ensure minimal unintended axial or bending vibration and maximal torsional vibration amplitudes. Validation of the test rigs desired behavior is presented using experimental methods and, completing the paper, exemplary results are shown.

Fri	09:50	Karajan Hall	Powertrain Components – Elastic Couplings (5A –3)

How to provide customer benefit by selecting the "best fit" product for a specific application

G. Gödecke, R. Seiler
VULKAN Couplings

Presently, many drivetrain couplings are still selected on the basis of the engine power, namely torque and speed. Additionally, steady state torsional vibration calculations might be required for highly flexible couplings in order to specify the values for dynamic torsional stiffness and power loss. The load profiles of specific applications such as ice going vessels or construction vehicles have been simplistically considered by service factors and/or high safety margins. In the vast majority of the cases, this pragmatic approach leads to rather oversized products, especially along a multi-tier supply chain. In terms of acoustic features, products were selected in a black and white manner: effective or not effective. It is obvious, that economic concerns have been subordinated under that comprehensible pragmatism. Nowadays, discerning customers are increasingly expecting a "best fit" selection of products in order to set up the most efficient drivetrain, providing best value for money. Focusing on acoustics, they are looking for a highly predictable and effective solution. This paper outlines three examples of customer value creation by consideration of maritime load ratings, applying a new coupling selection proposal for ice-going vessels and meeting acoustic requirements with effective driveline components.

Fri	09:50	Wolf-Dietrich Hall	Measurement and Monitoring (5B – 3)

Torsional vibration measurement of an angle grinder in real life applications

T. Gwosch, S. Matthiesen, A. Wettstein
IPEK, Karlsruhe Institute of Technology

This paper shows an experimental study of the torsional vibration in angle grinders at typical work-situations. The aim of this study is finding the influence of the usage profile on the torsional vibration of the power train and differ the vibration in load-dependent and user-dependent proportions. For the study, an angle grinder is fitted with rotary position sensors for measuring the power train vibration in various test cases like cutting or grinding. The evaluation in time and frequency domain shows the influence of the usage profile, the user behaviour and the excitation by the working process. These influence variables are mapped to the frequency range of the torsional vibration. The measurement results enable to locate the reasons of the torsional vibration in the power train of an angle grinder and can improve the validation activities in the product development process.

Fri	10:15	Karajan Hall	Powertrain Components – Elastic Couplings (5A –4)

Influence of damping factors on coupling applications

C. Mühlberger, K. Prenninger, J. Krah, M. Geislinger
Geislinger GmbH

Torsional elastic couplings can be used for a very wide range of applications. The first part of this paper shows a spring type coupling which has been optimized for acoustic applications. Due to the improved engine mounts most of the engine vibrations have been eliminated. Therefore the secondary path from the engine via the coupling into the gearbox and finally into the surrounding structure has become more critical. The specific design of this acoustic torsional elastic steel spring coupling shows very low friction which can reduce the gearbox vibratory torque to a uniquely low value. Another benefit is a very linear torsional stiffness behavior, also evident when applying low torsional vibratory torques. The second part shows an application where high friction is needed, for example on a genset application. In such a case high friction and damping torques are needed when passing through resonances during the engine run up. To summarize, it can be seen that spring type couplings can be optimized and tuned for a very wide range as far as stiffness, damping and friction are concerned.

Fri	10:15	Wolf-Dietrich Hall	Measurement and Monitoring (5B – 4)

Field measurement techniques and instrumentation for torsional vibrations determination

C. Grislin, N. Péton, G. Cousin, N. Denisot
GE Oil & Gas, OROS

Torsional vibration excitation in rotating machinery can cause system reliability issues or even catastrophic failures. All rotating machineries undergo some degrees of torsional vibration during operations. The torsional vibration is not as easily identified as the translational vibrations, due to lacking of simple and direct measurement devices. However, if left uninspected, torsional vibrations could do as much damage as that from translational vibrations. Typical damages developed under excessive torsional vibrations include shaft cracks, coupler cracks, gear wear, gear tooth failures, key failures, shrink fit slippage, etc. Therefore, torsional vibration detection and monitoring becomes an important step in rotating machinery condition monitoring, especially for those machines driven by a variable frequency drive (VFD), a pulse width modulation motor (PWM), or a synchronous motor (SM), etc. To detect the torsional vibration of the rotating machinery, several methods have been developed and/or improved. Commonly used methods include strain gauge based methods, torsiographs, tachometer frequency modulation based methods, laser vibrometer based methods, and zero-crossing detection based methods. On site, traditionally, the torsional vibration is detected by a phase demodulation process to the signals generated by tooth wheels or optical encoders. This demodulation based method has a few unfavorable issues: the installation of the tooth wheels needs to interrupt the machinery normal operation; the installation of the optical barcode is relatively easier; however, it suffers from short term survivability in harsh industrial environments. The geometric irregularities in the tooth wheel and the end discontinuity in the optical encoder will sometimes introduce overwhelming contaminations from shaft order response and its harmonics. In addition, the Hilbert Transform based phase demodulation technique has inevitable errors caused by the edge effect in FFT and IFFT analyses. Fortunately, in many industrial rotating machinery applications, the torsional vibration resonant frequency is usually low and the keyphasor® and/or encoder for speed monitoring is readily available. Thus, it is feasible to use existing hardware for torsional vibration detection.

Fri 11:05 Karajan Hall Rules and Regulation (6A – 1)

Marine propulsion – Barred speed passing and shaft fatigue life assessments – A classification society's perspective

E. Brodin, G. M. Bakken, G. Dahler, S. Avanesov, D. Sideris, O. Deinboll
DNV GL

Marine propulsion plants are subject to comprehensive torsional vibration studies to verify feasibility, incl. functionality and operational possibilities and limitations, but also motivated by safety and reliability. One essential mean in this context is to assure adequate fatigue safety margins of steel made components such as shafts. Methodologies and requirements set by manufacturers and classification societies for shaft fatigue are in general well described. Changes over the past decade in ship speeds and propulsion technology have been influenced by IMO energy efficiency requirements. Moving towards cleaner and more energy efficiency operations have caused new challenges also to torsional vibration assessments, especially for cargo ships powered by slow-speed two-stroke diesel-engines and direct-driven propellers. Some of these ships have experienced significantly long passing time through the barred speed range, and the shafts accumulate more load cycles at high stress levels. Therefore, the fatigue life prediction has become more important as a design parameter for these ships. This paper discusses the classification approach to these new challenges by alternative fatigue calculation methodologies for steel shafts, such as Bi-axial fatigue analysis and Strain-life relation together with Miner's linear summation method. They are further compared with DNV GL's CG0038 [2] and IACS UR M68 [6]. Given this background the latest changes in DNV GL Classification Rules are explored.

Fri 11:05 Wolf-Dietrich Hall Compressors Application (6B – 1)

Electro-mechanical modelling of a reciprocating compression train driven by induction motor

A. Fusi, F. Grasso, A. Sambataro, A. Baylon, L. Pugi
CST - Compression Service Technology, University of Florence

The purpose of this paper is to analyse torsional vibrations of the electromechanical systems composed by compression trains based on reciprocating compressor and induction motor. Since reciprocating compressors produce large fluctuating torques, the dynamic interaction between electrical and mechanical system causes natural frequencies modification and, consequently, torque amplification of the mechanical system, different from that calculated neglecting air-gap effect. The air-gap effect is studied starting from the development of an electromechanical model in MATLAB/Simulink environment. Electrical and mechanical model interact each other with their input/output in order to simulate the real torsional vibration of the compression train. Using state-space representation, the multi-physics model has been implemented including stator and rotor magnetic fluxes in the space-vector. Since the electromechanical system is described by non-linear differential equations, the model has been linearized around the steady and transient state operating point. Using this method, the natural frequencies changes with the linearization point so it is possible to analyse the system during both starting and steady conditions. According to API 618, the torsional analysis has been completed studying the electrical faults such as three-phase or two-phase short circuit. Finally, a dedicated tool, programmed in MATLAB environment, has been developed to avoid errors and reduce time needed for torsional analysis.

Fri 11:30 Karajan Hall Rules and Regulations (6A – 2)

New german grid code regulations and their relation to torsional vibrations

P. Böhm, P. Stolze
MAN Diesel & Turbo SE, Augsburg

Currently, the German Grid Code Regulations are in revision. For power plants connected to the medium voltage lines it will be mandatory to verify that the power plant will not disconnect from the grid when a so-called Low Voltage Ride Through (LVRT) event with certain intensity is happening. The new grid code regulations are binding since the beginning of 2017. For larger gensets and power plants an experimental proof for withstanding such an LVRT event is very cost-intensive. Because of this it was decided to conduct this proof via simulations. In order to do this it is necessary to model the complete drive train with the combustion engine, the coupling, generator and additional power plant periphery (bus bars, transformers etc.). Torsional vibrations and consequently active power fluctuations are inherent to gensets with reciprocating engines as prime movers. For the given task, however, it is enough to use a strongly simplified model of the combustion engine but it is necessary to take the coupling between prime mover and generator and also plant controllers (speed controller, power regulators etc.) into account.

Fri 11:30 Wolf-Dietrich Hall Compressors Applications (6B – 2)

Real time torsional vibration measurement on VFD emotor driven compressors in the oil and gas sector

C. Sleath, M. Cooper, C. Holmes
Torquemeters Ltd.

The increasing use of VFD driven E-motors has led to concerns regarding natural frequency excitation of couplings used in these large E-motor driven applications. Theoretical studies have been shown to be inaccurate with a spread of up to +7% to -12% (Pettinato et al, Proceedings of the Forty-Second Turbomachinery Symposium) giving rise to potential coupling failures. This paper outlines methodology for real-time monitoring, including a case study showing how this technology has been implemented for an isolated grid system. The technology is based on a well proven proprietary design, robustly engineered, and expected to remain in service for a typical plant lifetime of 20 years. There are no rotating electronics or contact points requiring service work or maintenance. The paper will describe the method of signal generation, it's processing, and post processing data display, as well as plant data connectivity. The case study section will demonstrate problems encountered with signal generation, the causes and solutions, and the requirements for a successful installation.

Fri	13:00	Karajan Hall	Engine Development – Managing Vibrations at the Source (7A – 1)

Not only torsional vibrations in the crankshaft of 2-stroke installations

W. Schiffer
Winterthur Gas & Diesel Ltd.

Torsional vibrations are dominant in shaft lines of diesel marine installations. Axial shaft vibrations are due to short stroke not of interest for four-stroke marine installations, but for two-stroke installations they cannot be neglected. Axial shaft vibrations are very rarely the cause of severe damage cases, but they generate dynamic forces acting on the ship hull. Long time ago torsional and axial vibrations for two-stroke installations were calculated based on a similar one-dimensional mathematical model. The results of the axial vibration calculation based on these simplified considerations were not satisfying. Tangential excitation forces acting on the crank pin of the crankshaft, which are main sources of torsional vibrations, influence also axial vibrations. This paper explains the meaning of the torsional-axial coupling coefficients from the crankshaft starting with a comparison of the impact from torsional and axial mode shapes. Differences between torsional damper, which are needed depending on the installation, and axial damper, which are always integral part of two-stroke engines, will be shown more in detail. Furthermore, it will be demonstrated, why the sense of rotation is nearly not influencing torsional vibrations, but axial vibrations.

Fri	13:00	Wolf-Dietrich Hall	System Reliability (7B – 1)

Coupling failures in VFD motor / Fan systems due to high torsional vibration

T. Feese
Engineering Dynamics Inc.

Variable frequency drives (VFDs) are used to control motors over a wide operating speed range. VFDs can create torsional excitation that in some instances cause torsional fatigue failures of couplings and shafts [1,2]. This case study deals with repeated failures of disc pack couplings on three newly commissioned combustion air blowers (fans). Field tests indicated that at certain speeds, the dynamic torque was significantly amplified by excitation of the first torsional natural frequency (TNF). The alternating torque reached 800% of full-load torque (FLT), which explained the coupling damage and could have also resulted in fatigue cracks in the motor and/or fan shafts if not corrected. The source of the excitation was electrical energy from the VFD, and not due to turbulence or pressure pulsation from the fan. During the testing, attempts were made to reduce the electrical energy by adjusting (tuning) various VFD parameters. Although these efforts were not completely successful in solving the problem, a correlation was established with the alternating torque when VFD parameters were changed. As a temporary solution, the VFD was reprogrammed to limit the maximum operating speed and to prevent excitation of the first TNF. The long-term solution primarily involved replacing the disc pack couplings with an alternate coupling design utilizing rubber blocks in compression. An analytical torsional vibration analysis was performed to evaluate several different coupling sizes and rubber blocks of various hardness values (durometers). It was predicted that the alternating torque amplitudes would be significantly reduced once the new couplings were installed. Follow-up field tests confirmed that the recommended coupling reduced the alternating torque to an acceptable level over the entire operating speed range. The torsional stiffness of the rubber block coupling was lower compared to the disc pack coupling, which in turn lowered the first TNF and eliminated the coincidence with the VFD excitation within the fan operating speed range. The rubber coupling also had more damping which further reduced the overall torsional vibration levels and improved VFD stability.

Fri 13:25 Karajan Hall Engine Development – Managing Vibrations at the Source (7A – 2)

Irregularity instead of harmony – Ways to improve torsional performance of a V20 engine

B. Mokdad, C. Henninger
Liebherr Components Colmar SAS, Liebherr Machines Bulle SA

Torsional dynamics of V-engines depend strongly on the V-angle, as it determines regularity of firing intervals. For small engines, equidistant firing is preferred in order to reduce rotational irregularity. However, high speed four stroke V20 cylinder engines usually have non-natural V-angles like 60° or 90°, which are inherited from smaller members of their engine family. As a consequence, firing intervals of alternating duration length occur, which induce dominant occurrence of 5th order excitation. This has serious impact on crankshaft torsional vibrations. Torsional harmony can be re-gained by choosing natural V-angle or split pin crankshaft, allowing for equidistant firing. The opposite way is to reduce 5th order excitation by introducing further irregularity in firing intervals by means of crank star modifications. The potential of both ways, towards harmony as well as irregularity, is discussed in detail, and demonstrated for Liebherr's D9820 engine.

Fri 13:25 Wolf-Dietrich Hall System Reliability (7B – 2)

Coupling failure in engine driven pipeline compressor system

T. Feese
Engineering Dynamics Inc.

Engine-driven compressor units at a gas transmission pipeline station experienced multiple coupling failures. These units had a torsionally soft coupling between the engine and compressor that utilized radial leaf springs. Pressurized oil was supplied to the coupling from an engine bearing through a central bore in the engine crankshaft extension. Torsional damping occurs when oil is forced through internal clearances as the coupling springs flex. Field measurements taken on one of the units showed that at certain operating points, the design limits of the coupling were exceeded in terms of angular oscillation and vibratory torque. Physical evidence (cracks at a 45 degree angle) and oil analysis containing copper also supported this finding. The worst condition was identified when operating near the first torsional natural frequency (TNF) with some of the compressor cylinders single-acting. As a short-term solution, restrictions were placed on the compressor speed and load steps to avoid exciting the first TNF. The long-term recommendation involved de-tuning the first TNF below minimum running speed by adding inertia to the system with a compressor flywheel. The purpose of the case study discussed in this paper is to raise awareness of how a torsional vibration problem can occur in reciprocating compressor systems. Several factors contributed to the coupling failure:

- The first TNF was within the operating speed range.
- Damping was over estimated for the first torsional mode.
- Not all of the compressor load steps were analyzed during the design stage.

Failure of the coupling was not anticipated based on the "ideal" operating condition. Therefore, it is important to perform a comprehensive torsional vibration analysis that encompasses all compressor operating speeds and load cases, uses conservative assumptions, and provides for sufficient separation margins from any dangerous torsional resonances.

Fri 13:50 Karajan Hall Engine Development – Managing Vibrations at the Source (7A – 3)

Review of the dimensing calculation process in torsional vibration and evaluation of possible development directions

C. Pestelli, P. Sundström, M. Almerigogna, A. Pettirosso
Wärtsilä Corporation

Calculation of Torsional vibration is surely the most fascinating engineering job in the area of vibration. Indeed, there is no other field that reached such a high level of accuracy in calculation and, more importantly, precisely defined and ruled. Ships equipped with large engines cannot sail without a torsional vibration certification, since engine operability is a must for safety at sea. This causes the modelling practice to be continuously refined for almost a century, but technological advancement is not always constant, sometimes big steps occur and it is very challenging to introduce them in a well-established methodology. Moreover, real world experience does not always fit the modelling theory especially when market movers brings engineering competencies to the limit by increasing performance and reducing costs, or introducing new fuels like LNG that bring new challenges. As the measurement chain has various elements, similarly, the process of verification through calculation has precise steps. The main aim idea of the present article is to analyse torsional vibration calculation in some aspects that might open up new development directions. For example, careful material analysis and observations led to the conclusion most steel alloys have no real infinite life time limit if tested long enough. This goes hand in hand with the need to adopt other lifetime estimation methods than maximum allowable torsional stress level and a common one is rainflow damage counting algorithm together with Miner's rule. Large Bore Dual Fuel Engine in HFO-Diesel and LNG-Otto mode is a perfect test case and will be studied applying rainflow damage counting algorithm together with Miner's rule. This approach is time domain analysis and different calculation and measurement will be compared to deeply investigate the effect of "regular" versus "irregular" combustion, from torsional vibration point of view, highlighting pros. and cons..

Fri	14:40	Karajan Hall	Engine Development – Future Concepts (8A – 1)

A procedure for calculaction of the maximum allowed engine power under misfire conditions: Application to 14 and 16 V medium speed four stroke stationary engines

F. Jiménez-Espadafor, A. López Lora, D. Palomo Guerrero, F. Fernández Vacas
Seville University, Endesa Generación

Four stroke medium speed diesel engines typically present V-structure cylinder blocks of 12-20 cylinders, being mainly entitled for vessel propulsion and power generation. Injection system failure reduces engine power; increases mechanical stresses on the crankshaft and accounts for a relevant percentage of engine outages. This work is focused on the design of a strategy for engine operation under one or two cylinders in misfire that it has been applied to 14V and 16V diesel engines. The strategy is based on a lumped-mass non-lineal torsional system model where excitation comes from the combustion pressure, engine friction and inertia. Combustion pressure curve has been estimated through a combustion model and later validated and it is based on a thermodynamic cycle with a Wiebe function for heat rate. An optimization procedure has allowed the fitting of the combustion model to mean engine parameters, including pick combustion pressure, from 50% up to 110 % rated load. The allowable crankshaft torsion in every degree of freedom has been calculated from crankshaft torsion at 100% rated power. From the torsional and combustion models, all feasible combinations of one and two misfiring cylinders for any load from 50% to 100% rated load has been evaluated. As results the maximum allowable engine loads compatible with at least one cylinder on misfire condition have been calculated.

Fri	14:40	Wolf-Dietrich Hall	System Evaluation (8B – 1)

Propulsion shafting alignment from analysis report to practice in the field, how to read and apply

M. Zeid
Caterpillar Propulsion

The marine propulsion shafting lateral analysis report (Alignment Report) is a common report which is traditionally issued by the propeller maker to Shipyard. The aim of this report is to maintain the lateral shaft behavior in line with the propeller maker's predictions. The alignment report is considered a reference document by itself and is subject to several checks and approval processes from the different parties involved (e.g. the Classification Societies). The shared interface which is used to represent the result of the analysis report is practical measurements as represented by the GAP-SAG between flanges and the Jack Load Test for specific bearings, and this is used as the method of verifying the alignment. This paper is basically presenting the different circumstances around the GAP-SAG and Jack Load Test measurements which can have significant influences on the final conclusion of the actual alignment of the shafting system.

Fri	15:05	Karajan Hall	Engine Development – Future Concepts (8A – 2)

Future concepts and development trends related to medium speed engines

M. Bierl
MA-C-S Engineering

In order to be attractive to the buying customer prospective concepts for medium-speed engines mainly must bring the following features together:
1.) Compliance with current and future exhaust emission limits
2.) Low purchase cost
3.) Low life-cycle costs
After a phase which has focused on the achievement of sharper NOx limits, a phase follows, in which fuel consumption {with regard to point 3} and power output {with regard to point 2} are dedicated as development targets again. Basic technologies which have achieved readiness for serial application during the last decade such as two-stage turbo charging, common-rail injection, variable valve timing, and their positive impact on Miller-Cycle capabilities, have been the basis for new engine concepts which raise the limits of what is technically possible to new benchmark levels and which are explained in more detail during the lecture. These concepts find optimized compromises in a novel manner in order to take account of the boundary conditions and interrelations described above accomplishing peak values, e.g. with regard to fuel consumption.

Fri	15:05	Wolf-Dietrich Hall	System Evaluation (8B – 2)

Performance mapping of tuned type torsional vibration damper for automotive on-highway engine application

A. Khule, R. Channapattan, H. J. Raja
Hodek Vibration Technologies Pvt Ltd.

Hodek Vibration Technologies Pvt Ltd. is a leading torsional vibration damper manufacturing company located in Pune-India. The product portfolio of Hodek comprises rubber or tuned type dampers and viscous dampers for engines in a displacement range from 0.8 litres to 95 litres for automotive, power generation, industrial and marine applications. Torsional vibration of the crankshaft is the twist induced from one end to the other originating from the gas excitation torque and the inertia torque of the reciprocating components. These vibrations lead to high stresses and failure of the crankshaft. In order to protect the crankshaft, torsional vibration dampers (TVDs) are used to bring the crankshaft stresses within the allowable limits. The damper is located at the crank nose where the crankshaft has the highest angular displacement. Torsional vibration dampers are broadly classified as rubber or tuned type and viscous dampers based on the damping media used. Tuned type or rubber dampers are generally preferred as being the lower cost product and controls the torsional vibrations within the engine operating speed range. Tuned rubber type dampers have some drawbacks and limitations in terms of heat load characteristics and changes in tuning frequency and dampening properties due to operating/environmental conditions. Excessive damper work and harsh operating conditions degrade these properties at a faster rate, which in turn causes premature damper failures. This paper presents and demonstrates the influence of various conditions for the causes of tuned damper failures. Torsional vibration analyses were performed analytically and experimentally in order to predict these failure modes and to obtain the dynamic loading of the crankshaft under various engine loading patterns. The outcome of the analysis is used to find an effective solution to the problem. Based on validation results some useful conclusions are reached.

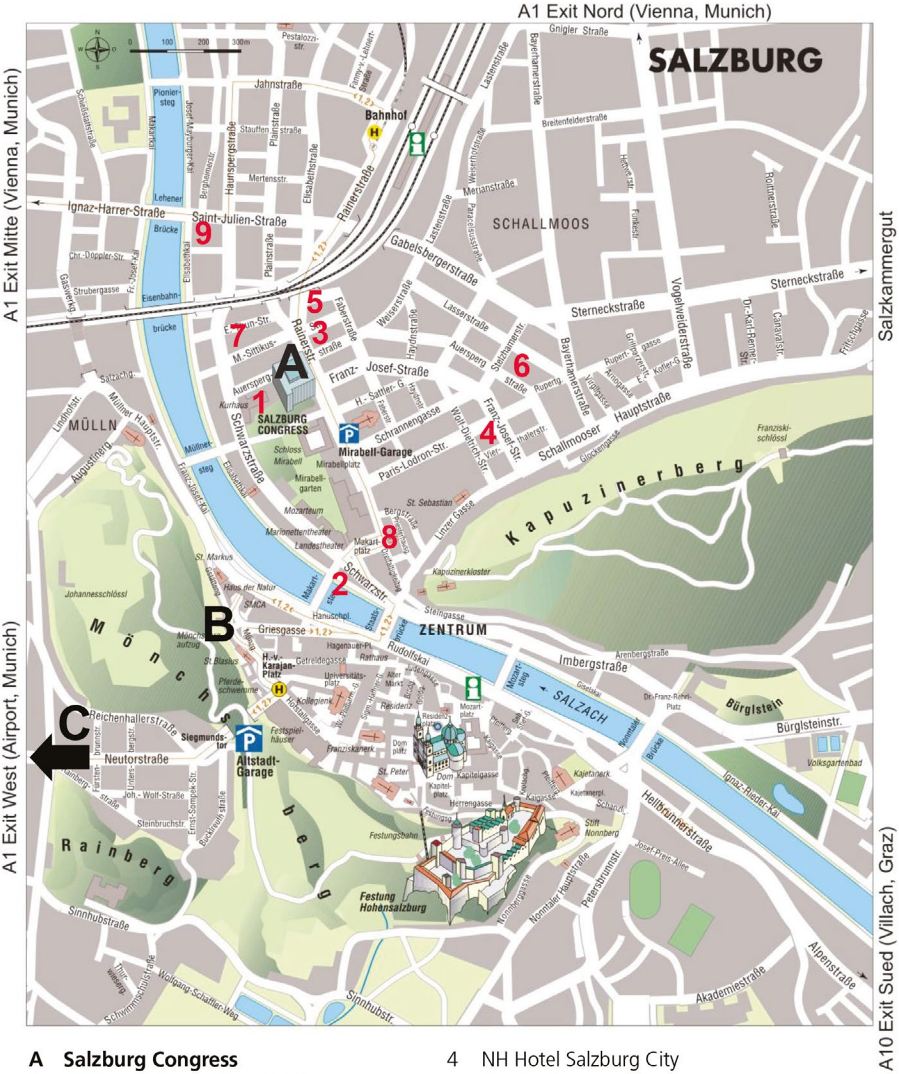
Fri 15:30 Karajan Hall Closing Session (9)

Effects of engine and vessel operating conditions on torsional vibration dampers

K. Prenninger, S. Lange, D. Richter-Trummer
Geislinger GmbH

Both sea-trials and field reports have proved that vessels do not only operate below the maximum continuous rating (MCR) propeller curve, but they can also continuously operate above it. This happens, for example, when vessels sail in bad weather conditions or in shallow waters due to too small margins in the engine power for the specific ship hull or propeller design, or due to special engine torque limiter settings. These conditions can occur over a longer period, not just in transient operation. These effects have been summarized in the term "Geislinger heavy running". This paper shows the influence of the "Geislinger heavy running" power curve, as opposed to the propeller curve, on the damper selection. This issue is exemplified by discussing the effects on the damper twist and the minimum oil supply pressure required, and illustrated by comparing simulated results to measurements.

Map - City of Salzburg



A	**Salzburg Congress**	4	NH Hotel Salzburg City
B	**Welcome Reception, M 32**	5	Hotel Imlauer
C	**Gala Dinner, Kavalierhaus Klessheim**	6	Hotel Auersperg
1	Hotel Sheraton	7	Hotel Villa Carlton
2	Hotel Sacher	8	Star Inn Hotel Gablerbräu
3	Hotel Crowne Plaza	9	Motel One Salzburg Mirabell

Symposium location

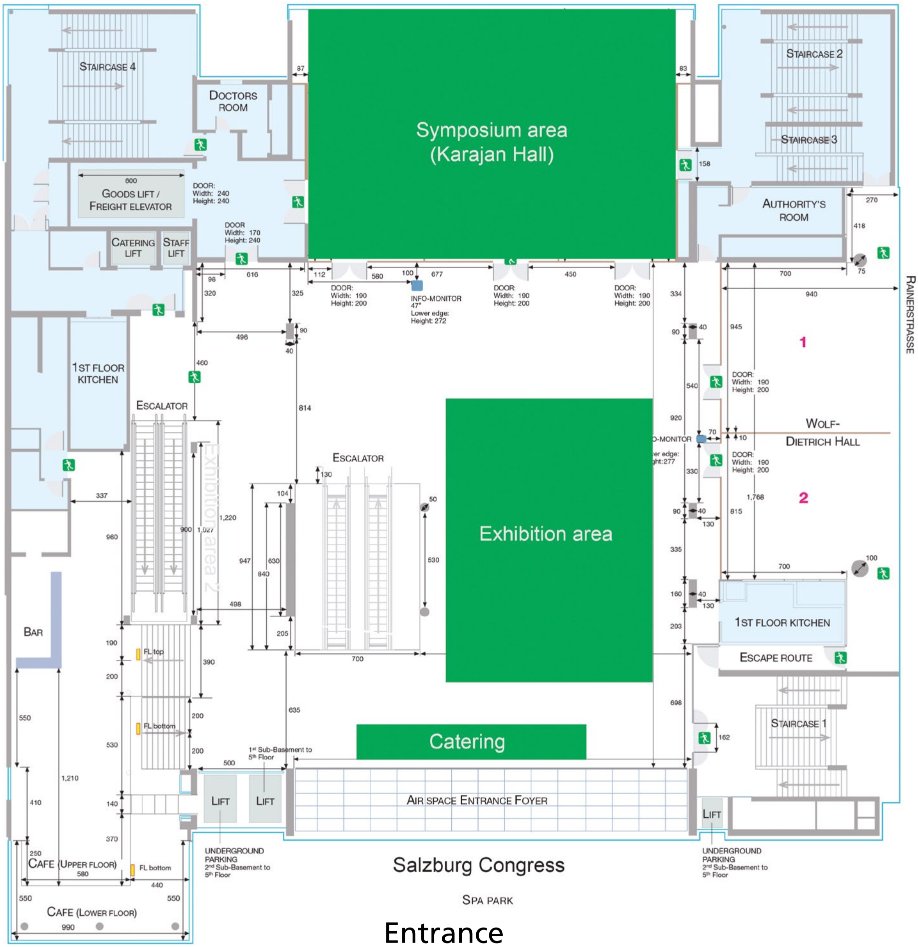
The Salzburg Congress is within walking distance of the historical city centre as well as most hotels, and can easily be reached by bus. It is also located right next to the famous Mirabell Gardens. The Symposium will be held on the first floor of the Salzburg Congress, in the Karajan Hall and the Wolf-Dietrich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

Salzburg Congress (see map “City of Salzburg” A)
Auerspergstraße 6
5020 Salzburg / Austria

Website: www.salzburgcongress.at

Symposium location: Salzburg Congress

Salzburg Congress floor plan



Exhibitors

AVL List GmbH
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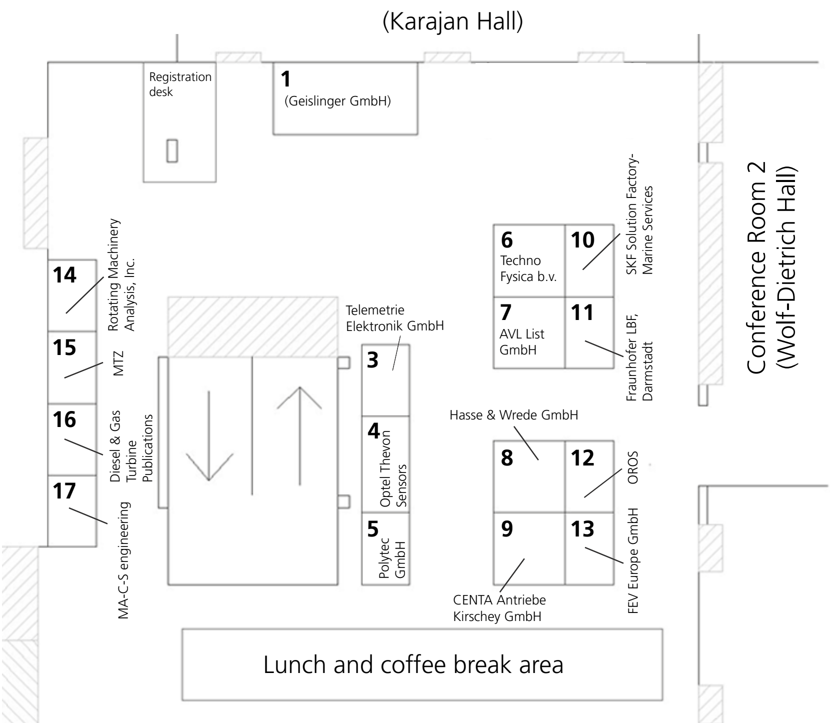

Welcome Reception

Welcome Reception*, **Restaurant "M32"**
Wednesday, May 17th, 2017, 18:00

Entrance: Mönchsbergaufzug (see Map "City of Salzburg" B), Page 40
Gstättengasse 13
5020 Salzburg, Austria

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

Restaurant M32

Old town of Salzburg

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 symposium fee includes the "Welcome Reception". The tickets for the elevator to the Mönchsberg will be available at its entrance.

Gala Dinner + Bus

Gala Dinner*, **Restaurant Kavalierhaus**
Thursday, May 18th, 2017, 20:00

Meeting Point: Salzburg Congress (see map "City of Salzburg" A), Page 40
First bus transfer 18:15; Last bus transfer 18:30 to Restaurant Klessheim
Transfer back to Salzburg Congress after 22:30

Kavalierhaus Salzburg

The Kavalierhaus in Salzburg was built by order of the Archduke Ludwig Victor in 1881/82 as a winter palace, a residence for the cold season. Archduke Ludwig Victor was very popular among the people of Salzburg, not least because of his involvement in improving the city's infrastructure, but also because of the annual celebrations he held at the palace gardens.

*The "Gala Dinner" is included in the Symposium Participation Fee. Participants will be escorted to and from the Kavalierhaus with a shuttle bus service.

Social Program

Salzburg City Tour
Wednesday, May 17th, 2017, 16:00

Meeting Point: Salzburg Congress
Participation rate*: EUR 18,- / Person, registration required

Before the Welcome Reception, we will offer an optional guided City Tour, starting at the Salzburg Congress at 16:00 and ending at the restaurant M32, the location of the Welcome Reception at 18.00.

From the Salzburg Congress, the tour brings you to Mirabell Palace, through the old city left of the river Salzach, past Mozart's residence and past one of the most famous music universities – the Mozarteum. After crossing the Staatsbrücke, you will find yourself in the heart of the baroque old town and you can explore sights like the Getreidegasse, St. Peter's, and the Salzburg Cathedral. The tour will end at the Restaurant M32, in time for the Welcome Reception.

*Please note that the City Tour is not included in the participation fee of the Symposium.

Partner Program

Hellbrunn Trick Fountain Tour
Thursday, May 18th, 2017, 13:30

Meeting Point: Salzburg Congress
Participation rate*: EUR 29,-/ Person, registration required

Summer palaces, as they were fashionable in the 17th century, were places of celebration, pleasure, and recuperation. They were the 17th century equivalent of holiday homes. Hellbrunn was built by the Italian architect Santino Solari by order of Markus Sittikus von Hohenems, Salzburg's Prince-bishop from 1612 to 1619. Markus Sittikus' celebration of love, life, and passion can still be felt today in the unique summer palace with its park and its trick fountains.

*The participation rate of EUR 29,-- includes the entry for the Hellbrunn water games, as well as the bus fee to the palace. Participants will be escorted to and from Hellbrunn.

Partner Program

Fortress Hohensalzburg Tour
Friday, May 19th, 2017, 13:30

Meeting Point: Salzburg Congress
Participation rate*: EUR 19,- / Person, registration required

The Fortress Hohensalzburg is a real eye-catcher, peaking out high above the baroque towers of the city. The castle in Salzburg is an unmistakable landmark, dominating the city's world famous silhouette. Even from afar, visitors are able to appreciate the might of this impressive historical building. Up close, the history contained in these powerful walls is almost tangible. Channel your inner adventurer and explore this historical site!

*The participation rate of EUR 19,-- includes the entrance fee as well as the ticket for the funicular railway. Participants will be escorted to and from the Fortress.

Social Program

Berchtesgadener Land Tour
Saturday, May 20th, 2017, 8:00

Meeting Point: in front of the Salzburg Congress.
Participation Rate*: EUR 50,- / Person, Registration required

The program depends on the weather in the morning:

If it is good weather, we will visit the Eagle's Nest (Kehlsteinhaus) at the summit of the Kehlstein (1834m), a rocky outcrop that rises above the Obersalzberg near the town of Berchtesgaden in the Bavarian Alps. It provides an excellent view over the area.

If it is bad weather, we will visit the 490 year old salt mines in Berchtesgaden. Experience the fascinating underground world of the salt-miners and discover the charm of the magnificently illuminated subterranean landscape.

We can tell you at the registration desk which option has been selected.

At noon, we will make a boat tour on the Königsee with lunch at the lake, and in the afternoon we will visit Berchtesgaden. The bus will return to Salzburg with an optional stop at the airport. We intend to be back in Salzburg no later than 17:00.

General Information

Media Check-In

All the presentations are run using the notebooks installed on site at the Salzburg Congress venue. The use of personal laptop computers for presentations is not permitted.

All presentations (PPT) should be handed in to the "Slide Centre" in each lecture room either in the morning or during the coffee breaks at the latest 2 hours before the presentation is due to be given. The data will be copied onto a central computer and sorted according to the order in which the material is to be shown.

All computers installed on site have been equipped with the 'Windows 7 Enterprise' operating system and with Microsoft Office 2010 – incl. PowerPoint 2010. Presentations should be stored as „*.ppt or *. PPTX" (PowerPoint) files. Please avoid the so-called Pack&Go formats such as: "*. pps, *. ppsx" (PowerPoint).

Presentations

All presentations are scheduled as follows:
• 20 minutes lecture
• 3 minutes discussion
• 2 minutes break (with the possibility of changing rooms)

As there will be two parallel sessions, this schedule should be strictly observed. It is not possible to exceed 20 minutes for a presentation. In each room, a laptop and a beamer are available.

Photography and Video Recording

Neither photography nor video recording of any lecture or poster is permitted.

Contact

The Organizer of the event is the Vibration Association.

Schwingungstechnischer Verein
(Vibration Association)
Hallwanger Landesstr. 3
5300 Salzburg, Austria

E-mail: info@torsional-vibration-symposium.com
Tel.: +43 662 664146

Website: torsional-vibration-symposium.com

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