TORSIONAL VIBRATION SYMPOSIUM

PROGRAM SALZBURG 2014

TORSIONAL VIBRATION SYMPOSIUM

Dear Colleagues,

The advisory board and the Vibration Association are pleased to welcome you all at the 1st Torsional Vibration Symposium from 21st to 23rd May 2014 in Salzburg, one of the most beautiful towns in Austria. We are looking forward to welcoming torsional vibration experts from more than 20 countries during this unique event.

There are many technical gatherings in the power transmission sector, but until now a specific meeting for torsional vibration experts was missing in the calendar. We are very proud and pleased that so many authors have submitted papers and that various companies and universities are joining us at the exhibition. This is a lot more than expected when we started planning this event in late 2012. During this symposium the latest technologies and technical trends will be introduced by experts from all over the world. The exchange of information between the torsional vibration engineers from universities, research institutes, consulting companies, software & measurement companies as well as from the industry will be of advantage to all of us. This conference, however, aims not only at contributing to the technical and scientific progress on torsional vibrations, but also at improving the cooperation between people with the same interests. Salzburg is the perfect place for such an event as it not only offers a very professional congress centre, but also an impressive city centre with a very long history, embedded in a beautiful alpine landscape.

With these goals in mind, we look forward to meeting you at the first Torsional Vibration Symposium.

Sincerely yours,
The Vibration Association

VIBRATION ASSOCIATION
Schwingungstechnischer Verein

Content

Advisory Board

Robert Gläser, Wärtsilä Switzerland Ltd.
Torsten Philipp, Geislinger GmbH
Per Rønnedal, MAN Diesel & Turbo
Matthias Schuchardt, MTU Friedrichshafen GmbH
Prof. Christoph Spensberger, Dresden University of Applied Sciences
Jonathan Walker, MTZ Industrial
Prof. Andreas Wimmer, Technical University Graz
Dr. Rick Zadoks, Caterpillar Inc.

Organization

The organizer of the event is the Vibration Association.

VIBRATION ASSOCIATION
Schwingungstechnischer Verein

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

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

Website: torsional-vibration-symposium.com

Keynote speaker

The keynote speech will be held by **Prof. Georg Wachtmeister**, who is known as one of the world's leading expert in the field of internal combustion engines.

Prof. Georg Wachtmeister is head of the Institute of Internal Combustion Engines at the Technische Universität München.

Technische Universität München

Professor Wachtmeister's research work focuses on reducing emissions and boosting the efficiency of internal combustion engines. This involves conducting research on new combustion processes with operating parameters that are far beyond the current state of the art. The department has extensive experience in CFD and FEM analysis. In addition to gasoline and diesel engines, natural gas engines are an important focus of his research. Using a test bed engine developed in his department, the frictional forces acting between the piston and piston rings and the cylinder liner can be determined experimentally in a running engine, at high precision and resolution across the crank angle range.

After completing undergraduate studies in general mechanical engineering (1984) and a doctorate (1988) at TUM, Professor Wachtmeister began his career at MAN B&W Diesel AG, starting out as technical manager for thermodynamics. He then became team leader for material strength (4-cycle engines) and manager of the Turbocharger Engineering Department. He was ultimately named senior vice president for 4-cycle engine technology. Professor Wachtmeister has been a full professor at TUM since 2004.

Program

Wednesday: May 21st, 2014

18:00	**Welcome Reception**, Restaurant "St. Peter Stiftskeller" Salzburg

Thursday: May 22nd, 2014

08:30	**Registration opens**
09:30	**Official opening**
09:45	**Keynote: Prof. Georg Wachtmeister** TU München, Head of the Institute of Internal Combustion Engines **Vibrations: A continuous challenge, a key for reliability, a chance for new features**
10:30	Coffee break
	Session 1: Torsional Vibration - Plenary Session
11:00	**Method to validate the simulation of crankshaft torsion** J. Stadler, H. Schaumberger, R. Steiner, Prof. A. Wimmer, T. Jauk Kistler Instrumente AG, GE Jenbacher, LEC / TU Graz
11:25	**Influence of emission regulations and fuel saving technologies on torsional vibrations in large engine applications** T. Philipp Geislinger GmbH
11:50	**Limiting values of dynamic loads in linear oscillators due to transient excitation (Presentation in German, with English slides)** Prof. H. Dresig TU Chemnitz
12:15	Lunch

	Session 2A: Powertrain Components	Session 2B: System Reliability
13:30	**Torsional vibrations stresses of alternators used in diesel-electric powertrains of locomotives against the background of increasing cylinder peak pressures** P. Stürzl, M. Schuchardt MTU Friedrichshafen GmbH	**Gear problems solved by the analysis of torsional vibrations** A. Laschet, B. van den Heuvel ARLA Maschinentechnik GmbH, RWE Power AG
13:55	**Modeling an electric vehicle powertrain and analysis of vibration characteristics** R. Schelenz, M. Wegerhoff, O. Drichel IME, RWTH Aachen University	**A full scale investigation of torsional vibration failure of a marine propulsion system intermediate shaft.** P. Filcek, K. Banisoleiman, J. Stainsby, S. Mathieson Lloyd's Register, EMEA
14:20	**Calculation of an elastic clutch with temperature-sensitive characteristics through system simulation in the time and frequency domains** U. Schreiber, Prof. C. Spensberger ITI GmbH, Dresden University	**Torsional vibration analysis of an emergency diesel generator (EDG-Set)** B. Buchmeier TÜV SÜD Industrie Service GmbH
14:55	Coffee break	

	Session 3A: Simulation	Session 3B: Noise and Vibration
15:20	**Efficiency boost in product development processes through support by torsional vibration simulation in early development phases** B. Juretzki, R. Schelenz, Prof. G. Jacobs IME, RWTH Aachen University	**Noise and vibration challenges due to torsional excited gearbox vibrations** P. Tellefsen, K. Cunningham Lloyd's Register Consulting
15:45	**Influence of simulation model detail on determinable natural frequencies** Prof. B. Schlecht, T. Rosenlöcher Institute of Machine Elements & Machine Design, TU Dresden	**Reduced transfer of structure borne sound in couplings** L. Kurtze, T. Philipp Geislinger GmbH
16:10	**Analysis of dynamic interaction between crankshaft and connecting rod through the use of complex nonlinear calculations** H. Roeser, C. Windelev Transmarine Propulsion Systems Inc.	**Vibration dynamics simulation of a diesel engine coupled system with flexible coupling under misfiring using physical and finite element modeling** M. Hasan, J. Holmberg, H. Kirschey Centa Antriebe Kirschey GmbH, Wärtsilä Ship Power
16:35	Coffee break	

	Session 4A: Industrial Applications	Session 4B: Fundamental Engineering
17:00	**Lateral-torsional vibration coupling in reciprocating compressors** F. Newman, T. Stephens, R. Harris Ariel Corporation	**Introduction of the new torsional vibration guideline VDI 2039 under special consideration of damping** F. Knopf, T. Philipp Hasse & Wrede GmbH, Geislinger GmbH
17:25	**Linear and torsional vibration study for an engine driven compressor system** W. Wang, J. Braun, R. Chundi, R. Khan IDC Technical Services	**Fuel efficient propeller design and torsional vibrations in propulsion machinery** G. Dahler, J. J. Iseskär, J. Holm DNV / GL
17:50	**Experience with torsional vibration measurements and calculations of reciprocating compressors** J. Lenz KÖTTER Consulting Engineers	**Self-excited torsional vibration phenomenon on specialized vessel electric propulsion systems** Prof. D. C. Lee, R. D. Barro Mokpo Maritime University, South Korea
18:15	End of Thursday session	
20:00	**Gala Dinner,** Restaurant "M 32"	

Session locations:

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

Program for Friday: May 23rd, 2014

	Session 5A: Ice Impact	Session 5B: Active Control
08:50	**Ice impact simulation for propulsion machinery** S. Persson MAN Diesel & Turbo, Copenhagen	**Active measures to reduce torsional vibrations** M. Matthias Fraunhofer LBF, Darmstadt
09:15	**Meeting ice impact analysis requirements through a unified Modeling for transient and frequency domain simulation** A. Abel, U.Schreiber ITI Gmbh	**Active control of crankshaft vibrations** M. Steidl, F. Knopf Hasse & Wrede GmbH
09:40	**Simulation of torsional vibration responses in ship propulsion shafting system caused by ice impacts** Yu. Batrak, A. Serdiuchenko, A.Tarasenko Intellectual Maritime Technologies, Ukraine	**Control and correlation of mainshaft torsional modes on windturbines and off-axis loaded dynamometers** W. L. Erdman DNV KEMA
10:05	Coffee break	

	Session 6A: Engine Development	Session 6B: Measurement and Testing
10:20	**Firing sequence optimization for a V20 cylinder diesel engine** C. Henninger Liebherr Machines Bulle	**Correlation of simulation to test for a flexibly coupled two-bearing generator system** R. Zadoks, J. J. Iseskär, T. Utengen Caterpillar Inc., DNV GL
10:45	**Firing order optimization in FEV virtual engine** K. Buczek, S. Lauer FEV Krakow, FEV GmbH	**Various torsional vibration measurement techniques for optimal trade-off between high accuracy and ease of instrumentation** A. Palermo, L. Britte, K. Janssens, D. Mundo, W. Desmet Universita' della Calabria, KU Leuven, LMS International, A Siemens Business
11:10	**Cranktrain design using coupled calculations and multicriteria optimization** P. Böhm MAN Diesel & Turbo, Augsburg	**Contactless method to determinate the rotation angle in torsional vibration based on video image correlation (VIC-3D) measuring system** Prof. I. Száva, S. Vlase, B.P. Gálfi, I. Serban, P. Dani University of Brasov, Geislinger GmbH
11:35	**Crank train torsional vibration optimization** C. Priestner, T. Ovari, M. Brunner, F. Zieher AVL List GmbH	**The comparison between measured and calculated torsional vibration loads in 2-stroke marine installations** M. Barraud, P. Bättig, R. Gläser Wärtsilä
12:00	**Final words**	
12:10	Snack	
13:00	Tour: Wolfgangsee / Boatride / Schafbergbahn Departure at the Salzburg Congress	

Abstracts

Thursday sessions

Thu	09:45	Karajan Hall	Keynote speach

Vibrations: A continuous challenge, a key for reliability, a chance for new features
Keynote: Prof. Georg Wachtmeister
TU München, Head of the Institute of Internal Combustion Engines

The closer we design the components to 100% material utilization the knowledge about vibration effects becomes more and more important. This target seems to be achievable since today the identification of harmful vibration modes is already possible by powerful simulation tools. In addition stress and vibration measurement technology reached a rather high level of accuracy. Nevertheless, there is still room of improvement. And besides methods of vibration analysis the availability of material properties related to vibration sensitivity plays an important role in this picture. In order to ensure reliability the knowledge of operational loads is decisive for a safe operation. Methods to predict nonlinear damage accumulation on the basis of known or at least predicted load profiles are an essential prerequisite. As a consequence of a continual weight reduction even single sporadic events such as thermo-shocks have to be taken into consideration of life time analysis. However, despite the big challenges and work load vibrations are posing to the development process they can be also use in a beneficial way. Malfunctions can be detected by recording i.e. structure borne sound with sensors. Furthermore control strategies can be derives from that signals. Or methods of condition based maintenance become feasible.

Thu	11:00	Karajan Hall	Torsional Vibration - Plenary Session (1)

Method to validate the simulation of crankshaft torsion

J. Stadler, M. Ciecinski, H. Schaumberger, R. Steiner, Prof. A. Wimmer, T. Jauk
Kistler Instrumente AG, GE Jenbacher, LEC / TU Graz

Engines with long or flexible crankshafts will suffer a significant amount of torsion between the different crankpins. As the crank angle is usually only measured at one position, the validation of a crankshaft torsion simulation will need a different method. A potential method will be discussed further in this paper. The measurement of the crank angle will achieve the best accuracy when the measuring location is closest to the referring crank pin. Crank angle position is typically measured using an optical measurement device, linked either to the crankshaft front end or, the flywheel end. However, for individual cylinders of a multi cylinder engine, this method is not suitable for intermediate cylinders. An initial validation of the crankshaft torsion can be performed, combining the front and back end measurement of the crank angle, but does this fulfill the requirement? Measurements of the crank angle at both ends already exhibited a significant occurrence of crankshaft torsion as a function of the engine load. In addition, a cylinder deactivation should not occur, because of its influence on the crankshaft torsion. For this reason, a method had to be found, with which it is possible to measure during fired engine operation. As the combustion flame interference to the optically measured result was too high, the gas exchange TDC was selected to validate the crankshaft simulation. With this new method, a good correlation between simulation and actual measurements could be achieved. In conjunction with previous methods, the simulation model can be validated for each cylinder at the gas exchange TDC.

Thu	11:25	Karajan Hall	Torsional Vibration - Plenary Session (1)

Influence of emission regulations and fuel saving technologies on torsional vibrations in large engine applications

T. Philipp
Geislinger GmbH

Compliance with future emission regulation standards has been one of the main development targets for the large engine industry during the last years. Rules like IMO Tier II/III for marine applications and EPA Tier 4 for land based off-highway applications have led to intensive development activities in order to fulfill the current requirements regarding exhaust gas conditions. The drastically reduction of nitrogen oxides (NOx) and particulate matter (PM) is typically achieved by not only optimizing a single engine parameter or component, but by a combination of different technical enhancements and modifications. Internal measures target the combustion process itself by modifications of ignition timing, increased peak pressure, optimized gas exchange or exhaust gas recirculation (EGR). These are often combined with after-treatments like selective catalytic reduction (SCR), particle filters or scrubbers. Besides these challenges the trend towards lighter engines with better fuel-efficiency and higher power density remains unbroken. However, issues like rising cylinder pressure lead to increased load on the mechanical components of an engine. In direct driven 2-stroke propulsion plants de-rating and slow-steaming have become keywords for state of the art fuel saving technologies. Very often this has a direct influence on the torsional situation in these applications.This paper gives an overview about the influence of different design strategies for emission regulation and fuel efficiency on the torsional vibration situation in large diesel and gas engines. It describes the effort that has to be made on the mechanical side in order to successfully combine reduced emissions with higher fuel efficiency and power density.

Thu	11:50	Karajan Hall	Torsional Vibration - Plenary Session (1)

Estimation of extreme values in the magnitudes of force and movement in dynamically loaded linear vibration systems

Prof. H. Dresig
TU Chemnitz

The calculation of temporal patterns in force and movement magnitudes is usually executed using software. Every CAD engineer must take responsibility for his results and check whether they are physically correct. He always needs a control, for example via independent programmes. Often, it is the extreme values which are of special interest, since these are critical as to whether the permissible value for loading or deformation is not exceeded. For linear vibrational systems, formulae are derived based on modal analysis and expressed in the form of inequations, and for mathematical–physical reasons these limit values cannot be exceeded. The extreme values for free vibrations in linear systems must always be smaller than these limit values. In the case of torsionally vibrating bodies with infinite degrees of freedom, limit values for torsional moments and torsional speeds at a given location (e.g. the coupling) are estimated in this way and compared with simulation results. Examples demonstrate how close the limit values lie in relation to the software results. The formulae developed represent a means of independent control for the results of simulation methods. They are suitable for rough calculations, for the evaluation of parametric influences and for the interpretation of computed and measured results for impact and impulse loadings.

Thu	13:30	Karajan Hall	Powertrain Components (2A)

Torsional vibrations stresses of alternators used in diesel-electric powertrains of locomotives against the background of increasing cylinder peak pressures

P. Stürzl, M. Schuchardt
MTU Friedrichshafen GmbH

The product portfolio of MTU Friedrichshafen GmbH comprises fast running diesel engines in the power range up to 10,000 kW for ships, for the oil and gas industry, for power generation and for heavy land, defense and rail vehicles. Many of those applications are hallmarked by a high number of operating hours and the need of high availability. In the rail segment diesel-electric locomotives are often equipped with a series 4000 engine and a one bearing alternator. The alternator is connected to the engine by a torsional rigid membrane coupling, which leads to a relatively high stress level in the alternator. Torsional vibration calculations are carried out in order to forecast these stresses and to ensure a sufficient strength of the alternator rotor. The present contribution demonstrates the influence of high cylinder peak pressures of modern diesel engines, necessary in order to fulfill new emission standards and to reduce fuel consumption, on the alternator stresses. Furthermore the challenge of setting up the alternator's mass elastic system and its influence on the calculation result is discussed.

Thu	13:55	Karajan Hall	Powertrain Components (2A)

Modeling an electric vehicle powertrain and analysis of vibration characteristics

R. Schelenz, M. Wegerhoff, O. Drichel
IME, RWTH Aachen University

Dynamic loads in vehicle powertrains lead to reduced component life and comfort for the passengers who notice them in the lower frequency range in the form of surging. Compared to a conventional combustion-engined powertrain, an electric one has a different topology without clutch and dual flywheel because of the missing excitation caused by the varying inertia and the combustion process. Additionally it has a higher dynamic response which leads to significant oscillations. The aim of this study is to characterize the vibration behavior of this different powertrain configuration which can be used e.g. building a state regulator to compensate the undesired oscillations with the electric machine itself. On the foundation of vehicle measurements and measurements on parts of the drivetrain a simulation model with differential, tire-road contact and the elastic engine-subframe-mounting is developed and validated regarding the lowest Eigenfrequency, the corresponding mode shape and behavior in time domain. With a parametric study the effects of the various components are analyzed. The vibration response is sensitive to excitations on the rotor and therefore can be controlled ideally with the electric machine. It is further noted that wheel-side excited frequencies above the lowest frequency become relevant for the transmission behavior and can be damped by the electric machine.

Thu	14:20	Karajan Hall	Powertrain Components (2A)

Calculation of an elastic clutch with temperature-sensitive characteristics through system simulation in the time and frequency domains

U. Schreiber, Prof. C. Spensberger
ITI GmbH, Dresden University

Powertrains with combustion engines force CAD engineers to think out of the box. The calibration of engine, clutch and driveline can be challenging, especially when the materials' characteristics, such as elasticity and damping, are temperature-sensitive. In order to handle torsional vibrations, the clutch must be designed to withstand both short, transient loads and steady states. The clutch must thus be analyzed as part of the whole powertrain with an accurate description of all mechanical and thermal interactions. A high performance pump drive with a Diesel engine and a dry, pneumatic clutch with highly flexible annular spring elements illustrate the modeling and analysis approach of such systems. Special attention is paid to transient and steady-state temperature behavior in the clutch as well as interactions between temperature and properties of the clutch's components. The particularity of the clutch described is the annular spring elements operating in both the torsional flux and the shift force flux. The clutch model is embedded in the complete powertrain with Diesel engine and pump unit by the help of a commercial simulation tool. Different operations of the pump drive can be simulated and analyzed by running transient and steady-state simulations in one model. The paper concludes with a discussion of the results and an evaluation of all parameters.

Thu	13:30	Wolf-Dietrich Hall	System Reliability (2B)

Gear problems solved by the analysis of torsional vibrations

A. Laschet, B. van den Heuvel
ARLA Maschinentechnik GmbH, RWE Power AG

After a short operating time, serious gear problems occurred in the reducers of a downhill belt conveyor system. The damages were found on the tooth flanks of the gears. In order to find the cause of these damages, extended measurements in combination with torsional vibration studies were carried out. Supported by modern computer simulation technologies the torsional vibration analysis could visualize the vibration problem and was crucial to come to a solution for a driveline optimization to avoid vibration problems in the future. The computer results had a rather good quality compared with measurements. Using advanced simulation models, the authors successfully used the problem solving strategy in combination with measurements and computations. By learning from experiences, the results can now be used to develop new driveline configurations to realize a dynamically optimized system behaviour.

Thu	13:55	Wolf-Dietrich Hall	System Reliability (2B)

A full scale investigation of torsional vibration failure of a marine propulsion system intermediate shaft.

P. Filcek, K. Banisoleiman, J. Stainsby, S. Mathieson
Lloyd’s Register, EMEA

Classification Societies have established Rules for permissible levels of torsional vibrations, as loss of propulsion due to this type of failure is a significant risk to the safety of life and property at sae. The paper presents an account of a full scale investigation into the failure of an intermediate marine propulsion shaft, due torsional vibration, on board a bulk carrier. Measured results are presented and are supported by analytical simulation results of the propulsion shafting system, together with details of metallurgical examinations of the fractured surfaces and a fracture mechanics approach. The paper concludes by identifying the root cause of the failure and the circumstances leading to the failure of the shaft.

Thu 14:20 Wolf-Dietrich Hall System Reliability (2B)

Torsional vibration analysis of an emergency diesel generator (EDG-Set)

B. Buchmeier
TÜV SÜD Industrie Service GmbH

The original fabric reinforced rubber coupling, which lies between the emergency diesel and the generator, was exchanged for a coupling of a similar type during a major overhaul of an EDG-set. After about one year, a mechanical damage on the new coupling has been noticed. A detailed examination of the coupling did not show any plastic deformation. However, a strong decomposition of the elastic part of the coupling has been noticed which points to a high thermal load of the coupling and to an excess of the decomposition temperature of the rubber. EDG-sets are normally on standby and during regular reviews the units have to provide full power for only a short time. Thus, the real operating lifetime of the coupling is about 100 hours. Hence, a breakdown of the coupling due to a continuous overload as a result of small dimensions can be excluded. The causes of failure can be put down to a high vibration load. The reasons for the high vibration load could be controller and drive speed oscillations as well as high torsional vibration. In order to analyze more precisely the causes of the coupling's breakdown and to avoid a future damage, TÜV SÜD did own calculations. With the help of multi-body simulations, calculations of torsional vibration were performed dependent on the load torque and with regard to the behavior of the revolutions and controllers. Besides the modelling, the examinations include the calculation of natural harmonics and vibration modes, the emergency diesel generator's stationary behavior during normal and misfire operations as well as a short circuit. The evaluation of the results showed a significant influence of the non-linear behavior of the coupling stiffness on the failure of the elastic part of the coupling. The findings of this examination contribute considerably to a higher plant safety regarding the availability of emergency diesel generators and the involving power supply in case of possible incidents.

Thu 15:20 Karajan Hall Simulation (3A)

Efficiency boost in product development processes through support by torsional vibration simulation in early development phases

B. Juretzki, R. Schelenz, Prof. G. Jacobs
IME, RWTH Aachen University

In the development of drive trains the knowledge about dynamic loads is essential for a safe and cost optimized product design. Therefore transient load situations like short circuit events in electrical motors or generators have to be considered because of their high impact on local component stresses. To avoid costs for changes it is essential to get a valid prediction for these loads as soon as possible. Torsional vibration simulation is a suitable tool to provide these load assumptions, because the critical excitations often appear mostly in the rotational degree of freedom. The efficient modeling approach of torsional vibration simulation can be used to support the development process especially in early phases. This presentation will show approaches to integrate rotational vibration simulation in very early phases of the development process on the example of a railroad drive train using the software DRESP developed by RWTH Aachen's Institute for Machine Elements and Machine Design. It will be shown how load assumptions and a dynamical system characterization can be provided with sparse information like from specification sheets. The results of these investigations are optimized target values for component's stiffness and mass values which concretize the specification for following design phases.

Thu	15:45	Karajan Hall	Simulation (3A)

Influence of simulation model detail on determinable natural frequencies

Prof. B. Schlecht, T. Rosenlöcher
Institute of Machine Elements & Machine Design, TU Dresden

The determination of the torsional natural frequencies of drive trains is mandatory to know the possibility of an occurrence of resonances due to an excitation of mode shapes. The excitation can be caused by the unbalance or misalignment of shafts, by gear meshing frequencies, by the characteristic of loads or further excitation mechanisms. The measurement of the torsional natural frequencies at the first prototype can be in some cases too late, because of the missing possibility to realise major constructional changes. To avoid resonances during operation the usage of simulation models in an early stage of the product development process is required. The assembly of a simulation model presupposes the definition of system boundary, the level of detail and the degrees of freedom. Depending on these decisions results the number of required parameters, the effort to model the system and the calculation time. However, especially the knowledge of the expectations towards the results and the accuracy of the model are of great importance for the decisions during the modelling process. The article and the presentation are showing the influence of the level of detail on the results as well as possibilities using modelling approaches that fit to the asked question for different industry applications (ships, cranes, bucket wheel excavators, roller mills, wind turbines).

Thu	16:10	Karajan Hall	Simulation (3A)

Analysis of dynamic interaction between crankshaft and connecting rod through the use of complex nonlinear calculations

H. Roeser, C. Windelev
Transmarine Propulsion Systems Inc.

This paper demonstrates how advanced analytic methods have been applied to determine the dynamic interaction between the crankshaft and connection rod that led to numerous connecting rod failures and consequent engine damages. The linear systems analysis is no longer adequate for the new modern high Bmep output engines. The reason for this is that the cyclic variation of the polar moment of inertia of the rotating parts during each revolution causes a periodic variation of frequency and corresponding amplitude of vibration of the reciprocating system. It also causes an increase in the speed range where the resonance effects occur. Consequently, large variations in inertia torques can give rise to the phenomenon of secondary resonance in the dynamic response of modern diesel engines, which cannot be explained by conventional methods. The advanced analytic methods outlined in this paper take into account the behavior of the nonlinear systems, i.e. buckling, plasticity, component contact, large deformations and changing geometry. In most cases of nonlinear systems, advanced numerical methods, such as finite element analysis are required to calculate the response of the system. The paper advocates that these advanced techniques may be applied for analyzing the complex nonlinear behavior of modern high powered systems.

Thu	15:20	Wolf-Dietrich Hall	Noise and Vibration (3B)

Noise and vibration challenges due to torsional excited gearbox vibrations

P. Tellefsen, K. Cunningham
Lloyd's Register Consulting

Sometimes torsional vibrations are referred to as being silent. This is however not the case when geared transmissions are involved as torsional vibrations will be transmitted to lateral vibrations in the gear contacts. For diesel driven propulsion systems involving geared transmissions an efficient control of torsional vibrations is thus crucial in noise and vibration sensitive applications like cruise ships, luxury yachts, seismic research vessels and some military vessels. During the last decade torsional excited gearbox vibrations has become one of the most common reasons for comfort complaints. Ensuring a good isolation towards torsional vibrations is thus important - but also a challenge as a number of pitfalls exists. Designing transmission trains considering comfort performance involves deep insight into how couplings behave in the acoustic frequency range at low vibration amplitudes. The dynamic stiffness of rubber couplings is for instance often significantly underestimated. Results from a number of cases will be outlined here, illustrating some of the possible pitfalls and countermeasures to avoid these. Furthermore, a 6-DOF modelling approach will be presented, showing a consistent way to evaluate geared designs towards comfort.

Thu	15:45	Wolf-Dietrich Hall	Noise and Vibration (3B)

Reduced transfer of structure borne sound in couplings

L. Kurtze, T. Philipp
Geislinger GmbH

In many cases, torsional vibrations are a reason for the generation of noise emissions. The primary path of these sound transmissions usually goes from a source like the engine trough the engine mount into the surrounding structure. Meanwhile, the engine mounts are improved to block most of these emissions. Thus, e.g. in luxury yachts and cruise ships, the secondary path from the engine via the coupling into the gearbox and finally into the surrounding structure becomes a critical issue. As the power train between the gearbox and the propeller has to be stiff, the classical methods for the reduction of structure borne sound are of limited use for these parts. But the elastic coupling is a driveline component, where modifications can be realised in order to reduce the overall sound emission. This paper presents two countermeasures which can be applied either separate or simultaneously. One countermeasure focuses on the reduction of the gearbox input vibratory torque in order to keep the excitation level as low as possible. The other countermeasure directly targets the reduction of structure borne sound which is transmitted via the coupling. To reduce the sound transfer directly in the couplings, a test rig has been constructed, which allows the measurement of the transmission loss under realistic load conditions. The coupling can be pre-stressed and torsional vibrations as well as structure borne sound are generated using two electrodynamic shakers. The measured transmission loss is the base for the acoustic optimization of the couplings.

Thu | 16:10 | Wolf-Dietrich Hall | Noise and Vibration (3B)

Vibration dynamics simulation of a diesel engine coupled system with flexible coupling under misfiring using physical and finite element modeling

M. Hasan, J. Holmberg, H. Kirschey
Centa Antriebe Kirschey GmbH, Wärtsilä Ship Power

The rotating devices are the main sources of noise and vibration in a driveline. A coupling is used between the engine and the driven side of a driveline in order to attenuate the critical vibrations and to compensate misalignment under operating conditions. Hence it is necessary to simulate the driveline in order to identify the critical speeds, loads and the magnitude of the vibratory torque where the shaft system experiences torsional oscillation. Under firing of a single cylinder in a combustion diesel engine, the crankshaft receives a torque pulse. The torque pulse can be modeled as an energy function which contains first twenty four harmonics of engine cycle speed. The input excitation torque for a particular cylinder alters if it runs under misfiring condition. It has a profound impact on dynamic torsional response of the system. Excessive torsional vibration can lead to failures of crankshafts, gears and couplings. Particular attention was paid to simulate the faulty operation condition such as misfiring. In this work, we executed simulation on a simple driveline which represents real world applications of a ship propulsion system. We use MapleSim to conduct the physical modeling and optimization. A user-defined excitation model was implemented for the input cylinder torque. We analyze both time and frequency domain in our example driveline. Moreover, parametric studies are done to optimize the operating condition. We also present an additional example of a driveline with rotational backlash of a gearbox to capture magnitude of the vibratory torque. Furthermore, we develop a continuum model using ABAQUS to capture the deformation behavior of an elastic coupling. The simulation engineers need both types of modeling to ensure the system's reliability. Finally, we compare the simulation results with measured experimental data. The validation shows a good match. We also present a mathematical model to generate transfer function from elastic element in order to characterize the acoustic behavior.

Thu	17:00	Karajan Hall	Industrial Applications (4A)

Lateral-torsional vibration coupling in reciprocating compressors

F. Newman, T. Stephens, R. Harris
Ariel Corporation

Reciprocating compressor vibrations are known to be caused by many excitation forces including unbalanced forces and couples, gas pulsations, gas rod load, and vertical crosshead forces. Recent review of slider-crank kinematics shows that high frequency lateral vibration can also be generated by crankshaft speed oscillations caused by torsional vibration. The forces generated by the oscillating crankshaft are transmitted to the compressor frame through the main bearings, crosshead shoes, and gas forces. These forces can be large enough to create unacceptable compressor vibration in the absence of mechanical resonance, and when small can interact with system mechanical resonances to generate unacceptable vibration levels. Large amplitude forces, which can be greater than 50 percent of the primary inertia force, are generated at frequencies different than the crankshaft oscillation frequency when torsional response levels are at or near traditional guideline limits. It is shown in this paper how the forces that act in the connecting rod bearings are caused by the crankshaft torsional vibration for the case of a rigid drive train. The amplitude and frequency of the forces generated by the torsional vibration are compared to the inertia forces for constant crankshaft velocity. Recent case studies are reviewed to demonstrate the reduction of compressor frame vibration, cylinder vibration, and attached acoustic manifold and piping vibration by reducing the torsional vibration. Traits and measurement techniques on how to identify torsional lateral vibration coupling in operating compressors are discussed. Finally, recommendations for torsional testing and analysis to avoid lateral frame and cylinder vibration caused by crankshaft torsional oscillations are given.

Thu	17:25	Karajan Hall	Industrial Applications (4A)

Linear and torsional vibration study for an engine driven compressor system

W. Wang, J. Braun, R. Chundi, R. Khan
IDC Technical Services

The coupled linear and torsional vibration behavior of an engine driven compressor system is analyzed in both the time and frequency domain. This article discusses the linear dynamic response of a compressor frame caused by crankshaft rotating speed differences due to torsional resonance. The authors extend a previous paper’s finding to a more comprehensive study including more parameters such as torsional resonance, phasing angle, self-balance, multiple orders, and multiple stages. A combined finite element analysis (FEA) and torsional vibration analysis (TVA) case study is completed based on an engine-driven compressor system.

Thu 17:50 Karajan Hall Industrial Applications (4A)

Experience with torsional vibration measurements and calculations of reciprocating compressors

J. Lenz
KÖTTER Consulting Engineers

Reciprocating compressors are unavoidable classical solutions in the field of natural and process gas compression with the ability to function over a wide range of operating conditions. The dynamic design of the reciprocating compressor is complicated due to the large number of conditions that have to be satisfied. Since, high torsional dynamic stress is often not recognised until damages appear, it is advisable to conduct a detailed torsional vibration analysis when planning a new drive train or modifying an existing one. In this paper, the different measures to influence the torsional behaviour of reciprocating compressors is presented with the help of different case studies.

Thu 17:00 Wolf-Dietrich Hall Fundamental Engineering (4B)

Introduction of the new torsional vibration guideline VDI 2039 under special consideration of damping

F. Knopf, T. Philipp
Hasse & Wrede GmbH, Geislinger GmbH

VDI guidelines are designed as practical guidelines for engineers. Due to the fact that in the field of torsional vibrations a common standardization was non-existent, the VDI 2039 introduces a long list of definitions and formulas, aiming at solving communication problems between engineers, who before often had to agree on their own wording before being able to discuss a torsional vibration problem. But the VDI 2039 is more. It is written and designed as a knowledge database to be used by torsional vibration experts. It includes an overview of calculation and simulation methods, torsional vibration measurement principles, assessment, reduction and creation of torsional vibrations and typical characteristics or anomalies of torsional vibrations. Damping is an important feature of the world as it prevents things from collapsing or breaking when being excited in resonance. It is also essential in the field of torsional vibrations as the amplitudes of vibrations directly depend on the damping properties of the system. The VDI 2039 introduces a unified wording and defines reliable and physically meaningful parameters to describe the quantity of damping in torsional vibrations. In the presentation we discuss: for what type of calculations damping can be neglected; when and how nonlinear properties of damping have to be considered; how to handle frequency dependent damping; which parameters are recommended by VDI 2039 to model and quantify damping and what kind of parameters and modeling should be avoided.

Thu	17:25	Wolf-Dietrich Hall	Fundamental Engineering (4B)

Fuel efficient propeller design and torsional vibrations in propulsion machinery

G. Dahler, J. J. Iseskär, J. Holm
DNV / GL

Torsional vibration analysis of propulsion machinery is essential for design evaluation of individual components as well as system functionality- and overall fitness for purpose assessments, assuring safe and reliable operations. Modern propulsion influenced by changed economic criteria, motivating for fuel saving, has become a mega trend. One consequence is changed propeller designs; slower speeds, larger propeller diameters and less power per diameter from de-rated engines. The propeller is further the single most important component for providing damping to the system, a parameter which is basically described by experience based- and empiric models. Proper calibration of such damping is important in-line with new propeller development. A recently build standard oil-tanker with slow-speed direct propulsion, but designed according to past practice and conventions, suffered from torsional vibrations beyond the permissible limits in the intermediate shaft. Sea-trial measurements detected harmful torsional responses, whereas calculations for class approval did not. The traditional calculation methodology overestimated the propeller damping resulting in too low torsional responses in the shaft. This paper highlights some of these mega trends in modern propeller designs, in combination with in-situ measurements and comparable theoretical analyses. Results from torsional vibration calculations based on newly developed alternative propeller damping methodologies are also presented.

Thu	17:50	Wolf-Dietrich Hall	Fundamental Engineering (4B)

Self-excited torsional vibration phenomenon on specialized vessel electric propulsion systems

Prof. D. C. Lee, R. D. Barro
Mokpo Maritime University, South Korea

Specialized vessel application includes efficient maneuverability under extreme conditions. As such, operation at speed requiring lower rpm for effective control is essential. In addition, vibration resonance and radiated noise from the propulsion shafting system must be kept to a minimum as much as possible. In this paper, a self-excited torsional vibration phenomenon occurring at the lower speed range of a specialized vessel is presented. The electric propulsion shafting system is composed of motor – flexible coupling – propeller – and supported by a thrust bearing configuration. During operation at speed lower than 30 rpm, a bouncing phenomenon was detected on the flexible coupling. This phenomenon resonated adding to increased vibratory torque amplitude at a particular frequency and resulting to the deformation on the circular rubber segment of the flexible coupling. The phenomenon is perceived to be caused during the damping process by the rubber elements tension and compression action. Further, the bouncing phenomenon produced thrust variation force on the thrust bearing and generated underwater radiated noise. On the other hand, at speed operation above 30 rpm, the bouncing phenomenon diminishes. Hence, this paper investigated this bouncing phenomenon causing irregularity on the propulsion shafting vibratory torque magnitude. Probable countermeasures regarding flexible coupling performance and operation critical speed avoidance are recommended.

Friday sessions

Fri	8:50	Karajan Hall	Ice Impact (5A)

Ice impact simulation for propulsion machinery

S. Persson
MAN Diesel & Turbo, Copenhagen

During the last years there has been an increasing demand for ships built for operation in areas with ice. Ships navigating in ice covered areas are required special attention to the propulsion system in accordance to the classification society regulations for ice class notation. The ice class regulations according to the IACS Polar class rules and the Finnish-Swedish class rules for the Northern Baltic require a transient simulation in the time domain of the propulsion system to get the torque responses when ice load is applied to the propeller. To meet the increasing demand on simulations for propulsion machinery operating in ice, MAN Diesel & Turbo has developed a transient calculation method integrated in our in-house torsional simulation software (named GTORSI). The new version of GTORSI is using the standard GTORSI input format. And with a few additional lines describing the ice load, the ice impact simulation can be executed. The mass-elastic system is solved in the time-domain with a Newmark integration method. Simulation results show good correlation between the time and the frequency based calculation method. In this paper the methods for the different parts of the simulation is described, such as the method for handling the speed and order dependent damping in the transient simulation.

Fri	9:15	Karajan Hall	Ice Impact (5A)

Meeting ice impact analysis requirements through a unified Modeling for transient and frequency domain simulation

A. Abel, U.Schreiber
ITI Gmbh

The recent introduction of transient analysis requirements in classification rules for ice class vessel propulsion systems created new demands for modelling, simulation and reporting for approval documents to be submitted to classification societies. Tools typically applied in classical steady-state torsional vibration analysis (TVA) are normally exclusively operating in frequency domain, so that the new transient simulation requirements potentially imply the acquisition of additional software tools, as well as a significant increase in modelling efforts. In this paper we present a solution, which minimizes the involved efforts by providing a user-friendly modelling and analysis environment, where all models can undergo transient as well as steady-state analysis, so that the propulsion models only have to created once for meeting all involved tasks such as natural frequency computation, steady-state analysis over speed, and transient load and response analysis under the impact of ice. Especially for propeller loads in ice conditions a variety of scenarios and ice classes is defined in the class rules. Within the presented solution these all have been combined into one model object, which can flexibly be adjusted to the various configurations defined by the rules. Functionalities and requirements for the modelling have been specified in close cooperation with DNV GL. After completion of implementation the compliance with the class rules has been checked and has been confirmed through a type approval certificate from DNV GL. In the paper we will review the benefits of a combined modelling for time and frequency domain and will introduce the propeller modelling for ice impact analysis in detail.

Fri	9:40	Karajan Hall	Ice Impact (5A)

Simulation of torsional vibration responses in ship propulsion shafting system caused by ice impacts

Yu. Batrak, A. Serdiuchenko, A.Tarasenko
Intellectual Maritime Technologies, Ukraine

Polar ships and the ships for navigating in ice suffer from the transient torsional vibration induced by ice impacts on the propeller very much. Calculation of transient torsional vibration induced by ice impacts for such ships became mandatory in January 2011. Conventional propulsion shafting steady torsional vibration calculations have no computational problems because the frequency-domain approach can be easily used. Time-domain transient vibration calculation approach, that should be used to calculate torsional vibration responses caused by ice impacts, has some issues discussed in this paper. The first is choosing of the method for integration of differential equations of shaft motion to have a reasonable computation time. Application of known standard methods requires of simplification of conventional mass-elastic systems to several mass. In this paper an effective method for the time-domain calculation that not requires of such simplification is discussed. The second issue is the question of detailed simulation of the propulsion plant installation dynamics to calculate torsional vibration responses. The third issue is the torsional waves in the propulsion shafting in a consequence of the ice impacts. And the last issue is how the alternating inertia moments of engine cylinders influence the torsional vibration responses caused by ice impacts.

Fri	8:50	Wolf-Dietrich Hall	Active Control (5B)

Active measures to reduce torsional vibrations

M. Matthias
Fraunhofer LBF, Darmstadt

In the last years a lot of investigations were done to develop active measures to reduce the transmission of structure-borne noise and vibrations. All these measures based on the physical principles of vibration compensation, vibration damping or vibration isolation. For some of these concepts new actuators based on multifunctional materials were design. Applications for these measures were engine mounts, dampers or coupling elements. A new field of application for active systems to reduce vibrations are powertrains as they are used in cars, ships or production machines. Therefor the different basic concepts of active engine mounts were transmitted into concepts for active couplings used in rotational systems. To show the potential of these active measures and investigate their mode of operation to influence torsional vibrations, numerical simulations of powertrains with different active measures were done. First experimental results from tests on an experimental (reduced size) powertrain were used to align the numerical models. These first investigations have shown the potential for active measures to reduce torsional vibrations. Based on these promising results a BMWi founded Project was started in 2011 to develop an active coupling for a powertrain of a ship. The paper gives an overview of the project and shows the first numerical and experimental results.

Fri	9:15	Wolf-Dietrich Hall	Active Control (5B)

Active control of crankshaft vibrations

M. Steidl, F. Knopf
Hasse & Wrede GmbH

The torsional vibrations of crankshafts, originating from the combustion process and the mass forces of the pistons, lead to high stresses and failure of the shaft. Usually, passive torsional vibration dampers are applied to reduce stresses below the fatigue limit. We present an active control concept consisting of an algorithm which generates the required input signal for an actively controlled actuator. The torsional motion of the crankshaft is governed by the one-dimensional Wave Equation. The presented algorithm decomposes this motion into two waves traveling in opposite direction, exploiting the fact that the torsional waves are non-dispersive. The actuator is controlled to completely absorb the wave traveling in its direction, thus preventing reflection of the wave and extracting the maximum amount of vibration energy from the system. The control concept thus virtually removes the boundary at the front end of the crankshaft and the shaft behaves like a semi-infinite continuum with all eigenfrequencies zero. We also show that the actuator requirements are very high due to the required high bandwidth and high alternating peak torque. This alternating torque has to be generated while the engine rotates at a high constant velocity, which requires either a very high rated power of the actuator or the use of a seismic inertia.

Fri	9:40	Wolf-Dietrich Hall	Active Control (5B)

Control and correlation of mainshaft torsional modes on windturbines and off-axis loaded dynamometers

W. L. Erdman
DNV KEMA

Windturbine drivetrains are typically confronted with a lightly damped torsional mainshaft mode that requires active damping for acceptable nominal performance. Additionally this mode is important for transmission planning purposes as it can be excited synchronously on multiple turbines during certain electrical system faults. This mode is also known to shift for a given drivetrain when it is brought from the turbine into a simple, torsion only dynamometer for testing purposes. This paper develops a linear, torsional dynamic model for a drivetrain operating in three environments; first within the windturbine itself, then on a simple, torsion only dynamometer, and finally, on a modern off-axis, or Non-Torque-Loaded (NTL) dynamometer. Similarities and differences in this mainshaft torsional mode in these three environments are discussed. Torsional active damping methods in the three cases are also provided. It is shown that the serially addition of an NTL fixture in the dynamometer expands the dynamic model to higher order above the windturbine and simple dynamometer cases resulting in more complex modes. Active damping and control of the NTL dynamometer is targeted at causing the system to behave torsionally as a windturbine, or simple dynamometer.

Fri	10:20	Karajan Hall	Engine Development (6A)

Firing sequence optimization for a V20 cylinder diesel engine

C. Henninger
Liebherr Machines Bulle

In reciprocating internal combustion engines, the crankshaft is subject to considerable torsional vibrations, which are a limiting factor for crankshaft fatigue and gear wear. The excitation is caused by the variation of the cylinder pressures during the engine cycles, as well as the acceleration of the pistons and the connecting rods. A key parameter for the excitation characteristics is the firing sequence. For engines with a small number of cylinders, there exist only few possibilities, which are well known from literature. However, the number of possible firing sequences grows proportionally to the factorial of the number of cylinders, which makes an efficient assessment of firing sequences a challenging task. In this contribution, a strategy for a comprehensive assessment of firing sequences is presented. Torsional dynamics criteria like torsional stress, angular vibration amplitudes, and torsional vibration damper power loss are considered, as well as non-torsional criteria for mass balancing, main bearing load, or gas cycle dynamics. The strategy is applied to a V20 cylinder engine which is currently being investigated within an advanced development study at Liebherr. Two different types of industrial application with distinct torsional characteristics are considered. An outlook for a future improvement of the strategy is given.

Fri	10:45	Karajan Hall	Engine Development (6A)

Firing order optimization in FEV virtual engine

K. Buczek, S. Lauer
FEV Krakow, FEV GmbH

The continuously increasing mechanical load of newly developed engines results in the need to optimize the engine design over a wide range of different aspects. In the time of application of high peak firing pressures, the layout of the firing order in multi-cylinder engines is an efficient way to reduce cranktrain/overall engine vibration and main bearing loads, whilst maintaining the same external balancing and preserving adequate gas flow dynamics through the engine induction and exhaust systems. The methodology of firing order investigation developed at FEV is the main topic of this paper. It is based on an algorithm that generates series of firing orders for predefined crankshaft crank throws configuration for which then torsional vibration simulations in FEV Virtual Engine are performed. The algorithm that generates the firing orders is such that it selects form all possible firing orders only those that are consistent with the boundary conditions of specific engine design. Depending on the optimization target, the corresponding output data per firing order is analyzed and rated. As an example of the application of above-mentioned algorithm, the results of an analyses of a V16 engine is presented in this paper.

Fri	11:10	Karajan Hall	Engine Development (6A)

Cranktrain design using coupled calculations and multicriteria optimization

P. Böhm
MAN Diesel & Turbo, Augsburg

For MAN Diesel & Turbo using virtual powertrain models is of crucial importance for the powertrain design process. In general, a cascading multi-step approach is used to take global aspects as well as local aspects into account. This contribution focuses on one of these building blocks, a multicriteria optimization process which acts as a basic module to balance multiple and partially contrary aspects like fatigue strength and mechanical efficiency at an early design phase. This module uses a genetic algorithm of recombination and mutation to derive optimized designs and to work out sensitivities. Four main coupled calculation blocks consider general design and design-space aspects, crankshaft fatigue strength aspects, bearing design aspects and aspects of the torsional vibration behaviour including damper layout. The latter will be given special attention.

Fri	11:35	Karajan Hall	Engine Development (6A)

Crank train torsional vibration optimization

C. Priestner, T. Ovari, M. Brunner, F. Zieher
AVL List GmbH

Three major trends dominate the development of large engines today. The power density of the engines is increasing to lower the costs per kW and on the other hand the fuel consumption requirements as well as the exhaust emission regulation are more demanding. In order to scope with this challenge a BMEP of 25-28 bar in combination with a peak firing pressure of 260-300 bar are usual development targets. Consequently, the increased mechanical load of the crank train requires for an optimization of the entire crank train, ideally in the early development phase. The presented automated torsional vibration optimization of the crank train does result in optimized configurations and dimensions for bearings, crankshaft strength and torsional vibration damper. In addition it reduces the time and cost for the simulation of the torsional system in the concept phase of engine development and provides more robust results earlier in the development phase. In the early development phase only a small number of input parameters are fixed and it is mandatory to provide the possible parameter combinations by simulation to achieve an optimized design in terms of torsional vibrations and manufacturability. Avoiding a "one factor at the time variation" the automated optimization delivers the best result for the torsional vibration system within certain damper and flywheel limitations as packaging and power specifications. A range of possible engineering solutions and a recommended best trade-off for the specific development process is provided for the front end, the rear end and crankshaft dimensions. The optimized torsional vibration crank train is the base for further fatigue, EHD bearing and NVH simulations. The target is to achieve a virtual design release to fulfil all engine targets in terms of durability and NVH for the first prototype engine.

Fri	10:20	Wolf-Dietrich Hall	Measurement and Testing (6B)

Correlation of simulation to test for a flexibly coupled two-bearing generator system

R. Zadoks, J. J. Iseskär, T. Utengen
Caterpillar Inc., DNV GL

Caterpillar and DNV have worked together to understand the torsional vibration response of Caterpillar diesel engines powering a flexibly coupled two-bearing generator system in a marine application. Activities summarized in this paper include the measurement of system torsional response and the correlation with torsional vibration simulation results. Measured data included cylinder pressure at multiple locations on the engine, torsional velocity at the engine flywheel, and dynamic torque in the section of the generator shaft between the hub and first bearing. The cylinder pressure data was used as loading input to the torsional vibration model, and the model parameters were analyzed against the measured values for flywheel velocity and generator shaft torque. Comparisons were made for four different steady state operating conditions and include magnitudes of critical orders and synthesized crank angle traces.

Fri	10:45	Wolf-Dietrich Hall	Measurement and Testing (6B)

Various torsional vibration measurement techniques for optimal trade-off between high accuracy and ease of instrumentation

A. Palermo, L. Britte, K. Janssens, D. Mundo, W. Desmet
Universita' della Calabria, KU Leuven, LMS International, A Siemens Business

Better energy efficiency, along with lower pollutant emissions, higher reliability and reduced levels for noise and vibration have become key elements for the success of products which involve rotating machinery. In the field of transportation (e.g. vehicles, aviation) lighter structures result in smaller rotational inertias, which are more prone to vibration and are more subject to the excitation of torsional dynamics. In the field of industrial machinery, reliability and efficiency gains can be obtained by monitoring the machine vibration signature. Accurate torsional vibration measurements represent, therefore, a key aspect for designing more competitive rotating machinery. The paper provides examples of measurements to compare the main techniques (coder-based, laser, accelerometric) and discusses the impact of different sources of error on the accuracy of the measured torsional vibrations or transmission errors. Errors entering the measurement chain at different stages are analysed. The effects of time accuracy and spatial accuracy on the overall measurement error are highlighted. Time accuracy is related to timing and sampling frequency; spatial accuracy is related to the instrument accuracy. Limiting factors on the overall measurement accuracy are identified and best practices for reaching high-quality measurements are proposed. Ongoing R&D actions to simplify torsional vibration measurements and a novel high precision test rig are presented.

Fri	11:10	Wolf-Dietrich Hall	Measurement and Testing (6B)

Contactless method to determine the rotation angle in torsional vibration based on video image correlation (VIC-3D) measuring system

Prof. I. Száva, S. Vlase, B.P. Gálfi, I. Serban, P. Dani
University of Brasov, Geislinger GmbH

The authors would like to present a theoretical approach about a contactless measurement method carried out with a measurement hardware system called "Video Image Correlation" (VIC-3D) produced by Isi-Sys GmbH, Germany and the dedicated software application provided by Correlated Solutions, USA. The Fulcrum module, as a part of the VicSnap subprogram, allows both a periodic motions synchronization and a quantitative evaluation of the produced phenomenon as well. Consequently, this module contains a high-flexibility stroboscope function with a quick capacity of reaction, being able to monitoring vibrations in the high-frequency range (up to several kHz). Supplementary, it is able to offer a quantitative evaluation of the linear and angular vibrations. The authors illustrate the above-mentioned system's facilities (a quantitative evaluation) by means of the angular vibrations/oscillations monitoring of a plastic disc (a CD one), viewed from frontal direction. The disc is mounted on the shaft of a small stepper motor, which is steered/controlled by means of an original electronic system. This electronic system allows, by means of an asymmetric cyclic feeding, producing torsional vibrations of the shaft in a wide range of frequencies. Similarly with the crankshaft (where the rotation isn't perfectly uniformly, requiring a flywheel), here one can be monitored also torsional vibrations of the shaft, together with the fixed small plastic disc. The above mentioned software enables a quantitative evaluation of these angular vibrations (their amplitude, respectively their precise frequency). As a distinctive feature it has to be mentioned that VIC-3D/Fulcrum module is able to monitoring displacement fields in a wide range (starting from microns to several cm), respectively that the used lighting device (laser-diodes) presents a very quick capacity of reaction. Consequently, the authors consider that this measurement system can be considered as a powerful instrument in high-accuracy-, high-efficiency-, respectively high-frequency phenomenon monitoring in the field of automotive industry (both vehicles and engines).

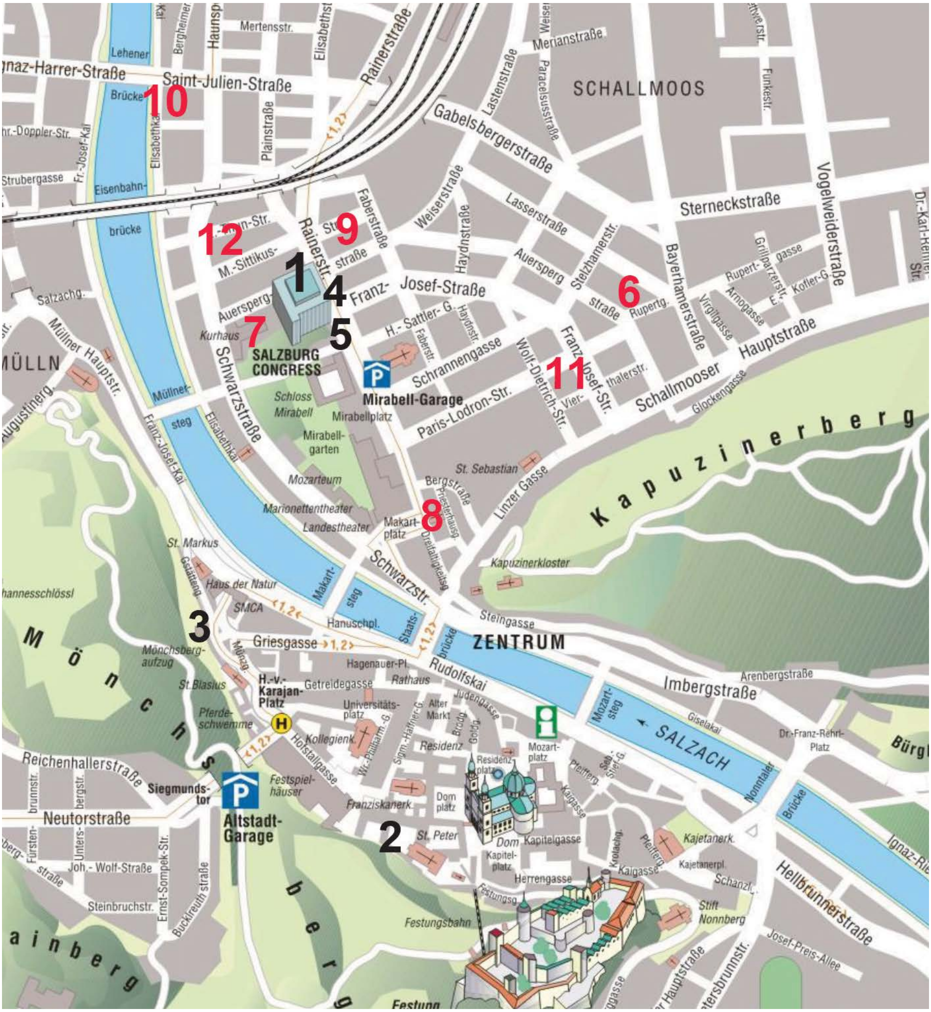
Fri 11:35 Wolf-Dietrich Hall Measurement and Testing (6B)

The comparison between measured and calculated torsional vibration loads in 2-stroke marine installations

M. Barraud, P. Bättig, R. Gläser
Wärtsilä

Torsional vibrations often have to be measured on ship propulsion systems during sea trials to confirm the calculated torsional vibration loads and to make sure the recorded torsional vibrations comply with the corresponding limits as given by the Classification Societies and other organizations or manufacturers. The recorded torsional vibrations not always match exactly with the original calculation. In addition, there are components where it is difficult or even impossible to measure the torsional vibrations directly. The torsional loads in these locations have to be evaluated based on values measured a different location. By adapting the calculation parameters until the calculated torsional vibrations at the measurement position match with the recorded values, it is possible to evaluate the corresponding torsional loads in further system components. With the torsional vibration calculation model tuned and confirmed for the conditions during measurements it is also possible to give reliable predictions how the torsional loads will be under different operating conditions. In this contribution we discuss the steps needed and which parameters are relevant to get a good fit between calculation and measurement and how to predict the torsional loads in any arbitrary location in the propulsion system.

Map - City of Salzburg



1 **Salzburg Congress**
2 Welcome Reception,
Restaurant "St.Peter Stiftskeller"
3 Gala Dinner,
Restaurant "M32" (Elevator on the Mönchsberg)
4 Departure, "Sound of Music" - Tour
5 Departure, "Wolfgangsee/Boatride/Schafberg" - Tour

6 Hotel Auersperg
7 Hotel Sheraton
8 Star Inn Hotel Gablerbräu
9 Hotel Crowne Plaza
10 Motel One Salzburg Mirabell
11 NH Hotel Salzburg
12 Hotel Villa Carlton

Symposium location

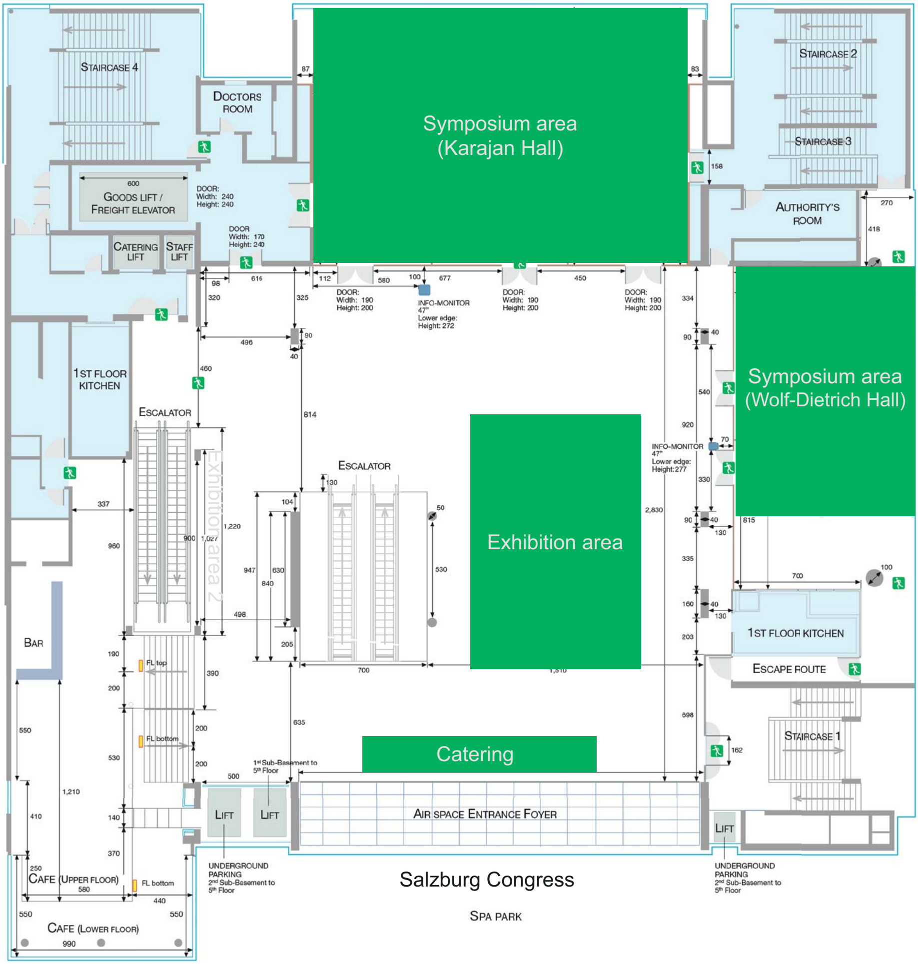
The Salzburg Congress is within walking distance to the historical city centre and most hotels and located right next to the famous Mirabellgarten. The main entrance of the Salzburg Congress can be found right next to the Mirabellgarten and can be easily reached by bus. The Sympsoium location is on the 1st floor of the Salzburg Congress at the Karajan Hall and the Wolf-Dietrich Hall.

Salzburg Congress
Auerspergstraße 6
5020 Salzburg / AUSTRIA

Website: www.salzburgcongress.at

Symposium location: Salzburg Congress

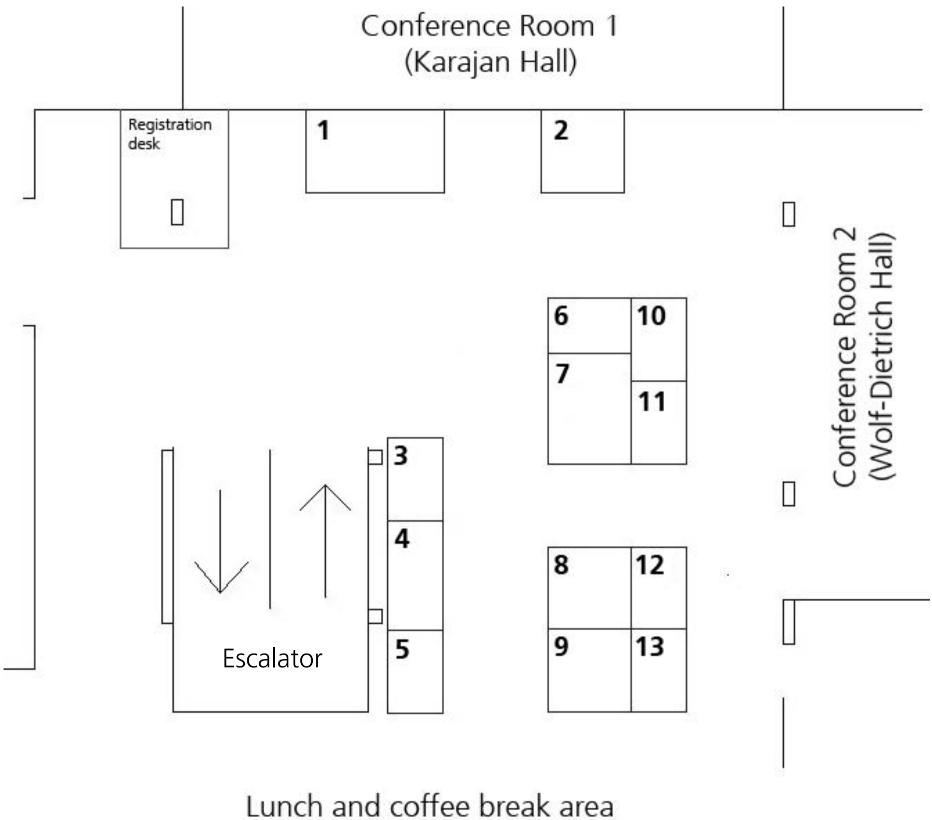
Salzburg Congress floor plan



Entrance

Exhibitors

1. Geislinger GmbH
2. ITI GmbH
3. KÖTTER Consulting Engineers GmbH & Co. KG
4. Optel Thevon
5. Gantner Instruments GmbH
6. LMS, A Siemens Business
7. AVL List GmbH
8. MTZ Industrial
10. SIMPACK AG
11. SKF Marine Industry Service Centre
12. FEV GmbH



Welcome Reception

Welcome Reception*, Restaurant "St.Peter Stiftskeller"
Wednesday, May 21st, 2014, from 18:00 onwares

Address: St. Peters Stiftskeller, Sankt-Peter-Bezirk 1/4, 5020 Salzburg, AUSTRIA

"St. Peter Stiftskeller – The Restaurant" is located in the centre of Salzburg's old town, where the traces of high culture are omnipresent. It is regarded as the oldest restaurant in Europe and offers hospitality for more than 1200 years. This is the place where illustrious guests have been welcomed for hundreds of years – from Mozart and Haydn to Dr. Faustus. Nowadays the location effortlessly connects the old and the new on highest gastronomic levels. The guests can truly sense the history, however the doors are also open to the modern world.
The exquisite cuisine offers dishes of local traditions as well as an international culinary repertoire. The sumptuously decorated Salons provide an extraordinary setting, a feast for the senses and pure enjoyment. That offers an experience of time-honoured and genuine hospitality.

** The symposium fee includes the "Welcome Reception". The Tickets for the "Welcome Reception" will be available, for Symposium participants, at the entrance of St. Peter Stiftskeller.*

Gala Dinner

Gala Dinner*, Restaurant "M32"
Thursday, May 22nd, 2014 , at 20:00

Address: Restaurant M32, Mönchsberg 32, 5020 Salzburg, AUSTRIA

The M32 is located at one of the city-mountains in Salzburg. The design of Matteo Thun, dominated by the 390 stag's antlers meets naked concrete and vivid colors. Just a few meters further the eyes meet the city Salzburg. The restaurant offers an amazing view all over the city. Beside the special location you can find traditional Austrian and simply Mediterranean Cuisine. The M32 offers a modern and creative yet delightful and natural atmosphare combined with stunning views and excellent food.

** The symposium fee includes the "Gala Dinner". The entrance tickets for the gala dinner and the elevator onto the Mönchsberg will be available at the registration desk.*

Partners program

"Sound of Music" - Tour by bus
Thursday 22nd May, 2014

14:00 Departure at the Salzburg Congress

18:00 Arrival – Salzburg Congress

Participation rate: EUR 60,- (per person)

The tour, which has been the most popular tour in Salzburg since 1967, is a combination of the historical city and the breathtaking Salzkammergut – Lakes and Mountains area, as well as a famous musical and cultural centre. Many film locations from the Sound of Music will visited as well as other local places of history and culture along the way.

** Please note that the social program is not included in the participation fee of the Symposium.*

Social Program

"Wolfgangsee – Boatride – Schafberg" - Tour
Friday 23rd May, 2014

13:00	Departure – Salzburg Congress
14:00	Boatride from St.Gilgen to St.Wolfgang
15:00	Ride with the famous Schafberg-railway up the Schafberg mountain
16:15	Traditional Austrian snack on the mountain at "Gasthaus Schafberg-Alpe"
19:00	Arrival – Salzburg Congress

Participation rate: EUR 100,- (per person)

Lake Wolfgang counts, with a surface of about 13 square kilometres, as one of the largest lakes in the Salzkammergut. In its deepest spot it is 140 metres deep. There are three villages situated at Lake Wolfgang: St. Gilgen, Strobl and St. Wolfgang. Our first spot St. Gilgen is a well-known travel destination. Closely connected to Wolfgang Amadeus Mozart (his mother was born here, his grandfather worked in town and his sister "Nannerl" moved here after her marriage), St. Gilgen provides a great view of the surrounding mountains. After exploring the town, a boat will sail around the Lake Wolfgang to the city "St. Wolfgang". From there on, the "Schafbergbahn", the steepest cogwheel railway in Austria and part of the film "Sound of Music", will take us on top of the mountain "Schafberg". After a few minutes the track crosses the provincial border between Salzburg and Upper Austria and then continues it's steep ascent through lush fields and green forests. Since 1893 mighty steam locomotives have powered their way from the lake-side base station at St. Wolfgang to the 1783 m high summit of the Schafberg. The Schafbergbahn allows every visitor to conquer the mountain in comfort and style, making the entire journey an unforgettable experience. From the top you may see numerous Alpine lakes and the Dachstein glacier. At the Dorneralm (1015) the first crossing point is reached. This is were the historic steam locomotives pause to take water. The next stop is the quaint station of Schafbergalpe at 1363 metres, where we will have lunch at the Schafberg Alpe Restaurant. This small, family-run restaurant is famous for its traditional Austrian specialities.

** Please note that the social program is not included in the participation fee of the Symposium.*
A ticket will be required.

Contact

The organizer of the event is the Vibration Association.

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

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

Website: torsional-vibration-symposium.com

VIBRATION ASSOCIATION
Schwingungstechnischer Verein

Photo: City of Salzburg

TORSIONAL VIBRATION SYMPOSIUM

in cooperation with

GEISLINGER®
COUPLINGS AND DAMPERS. BUILT TO LAST.

Supporting your vision

MTZ industrial

organized by

VIBRATION ASSOCIATION
Schwingungstechnischer Verein