Zurich University
of Applied Sciences

School of Engineering
IMES Institute of Mechanical Systems

Abstracts
22nd Blade Mechanics Seminar

Tuesday, 12th September 2017

Eulachpassage, TN E0.58, Technikumstrasse 71, 8401 Winterthur, Switzerland

ZHAW Zurich University of Applied Sciences
IMES Institute of Mechanical Systems, Winterthur, Switzerland

Name:	***Company:***
Dr. Norbert Suerken,	Siemens AG, Power and Gas, Germany

Title key note presentation:

Lifing Challenges of Steam Turbine Blades under Changing Operation Conditions due to Renewable Energy Power Fluctuation

Abstract:

Lifing may be defined as the engineering art of improving the fatigue life of specific technical components and the fatigue properties of materials. For conventional base-load power plants, the turbomachinery component life largely depends on the number of starts and the operation hours. However, in an energy market dominated by renewable energy sources, “flexibility” becomes a key requirement for turbomachinery.

Frequent and continuing part-load operation, rapid load and temperature changes (load-cycling) as well as a largely increased need for start-stop cycles (speed-cycling) are getting common. In other words, the life-cycle assessment of turbine components needs to include additional lifing parameters to reflect more speed cycles at higher peak loads (static & dynamic) and broader load variations. Additionally, the required operation regime may lead towards elevated flow excitation of the blading and degraded steam chemistry, which may necessitate on-site monitoring in the field. A good example for such conditions is windage operation at deep part load (low volumetric flow), which increases the blading temperatures and generates unsteady excitation forces acting upon the last stage blades of low-pressure steam turbines.

In the keynote, an OEM’s view is given on how these changed requirements can practically be met by turbine blade design. Important aspects such as material data acquisition, LCF and HCF analysis as well as operational influences on the component lifing will be treated starting with historical and theoretical deliberations, progressing via experimental component fatigue testing and concluding with real size application validation. Special attention is given to recent design and assessment methods for large blades being necessarily exposed to High and Low Cycle Fatigue. The determination of “moving life leading locations” under varying loading, operating and aging conditions will be handled as well as accompanying condition monitoring of blades shall be put up for discussion.

Name: **Company:**

Jun.-Prof. Dr. Malte Krack University of Stuttgart, Germany

Title:

Effect of Creep on the Nonlinear Vibration Characteristics of Blades with Interlocked Shrouds

Abstract:

Under centrifugal loading and high temperatures, inelastic creep deformation causes local stress redistributions and an overall shroud preload reduction. In the presented case study, the deformed configuration and the shroud preload conditions are extracted as a function of the hold time. A nonlinear modal analysis is then carried out, for each hold time, to determine the amplitude-dependent modal damping and frequencies under consideration of the dynamic contact interactions in the shroud joints. It is found that for a given response level, the resonance frequency and the effective damping can deviate considerably from the initial ones. Moreover, the overall damping potential is slightly reduced.

Name: **Company:**

Dr. Harald Schoenenborn MTU Aero Engines, Germany

Title:

Analysis of the Effect of Multi-row and Multipassage Aerodynamic Interaction on the Forced Response Variation in a Compressor Configuration – Aerodynamic Excitation & Mistuning Effects

Abstract:

This presentation is based on the two ASME-papers GT2017-63018 & -63019. The aeroelastic prediction of blade forcing is still a very important topic in turbomachinery design. Usually, the wake from an upstream airfoil and the potential field from a downstream airfoil are considered as the main disturbances. In recent years, it be-came evident that in addition to those two mechanisms Tyler-Sofrin modes, also called scattered or spinning modes, may have a significant impact on blade forcing. In Schrape et al. [1] it was found that in multi-row configurations not only the next, but also the next but one blade row is very important as it may create a large circumfer-ential forcing variation which is fixed in the rotating frame of reference. In this presentation a study of these effects is performed on the basis of a quasi 3D multi-row and multi-passage compressor configuration. It is shown that the effect of the circumferentially different blade excitation has mainly to be contributed to the Ty-ler-Sofrin modes. The effect of the influence of various clocking positions, coupling schemes and number of harmonics onto the forcing is investigated. It is also shown that along a speed-line in the compressor map the blade-to-blade forcing variation may change significantly.

The question arises how this effect interacts with random mistuning, which is also known to create large differences in resonance amplitudes from blade-to-blade. The answer is given in this presentation, showing that the Whitehead-Limit may be ex-ceeded significantly.

Name: ***Company:***

Tobias R. Müller ITSM University of Stuttgart, Germany

Title:

Low-Engine-Order (LEO) Excitation of a Transonic Axial Turbine Stage

Abstract:

The effects of detailing on the prediction of forced-response in a transonic axial turbine stage, featuring a parted stator design, asymmetric inlet and outlet casings as well as rotor cavities, is investigated. The origin and further progression of several low-engine-orders (LEO) within the flow field, as well as their interaction with different geometric details has been analyzed based on the numerical results obtained from a full 360° CFD-calculation of the investigated turbine stage. In this context, a special focus is placed on the influence of the adjacent rotor cavities. Finally, the blade vibration amplitudes are numerically predicted within a harmonic forced-response analysis and compared with tip-timing data.

Name: ***Company:***

Dr. Evgeny Petrov Sussex University, UK

Title:

Sensitivity Analysis of Stability for Nonlinear Vibrations of Gas-Turbine Structures with Accurate Reduced Modelling

Abstract:

The efficiency of the developed methods is demonstrated on a set of test cases including simple models and large-scale realistic bladed disc models with different types of nonlinearities: cubic nonlinear elastic interaction, friction, gaps.

For the analysis of essentially nonlinear vibrations it is very important not only to determine whether the considered vibration regime is stable or unstable but also which design parameters need to be changed to make the desired stability regime and how sensitive is the stability of a chosen design of a gas-turbine structure to variation of the design parameters.

In this paper, an efficient method is developed for analysis of sensitivity of characteristics of stability of nonlinear periodic forced response vibrations in gas-turbine engine structures and turbomachines with friction, gaps and other types of nonlinear contact interfaces. The method allows using large-scale finite element models for structural components together with detailed and high-fidelity description of non-smooth nonlinear interactions at contact interfaces between these components. The sensitivity of the stability factors are calculated with respect to variation of the contact interface parameters and with respect to geometry and modal properties of linear structural components of an assembly.

The highly accurate reduced modelling methods are proposed to ensure using industrial-size structural models in the assessment of the stability sensitivity. The efficiency of the developed approaches is demonstrated on a set of test cases including simple models and large-scale realistic bladed disc models.

Name: ***Company:***

Andrea Cavicchi Ansaldo Energia, Italy

Title:

Interface Reduction in Component Mode Synthesis of Bladed Disks by Orthogonal-Polynomial Series

Abstract:

The component mode synthesis based on the Craig-Bampton method has strong limitations when applied to large models: the reduced-order model contains many unnecessary interface DOFs and the reduction step becomes extremely time consuming. Traditional Interface Reduction (IR) techniques leave the mentioned problems partially open, while the recently-proposed Orthogonal Polynomial Series (OPS) method showed a much better numerical efficiency, at least when dealing with simple interface geometries. In this contribution, the OPS method is applied to real industrial components involving cooled blades and attachment with complex geometry. OPS is compared with other IR techniques in terms of accuracy and numerical cost.

Name:	**Company:**
Prof. Dr. Damian M. Vogt	ITSM University of Stuttgart, Germany

Title:

Investigation of the Aerodynamic Excitation of Rotor Blades in a Vaned Radial Turbocharger Turbine

Abstract:

Funded by the Research Association for Combustion Engines (FVV), the project "Blades Forces" presented herein pursues the aim of developing and validating a new numerical tool for the prediction of aerodynamically induced blade vibrations in turbomachines using commercially available simulation software. Besides the approach applied for identifying resonance crossings of potential risk, the tool concept taking into account the aerodynamic forcing and damping as well as structural mistuning is presented. Finally, a validation of the numerical results by means of test data acquired with a large-scale turbocharger test facility is presented, including time-resolved pressure measurements and blade vibration measurements.

Name:	**Company:**
Yves Bidaut	MAN Diesel & Turbo Schweiz AG, Switzerland

Title:

Detection of Rotating Stall in Open Impellers of Centrifugal Compressors and Determination of Induced Mechanical Stress

Abstract:

Usually, unshrouded centrifugal compressor impellers are subjected to high static stress be-cause they operate at high rotational speeds and volume flow rates. Due to the remaining small margin for dynamic stress, the identification of the dynamical behavior of the impeller in opera-tion is of crucial importance. In addition to the well-established impeller blade excitations caused by the stationary parts the presented study focuses on the measured unsteady rotating flow fea-ture (rotating stall) which should be considered during the design phase.

The fluid-structure interaction between rotating stall cells and impeller blades was experimen-tally characterized during the measurement campaigns on two different full-size units operating under real conditions. In these tests, dynamic strain gauges and pressure transducers were mounted at various locations on the impeller of the first stage. The casing was also equipped with dynamic pressure transducers to complement the study.

The results revealed that the rotating pressure fluctuations generate an additional impeller excitation whose amplitude and frequency depend on the operating conditions. In one particular operating condition the excitation can cause resonant impeller blade response. Nevertheless, the recorded induced mechanical stresses are only around 10% of the endurance limit of the material and hence are not critical.

Comprehensive measurements were subsequently performed on an additional compressor where the first stage was partially and similarly instrumented like the previous two tested config-urations. In this test campaign the focus was placed on the bearing vibrations and on the sound radiated in front of the first stage. It appeared that the rotating cells can also be detected in the lateral vibration probes as well as in microphones.

Name:

Loris Simonassi

Company:

Institute of Thermal Turbomachinery and Machine Dynamics – TU Graz University of Technology, Austria

Title:

On the Influence of different Design Philosophies of Turbine Exit Guide Vanes on the Vibrational Behaviour of the Upstream Low Pressure Turbine Rotor

Abstract:

New low pressure turbine architectures of aero engines are designed in order to optimize components weight, decrease the fuel consumption and noise emissions.

This study deals with the effect of innovative turbine exits casings (TEC) designs on rotor blade vibrations under engine relevant operating conditions. Different turbine exit casings were investigated. A telemetry system in combination with strain gauges was applied for blade vibration measurements.

The aerodynamic and acoustic improvements of the new TEC configurations lead to higher mechanical blade loading and vibration amplitudes. This comparison also provides a basis for numerical code validation and future developments.