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Abstracts
20th Blade Mechanics Seminar

Tuesday, 8th September 2015

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. Paolo Calza	AvioAero Italy, GE Aviation

Title key note presentation:

Mistuning: a New Design Parameter for LPT Operational Safety - Current and New Horizons

Abstract:

A challenge in next generation engines is to find the best trade-off between the conflicting aerodynamic and structural demands. Several design features are commonly used by LPT manufacturers to reduce flutter or vibration attitude, but with some costs in terms of efficiency, manufacturing and weight. Some of these are more focused towards aerodamping control, while others are linked to mechanical damping increasing. In all cases, reliable and robust aeromechanical design capabilities are crucial in efficiently and promptly managing flutter or resonance problems occurring from the earliest design phase.

To prevent flutter issues, the optimal aero-design needs to be accommodated by introducing geometry modification, although there are some negative impacts in terms of efficiency and weight. Conventional flutter analyses are based on “perfect tuned configurations”. Then, all airfoils vibrate in the same way with an Inter-Blade Phase Angle defined by the Nodal Diameter. The mistuning breaks this aeroelastic symmetry with a consequent reduction of the reciprocal aerodynamic interactions. This effect can be intentionally amplified by designing airfoils with minor differences to stabilize flutter. Hence, the mistuning technology represents a great opportunity to avoid flutter instability without impacting on aero-performance and weight.

The presentation is focused on recent experimental/numerical achievements performed to mature the mistuning technology on LPT. A flutter unstable configuration (tuned) was designed and tested in a Cold Flow and flutter-vibrations were measured. The same configuration was then mistuned to stabilize flutter phenomena. No vibrations were detected for this configuration during the Cold-Flow test. Therefore, the test results demonstrate that the mistuning has a positive effect on flutter stability. In addition, the overall mechanical Damping was characterized in an innovative in-vacuum spinning-rig designed and built to excite asynchronous vibrations. Finally, the outcomes of the two test campaigns were analyzed and cross-correlate to better interpret the physics behind the measured vibration amplitudes

Name: ***Company:***

Radoslaw Przysowa ITWL – Air Force Institute of Technology, Poland

Title:

Monitoring of LPT Blade Vibration in the largest power plant in Europe

Abstract:

Radosław PRZYSOWA, Jarosław SPYCHAŁA, Edward ROKICKI

A few years ago several cracks in roots of ND37 blade were found in the last stages of 13K370 steam turbine. Self-excited vibration in off-design flow condition contributing to High Cycle Fatigue was identified to be the root cause by Alstom engineers. A restricted zone on the diagram of the condenser pressure vs the mass flow was proposed and implemented as a remedy afterwards.
ITWL cooperates with the operator and the OEM to develop a monitoring system protecting LP steam turbine against excessive blade vibration to be able to operate in the restricted zone. The concept of the system and selected results of blade vibration measurement with tip-timing method are presented.

The project has been supported by Polish Government in 2012-2014; agreement No PBS1/B4/5/2012.

Name: ***Company:***

Agathe Vercoutter Turbomeca, France

Title:

Recent applications on blade vibration estimation from tip-timing data

Abstract:

Estimation of blade dynamic behaviour requires measurements in operation. In this context, tip-timing appears to be a promising measurement technology, as the set-up is quite easy, probes do not endure hard conditions (except from thermal ones), it is non-intrusive and all the blades can be monitored and analysed separately. In practice, specific processing methods are needed to estimate the vibration content of tip-timing signals.
This presentation summarizes several test cases; they focus on various topics such as blade spatial organization, forced response amplitude, mistuning and blade response under asynchronous excitation. All these analyses emphasize the capacity of understanding some characteristics of the excitation sources from blade response estimation.

Name: ***Company:***

Torsten Heinze Leibniz University Hannover, Germany
Institute of Dynamics and Vibration Research

Title:

Vibrational Behaviour of Friction-Damped Bladed Disks considering Rotational Speed-Dependent Structural Quantities

Abstract:

When evaluating the vibrational behaviour of spinning structures in the field of rotating machinery, it is common practice to factorize the structural quantities such as stiffness, damping and excitation at a reference rotational speed, and from then on, regard those quantities as constant within a small frequency range. This approach holds for linear as well as nonlinear problems, as long as rotational speed-dependency is minor compared to the reference.
This presentation discusses the influence of the rotational speed on structural quantities on the basis of two different models: a single-degree of freedom model and a multi-degree of freedom model. The former is used to approximate the first bending mode of a blisk segment, whereas

the latter is used for analysing the vibrational behaviour of a cyclic symmetric blisk segment subject to nonlinear contact forces. The resulting forced responses are examined for credibility of the method and for identifying its limits.

Name: ***Company:***

Patricio Almeida — Safran Turbomeca, France

Title:

Experimental Analysis of Modal Interaction between a Centrifugal Compressor and its Casing

Abstract:

In axial and centrifugal compressors, minimizing the clearance between the blade tips of the impeller and its surrounding casing increases the aerodynamic efficiency, but also the probability of contacts. An energy exchange is then produced between the two structures, leading to forced excitation of the natural modes and potentially to dynamical instabilities, such as interaction phenomena. In both cases, the structures may suffer subsequent structural damages. Mastering blade-to-casing interactions is thus a phenomenon that turbomachinery manufacturers intend to incorporate into the design process of an engine. The vibration behavior of the system should take into account the predominant physical phenomena. In this context, this work focuses on the study of the dynamic and thermomechanical behavior resulting from blade-to-casing interactions between a low-pressure centrifugal compressor (or impeller) and a casing lined with abradable coating.
The main purpose of this work is to build a likely scenario to explain the various phenomena present when contact occurs, and the creation of a database for subsequent comparisons with numerical simulations. To achieve this, a test rig heavily instrumented has been used in order to better understand the influence of various physical phenomena (dynamic, wearing, heating). Analysis of experimental and numerical results shows transient events, characterized by a simultaneous increase in amplitude on both the rotating and stationary structures. The spectral content of the response highlights the presence of harmonics of the rotating speed and some sidebands aside from the main excited frequencies, which may cause the system to experiment significant dynamic response when they coincide with the natural frequencies of structures.

Keywords: centrifugal compressor, experimental analysis, blade-casing contact, modal interaction, spectral analysis

Name: ***Company:***

Evgeny Petrov — University of Sussex, School of Engineering and Informatics, United Kingdom

Title:

Sensitivity and Robustness Analyses of Non-linear Bladed Disc Dynamics

Abstract:

There are two major causes of vibrations in gas-turbine structures: (i) excitation by time-varied external forces applied to a structure and (ii) self-excitation, which can occur, for some fluttering vibration modes, due to interaction of a vibrating structure with gas flow.
Gas-turbine structures are typically assembled structures, which comprise friction, gap and other types of the contact interfaces: such as damper devices, interlock shrouds and root joints in bladed discs, etc. Forces occurring at these interfaces are strongly nonlinear because of friction forces, unilateral interaction forces acting along normal to a contact interface, closing and opening clearances during vibrations, etc.

The nonlinear contact interfaces can have dominant influence or affect significantly the amplitude levels and resonance frequencies for forced vibrations and can suppress the exponential growth of flutter amplitudes to form a periodic motion of limit cycle oscillations for flutter-excited vibrations. The nonlinear vibration regimes can be highly sensitive to variation of the parameters of contact interfaces and design parameters of the structure. Appropriate choice of parameter values can reduce the levels of vibration amplitudes to those when they cannot

cause immediate failure and, even, do not contribute practically to the accumulation of high-cycle fatigue damages. The effective choice and control of the vibration levels require methods for quantitative assessment of their sensitivity to variation of structural and contact interface parameters.

Moreover, in addition to finding parameters providing the acceptable vibration levels, inevitable variability and scatters of design parameters and operating conditions during manufacture and during gas-turbine engine operation require determination the parameters which ensure the robustness of the design: when changes of design parameters within ranges of their variability do not affect significantly the vibration amplitudes.

In this paper, efficient frequency-domain methods are discussed which allow direct and efficient calculation of the sensitivity coefficients for: (i) the nonlinear forced response and (ii) amplitudes and frequencies of flutter-excited limit-cycle oscillations for structures with friction and gap contact interfaces. The methods use realistic large-scale finite element models of structures and multiharmonic representation of the periodic vibrations. The approaches are developed to calculate design parameters maximising the design robustness.A set of representative examples of the application of these methods are given.

Name: ***Company:***

Adil Alam Alstom Power, Baden, Switzerland

Title:

Impact of manufacturing process on eigenfrequencies of turbine blade

Abstract:

A. Alam, V. Vassiliev, K.Stärk

To ensure safe turbine operation the eigenfrequencies of turbine blades should belong to a range outside of excitation frequencies. The eigenfrequencies in operation are measured during design phase and then the relationship is established between eigenfrequencies in operation and in static conditions in bench test. (These values are different due to influence of temperature and load). The bench test is mandatory quality check for each manufactured blade. Analysing the results of bench tests it was observed that manufacturing process affects the natural frequencies. To better understand this effect the investigations, which included dimensional checks using advanced technologies, extensive Lab testing, and analytical investigations were carried out. These investigations showed that between other factors the cold straightening process have an impact on the natural frequencies. In this work the results of the analysis are presented and discussed.

Name: ***Company:***

David Hemberger IHI Charging Systems International, Germany

Title:

Mistuning of Small Turbine Wheels in Automotive Turbochargers

Abstract:

This presentation gives an overview of the main source of mistuning for casted turbine wheels in automotive turbocharger applications. The source of mistuning may be the geometric difference in shape and / or the effect of in-homogeneities in the material. To examine this, various numerical models were evaluated, but also measurements during operation and standstill condition were carried out. Casted turbine wheels with different grain structures and also milled turbine wheels from forged blanks were analyzed. Besides this, FE-models based on casting simulations were used to analyze residual stress and material property effects on mistuning.

Name: ***Company:***

Omid Sedaghat MAPNA Turbine Blade Engineering & Manufacturing Co., Iran

Title:

Free and Forced Vibration Analysis of Mistuned Freestanding Turbine Blade

Abstract:

One of the major concerns in turbomachinary industries is High Cycled Fatigue (HCF) and the consequent blade failure. The main reason for this issue comes from the high amplitude forced vibrations due to the unsteady aerodynamic loads encountered the blades with different harmonics of nozzle passing frequencies. The flutter instability of the blade is the principal second cause of failure. Using frictional damping and mistuning of the blades are the main treatment in practice.
In the present study, we discuss the substantial role of mistuning of different parameters on the rotor blade instability and forced response. The aeroelastic model of the blades is established using the beam theory for structural dynamics within the framework of the analytical unstalled aerodynamic theory. The influence of alternating and random mistuning on the instability and the stress arise(s) from the forced response were demonstrated. The effect of shear deformation which is prominent in short length blades was studied as well. The results show that the mistuning of different parameters reduces the vibration amplitude and makes the system more stable.

Name: ***Company:***

Sebastian Willeke Leibniz University Hannover, Germany
Institute of Dynamics and Vibration Research

Title:

Mistuned Bladed Disks with Aeroelastic Coupling

Abstract:

Localization of vibrational energy in mistuned bladed disk results in local amplification of blade vibration amplitudes compared to maximum deflections of cyclic symmetric structures. This energy concentration in few blades primarily depends on the level of mistuning as well as on coupling mechanisms between individual blades. Besides structural inter-blade coupling across the disk, aeroelastic effects due to the working fluid have to be considered in this context.
To assess the vibrational response of randomly mistuned configurations efficiently, a reduced-order model comprising aeroelastic influences is developed. Results obtained by stochastic analyses of a sample blisk are presented to demonstrate the significance of aerodynamic coupling effects in mistuned bladed disks.

Name: ***Company:***

Luigi Carassale University of Genova, Italy

Title:

Damping Estimation for Turbine Blades in Run-up Tests

Abstract:

Luigi Carassale, University of Genova, Genova, Italy
Michela Marrè-Brunenghi, Ansaldo Energia, Genova, Italy
Stefano Patrone, Ansaldo Energia, Genova, Italy

Blade damping is usually estimated through run-up (or run-down) tests, exploiting the response amplification observed when the engine orders cross a resonance. The quantification of damping in these conditions is rather complicated, due to the unsteady dynamics produced by necessarily fast resonance crossings. We show through a numerical simulation that the usual identification procedures lead to a systematic overestimation of damping due both to the finite sweep velocity, as well as to the variation of the blade natural frequency with the rotation speed. An identification procedure based on the time-frequency analysis is proposed and validated through numerical simulations.

Name: | ***Company:***

Florian Schönleitner | Graz University of Technology, Austria
Institute for Thermal Turbomachinery and Machine Dynamics

Title:

Experimental Blade Vibration Measurements on Rotating Turbomachinery Blades

Abstract:

L. TRAUSSNIG, F. SCHOENLEITNER, T.SELIC, F. HEITMEIR, A. MARN

The knowledge of blade vibration characteristics is essential for the aero elastic design. Blade vibration measurements in turbo machines are in comparison to other particular cases difficult. Beside optical methods such as tip timing, strain gauge measurements are the best solution for a high quality of results. Due to high requirements and challenges at operating conditions in aero engine rotor blading, experimental data does not exist of rotating systems, especially in the area of the low pressure turbine. Based on these facts a new research project regarding blade vibration measurements and aero elasticity under engine representative conditions of a low pressure turbine was started at Graz University of Technology. For these investigations a telemetry system has to fulfill highest technical requirements and was developed. Beside basic steps of blade instrumentation and telemetry setup, experimental results of blade vibration measurements are presented within this presentation. Out of it many different characteristics and aspects can be discussed.

Name: | ***Company:***

Andrea Gadda | Politecnico di Milano, Italy,
HSLU Luzern T&A, Switzerland

Title:

A GPU-Parallelized Fluid-Structure Interaction compressible RANS solver for turbomachinery applications

Abstract:

Computational Fluid Dynamics (CFD) is a fundamental tool for industrial applications. The usual approach relies on the negligible structural deformations due to aerodynamic loads. In some cases, however, where power efficiency is the ultimate goal (e.g. propulsion), an accurate prediction of the fluid-structure interaction is mandatory. This is particularly true for flutter and trim analysis of airplanes and turbomachinery blades. Alongside with results accuracy, computational efficiency is indispensable. The purpose of the presentation is to show the architecture of a GPU-accelerated Fluid-Structure Interaction (FSI) solver for compressible viscous flows. The proposed approach is validated with typical industrial cases.