SURVISHNO CONFERENCE 2025

SURVeillance, VIbrations, Shocks and NOise

MAY 21 – MAY 23

ABSTRACT BOOKLET

Table of Contents

GENERAL INFORMATIONS

SURVISHNO is a joint organization of the conferences Surveillance, VISHNO (Vibration Shocks and Noise) and EVA (Experimental Vibration Analysis), which aims at bringing together actors – researchers, scientists, and industry professionals – in the fields of vibrations, structural dynamics, and health monitoring. The conference will provide a forum for the most recent advances in these fields as well as a unique opportunity to interact in a collegial atmosphere.

Conference localization

Conferences will take place in the ISA-SUPMECA building, and more specifically in the Aphitheater Geneviève Inglebert and in Amphitheater Nelly Blanc. Lunch and coffee breaks will be in the room named Aquarium.

Welcome cocktail, May 21th - 18h00

The welcome cocktail will be offered on Wednesday 21 May from 18h00 in the Aquarium.

Gala dinner

Gala will take place on Thursday 22 May from 19h00 (7.00 pm) at the Hôtel Le Charmant located 53 Rue du Landy, 93200 Saint-Ouen-sur-Seine. A Gala ticket will be required to enter the building.



WIFI access

WIFI access is available using EDUROAM.

PLENARY SESSIONS

May 21th, 14h00 – 15h00 : Étienne BALMES, École Nationale Supérieure des Arts et Métiers / Laboratoire Procédés et Ingénierie en Mécanique et Matériaux & SDTools - Classification of experimental squeal occurrences using a harmonic balance vector signal

Brake squeal is an instability that generates self-excited limit cycles with periods and vibration levels that, in real experiments, vary with time and operating conditions. To analyze test results, it is proposed to use a Harmonic Balance Vector (HBV) signal model, that combines the space-time decomposition of the Harmonic Balance Method, where spatial distribution of each harmonic is described by a complex vector and frequency is common all sensors, with analytic signal methodologies, where quantities are assumed to be slowly varying in time. Synchronous demodulation and principal coordinate definitions are combined in a multi-step algorithm that provides an HBV estimation. On an industrial brake test matrix, HBV is shown to be robustly applicable. The HBV signal being slowly varying allows subsampling and reduces the volume of test data by two orders of magnitude. Limit cycle frequency, amplitude and shapes can thus be kept in the parallel coordinates containing operating parameters: pressure, velocity, temperature, torque, disk position, disk/bracket distance. This opens a path to a range of analyses otherwise difficult to perform. Classification of occurrences is first discussed showing pressure and amplitude dependence. The effect of amplitude on both frequency and shape is then demonstrated. The relation between squeal test results and the classical complex mode transition to instability, when parameter changes, is then analyzed using a proposed transient root locus for intermittent growth/decay events shown to be correlated with wheel position. Distance measurements indicate that disk shape variations of a few microns play a clear parametric role. Parametric testing and clustering are then used to map the instability region and its edges. Prospective uses of these results to combine test and finite element results are discussed last.

May 22th, 09h00 – 10h00 : Hugo ANDRÉ, Université Jean Monnet de Saint-Etienne / Laboratoire d'Analyses des Signaux et Procédés Industriels (LASPI) - From Noise to Insight: Turning Instantaneous Angular Speed Variability into Diagnostic Power

For over fifty years, time-domain vibration analysis has been a cornerstone of condition-based maintenance for rotating machinery. However, its limitations become evident as soon as operating conditions deviate from stationarity. To overcome these limitations, my research has focused on observation in the angular domain, and more specifically, on the direct use of instantaneous angular speed as a diagnostic signal.

The first line of research is based on the hypothesis that electromechanical faults induce detectable perturbations in the angular speed of a machine. This hypothesis has led to the development of mechanical and statistical models designed to interpret the structure of the instantaneous angular speed (IAS), to identify its sources of noise, and to explore its diagnostic potential. This unconventional signal carries rich information that can be harnessed using original processing tools, often based on cyclostationary properties.

This novel way of observing machine behavior has also helped enhance more traditional vibration monitoring techniques by improving their ability to cope with inherent speed variations. The second line of research aims to synchronize signal sampling with defects in rotating components by estimating the instantaneous frequency — without the use of dedicated angular sensors — from vibratory, acoustic, inductive, or even video signals. This change in perspective enables the analysis of signals under variable operating conditions, provided that the resulting non-stationarities are appropriately addressed through a combination of signal processing and data-driven approaches.

In the particular case of bearing monitoring under slippage conditions, we are now realizing that referring to "the" rotational speed of the drivetrain in the singular is no longer sufficient. The bearing experiences a form of slippage — and rather than being a nuisance, this slippage presents a unique opportunity. The desynchronization between the bearing and the shaft can, in fact, be leveraged to improve our monitoring capabilities. What was once considered a limitation can now be turned into an advantage: a means to isolate the bearing's contribution and even assess its health status.

May 23th, 09h00 – 10h00 : **Stefania LO FEUDO, Yunhyeok HAN, ISAE-Supméca - Institut supérieur de mécanique de Paris / Laboratoire QUARTZ - Survival Guide to Vision-based Vibration Measurements**

Is it possible to perform accurate and robust experimental vibration measurements using optical instruments? What are the smallest measurable displacements, and what frequency ranges can be captured? Which objective lens should be used, and where should the camera be positioned? Will the light be sufficient? What surface treatment is both feasible and effective for the image post-processing phase? Will the recorded image sequences be usable? These are some of the questions that arise before conducting vision-based vibration measurements. In this presentation, we will guide you through our search for answers, covering the preparation phase, dynamic tests, image processing, and preliminary analysis of the results from a challenging experimental campaign carried out on the LNEC's shaking table in Lisbon on a reinforced concrete U-core shaped wall subjected to seismic excitation (ERIES project – ALL4WaLL). As part of this investigation, we will also introduce VibrationTracker, the open-source software developed by our team. This tool offers features for calibration, target initialization, tracking, 2 and 3-dimensional vibration analysis, and full-field measurement using Digital Image Correlation.

ESCAPE GAME, The coordinates of knowledge

In the fascinating world of vibrations and acoustics, some ideas travel further than the waves they describe. They travel through laboratories, resonate in lecture theaters and inspire new generations of researchers.

For this 2025 edition of SURVISHNO, the organizing team wanted to honor a talented, creative researcher from our community through a scientific quest. By taking part in this quest, you are not just playing a game. You are helping to shine the spotlight on a man of science, a teacher and a builder of knowledge.

To identify this researcher, clues will appear in the various workshops of the scientific program. Thirteen cards will be scattered around the rooms and coffee stands for a limited time. They include 11 cards containing numbers, 1 card with a flag and 1 picture card. If you can put the numbers together correctly and interpret the symbols, you will be able to identify the name of this inspiring researcher.

And if that name sounds familiar... that is because it is the name of a professor you might come across in a session or in a corridor.

Your quest

During the three days of the congress, go in search of the 13 clue cards.

- Find the 13 cards (photograph them)
- Match the numbers and symbols to identify the teacher
- Take a selfie with him (bonus if he makes a face)
- Send your photo to : xavier.chiementin@univ-reims.fr

Be discreet, our researcher is not informed of this quest.

Rules of the game

The cards must remain in their place. Note that the cards are only visible for a certain time (15', 1h, 2h). 5 will be visible on Wednesday, 6 on Thursday and 2 on Friday. Last chance: Friday 12.30-14.00, all 13 cards will be visible again at the same time, during the meal. Prize-giving ceremony on Friday 14h00-15h00: The first to solve the enigma and give the organizers the right name will receive a surprise and the eternal gratitude of the scientific community... or almost!

CONFERENCE PROGRAM

	Wed. 21	Thu. 22	Fri. 23
09:00		Plenary session - From Noise to Insight: Turning Instantaneous Angular Speed Variability into Diagnostic Power	Plenary session - Survival Guide to Vision-based Vibration Measurements
10:00		Rotating machinery Digital Twin	Active and passive control of vibrations Electric machines Coffee Break
11:00		Coffee break Rotating machinery Dynamics of MEMS and NEMS Model system and identification Active and passive control of vibrations	Start-up plenary session - Validation of Image-Based Modal Analysis Techniques for
12:00		Lunch	Vibroacoustics and fluid/ structure interaction Vibration-based Structural Health Monitoring Lunch
13:00	Welcome Reception - Coffee Conference opening		
14:00	Plenary session - Classification of experimental squeal occurrences using a harmonic balance vector signal	Rotating machinery Active and passive control of vibrations	Remise ESCAPE GAME - CONCLUSION
15:00	Numerical methods for structural dynamics Nonlinear Dynamics (including contact, impact, friction, ...) Coffee break	Coffee break	
16:00	Experimentations in structural dynamics, sensors and metrology Nonlinear Dynamics (including contact, impact, friction, ...)	Start-up plenary session - MECALAM	
17:00		Rotating machinery Active and passive control of vibrations	
18:00			

May, 21th — Afternoon Presentations

May 21th, 14h00 – 15h00

PLENARY 1, Amphitheater N. BLANC

Classification of experimental squeal occurrences using a harmonic balance vector signal
Etienne BALMES
École Nationale Supérieure des Arts et Métiers / Laboratoire Procédés et Ingénierie en Mécanique et Matériaux & SDTools

May 21th, 15h00 - 15h45 : Session Numerical methods for structural Dynamics, Amphitheater N. BLANC

A Comparison of Iterative Eigenvalue Solvers for Structures with Frequency-Dependent Material Properties **15h00**
Matteo Couet[1,2,3] Jean-François Deü[1], Lucie Rouleau[1], Fabrice Thouverez[2], Marion Gruin[3]
[1] Laboratoire de Mécanique des Structures et des Systèmes Couplés, Conservatoire National des Arts et Métiers, Paris, France [2] Laboratoire de Tribologie et de Dynamique des Systèmes, Ecole Centrale de Lyon, Ecully, France [3] Safran Aircraft Engines, Moissy-Cramayel, France

Fast computation of band diagram and band gap location from high order eigenvalue derivatives **15h15**
Benoit NENNIG[1], Martin GHIENNE[1], Emmanuel PERREY-DEBAIN[2]
[1] Institut supérieur de mécanique de Paris (ISAE-Supméca), France [2] Université de technologie de Compiègne, France

Dynamical analysis of viscoelastic structure based on the fractional models **15h30**
Rongqi DANG, Gang CHENG, Roger SERRA
Institut National des Sciences Appliquées Centre Val de Loire, France

A Comparison of Iterative Eigenvalue Solvers for Structures with Frequency-Dependent Material Properties

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Viscoelastic materials are widely used in the industry, either via localized treatments (e.g. anti vibration supports) or distributed treatments (e.g. free or constrained layer damping patches [3]) to attenuate vibrations in industrial structures. To design these devices, designers need to be able to accurately predict their effects on the dynamic behavior of the structure, hence quantifying their impact on the natural frequencies and the modal loss factors associated to the vibration modes to be damped [5]. These quantities can be obtained by solving a generalized eigenvalue problem of the finite element discretized structure. However, viscoelastic material are modeled by complex frequency-dependent material laws that introduce a complexity in the problem. Iterative complex eigensolvers are extremely costly in computing ressources [2, 1], and conventional reduction methods can lead to largely inaccurate results when applied to highly damped structures [4].

In the present work, a projection-based reduction method combined with an iterative solving method is proposed to reduce the computational cost while ensuring accuracy. This method is compared to other methods on a simple case and then applied to a large industrial problem. The accuracy and the efficiency of the proposed method compared to state-of-the-art methods is demonstrated on an academic test case consisting of a cantilever sandwich beam, and the sensitivity of the method to different parameters such as the level of damping, the size of the problem or the number of modes to be computed is assessed. The benefits of this method on an industrial structure is also highlighted. For the same level of accuracy, this method requires less processing ressources and is more efficient than the state-of-the-art methods on large size finite element models.

Keywords:
Viscoelasticity, Constrained layer damping, Resolution methods, Modal projection, Eigenvalue problem

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Fast computation of band diagram and band gap location from high order eigenvalue derivatives
SURVISHNO Conference 2025

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Abstract
With the advent of metamaterials and phononics crystals, there is a growing need for computationally efficient methods to get dispersion properties of periodic structures like band gap position or group velocities. Thanks to the Floquet–Bloch theorem, waves in periodic media can be discretized with standard finite element method over an unit cell leading to large sparse matrices eigenvalue problem for the Bloch wavenumber or the frequency. Computing the dispersion diagram consists in solving this parametric eigenvalue problem either for the wavenumber as a function of the frequency or the frequency as a function of the wavenumber. The choice of both formulation depends mainly on the presence of dissipation mechanisms which make frequency dependence more complex. When the matrices are analytical functions of frequency, which is generally the case for systems with no damping or with viscous damping, the derivatives of the eigenvalue can be computed up to arbitrary order with a great numerical stability. For instance, it could be done with the bordered matrix or with the adjoint method. Unfortunately, the radius of convergence of this high order Taylor series is strongly limited in the vicinity of band gap opening and closing point because they correspond to a defective eigenvalue, associated to a branch point singularity. The parameter value that leads to a defective eigenvalues is known as an Exceptional Point (EP). Recent works of the authors have been devoted to understand the properties of EPs and to introduce analytic functions in their vicinity leading to convergent Taylor series. These series allow to locate the EP and to track accurately the eigenvalues with respect to parameters such as the frequency. The aim of this work is to illustrate how this method allows to recover dispersion curves from few initial computation of the eigenvalue problem and to locate the band gap without damping.

Keywords:
Band diagram; Band gap; Dispersion curves; Eigenvalue perturbation; Exceptional point;

References

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Dynamical analysis of viscoelastic structure based on the fractional models
SURVISHNO Conference 2025

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Abstract

The objective of this research is to describe the viscoelastic behavior by using a fractional model and to conduct the dynamic analysis of a structure under various loading conditions. Fig. 1 illustrates three mechanical constitutive elements and the associated behavior laws. Spring, governed by Hooke's law, represents purely elastic behavior. Dashpot, governed by Newton's law, describes purely viscous behavior. The spring-pot employs the fractional derivative to characterize complex viscoelastic behavior [1]. In this research, the parameters in the fractional model were identified by the dynamic mechanical analysis data. Fourier transform was used to convert the fractional model from the time to frequency domain to facilitate the fitting procedure. The advantage of the fractional model with fewer parameters was validated by comparing it to the integer models. The identified model was integrated into the governing equation of the structure to predict its mechanical responses. An efficient algorithm was required to solve the fractional governing equation [2]. A numerical algorithm based on the shifted Chebyshev polynomials was developed and its accuracy was validated by the error analysis of the numerical examples. The mechanical response of the viscoelastic structure was analyzed under different loading conditions. The fractional model successfully captured the viscoelastic behavior of the material. This research provided an efficient model and numerical algorithm for the dynamic analysis of viscoelastic structures.

Keywords:

Viscoelastic structure; Fractional models; Parameter identification; Dynamic analysis

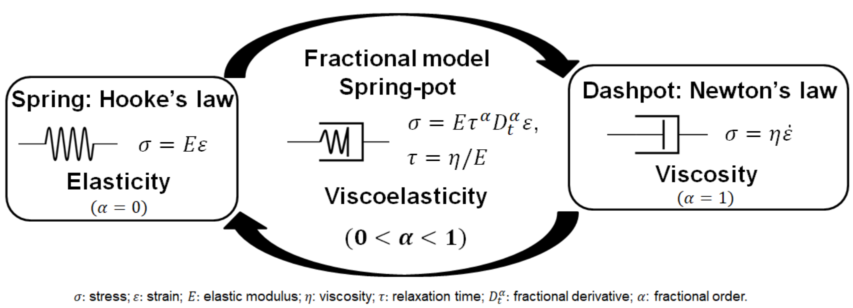

Figure 1: Schematic of viscoelastic constitutive elements.

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May 21th, 15h00 - 15h45 : Session Nonlinear Dynamics

A contact damping in bearing model for improving robustness of a digital twin based faults diagnosis **15h00**

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A unified framework for nonlinear vibrations of cable **15h15**

Charlélie BERTRAND

ENSAM, Campus de Lille, LISPEN, France

Bistable unit-cell, from the characterization of a single element to a lattice **15h30**

Antoine Faulconnier[1], Apostolos Paliovaios[2], Georgios Theocharis[2], Vassos Achilleos, Stéphane Job[1], Vincent Tournat[2]

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A contact damping in bearing model for improving robustness of a digital twin based faults diagnosis

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Abstract
This paper highlights the use of contact damping to improve the model's accuracy in tracking the evolution of rolling bearing fault using scalar indicators. The goal is to create a digital twin capable of estimating the remaining useful life (RUL) of bearings. A model has been developed that integrates both Hertzian forces and damping in the contact dynamics. The damping formulation, based on dissipation theory, includes parameters that allow for monitoring the fault severity and speed. The analysis performed on the model shows a monotonic trend for the kurtosis and RMS indicators of speed and fault severity. The limitations of this model prevent the identification of saturation for high severities.

Keywords
Bearing model, contact damping, robustness, digital twin, monitoring.

1 Introduction

Bearings are critical components of rotating machinery, prone to failures that can lead to breakdowns, increased maintenance costs, and reduced productivity [1], [2]. In this context, the detection, and even more so the monitoring, of bearing faults becomes crucial as it enables maintenance activities to be planned in order to reduce costs and increase reliability [2], [3]. With the advent of Industry 4.0, recent research has focused on digital twin diagnosis using Machine Learning Algorithms (MLAs) [4], [5], suggesting to explore aspects of remaining useful life estimation that include model-based or hybrid monitoring. This challenges the robustness of models to reproduce the behaviour of bearing dynamics under different operating conditions (fault severity, speed, load), which is not always straightforward due to the non-linearities it presents. Existing models [6], [7], [8], [9], like the Half-Sine Model (HSM) and Two-Arc Model (TAM), simulate fault excitation but often fail to maintain consistent damping of shock impulses across different fault severity levels, as a result of the non-linearities introduced by Hertzian contact forces, hence the need to compensate by including contact dissipation.

Here, the modelling as described by the equation of motion of the global system in (1) introduces dissipation forces into the non-linear contact forces (2) through a damping approach (Half Sine Damped Model :HSDM or Two-Arc profile Damped Model :TADM), depending on the amplitude of the vibrations induced by the presence of the defect.

The proposed model (Figure 1) presents a shaft line drive from the ITheMM SURVIB test bench discretized into 9 two-nodes Timoshenko beams with 3 DOFs per nodes. The elements concentrated on the shaft are, the inertia of the motor, which is placed at node 1, the bearings; a healthy one at node 3 and a test bearing at node 6. A hydraulic jack placed at node 8 applies a radial load in the horizontal direction.

$$[M]\ddot{X} + [C]\dot{X} + [K]X = \{Fext\} + \{Fnl\} \tag{1}$$

$$Fnl = -\sum_{i}^{N_b} K_h \delta_i^{3/2} [Cos\theta_i; Sin\theta_i] - \sum_{i}^{N_b} C_h \dot{\delta}_i [Cos\theta_i; Sin\theta_i] \tag{2}$$

K_h, δ_i, θ_i et C_h respectively, the contact rigidity, the contact deformation of the i[th] ball, the angular position of the i[th] ball and the contact damping.

From energy dissipation theory [10], the damping coefficient C_h is derived as a function of fault depth H_d and the excitation speed. χ includes the loss factor and the transfer parameters of the non-linearities. The choice of C_h is decisive in observing the impact of damping. ϵ represents the estimated amplitude of vibrations at the local contact point in the absence of the fault, while ω_c is the cage pulsation.

$$C_h = \frac{\chi.(\epsilon + H_d)^{1/2} \cdot K_h}{\omega_c} \tag{3}$$

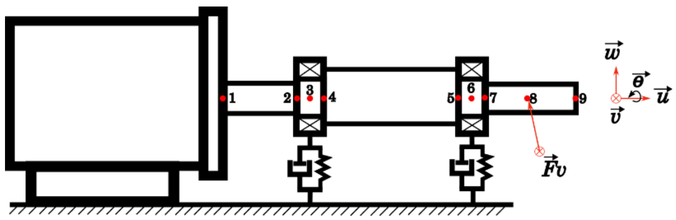

Figure 1. Model for experimental SURVIB Bench

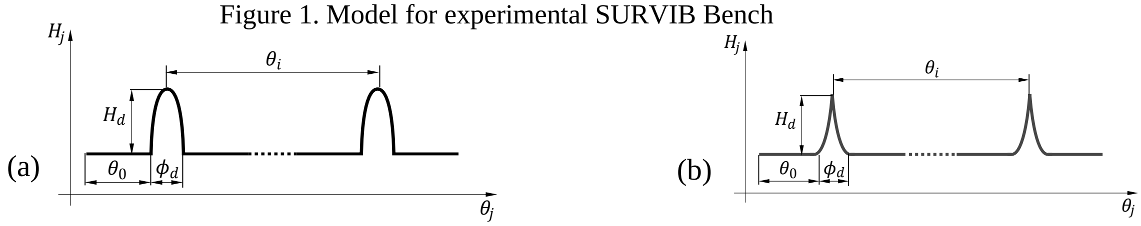

Figure 2. Fault excitation profile (a) Half Sine excitation Model, (b)Two-Arc excitation Model

Two fault excitation models are used: HSM (Figure 2.a) and TAM (Figure 2.b); ϕ_d is the angular value of the defect, θ_0 is the angular position of the defect. H_j is the time varying penetration into the defect and H_d the maximum value.

2 Results and analysis

The results (Figure 3 and Figure 4) show that by incorporating contact damping into the model, it is possible to track the fault severity and speed, although the trend is not as close to the experimental results since the model does not incorporate saturation aspects when the severity becomes high. Let's use the Absolute Monotonicity Index (AMI) and the Relative Monotonicity Index (RMI) to quantify monotonicity score.

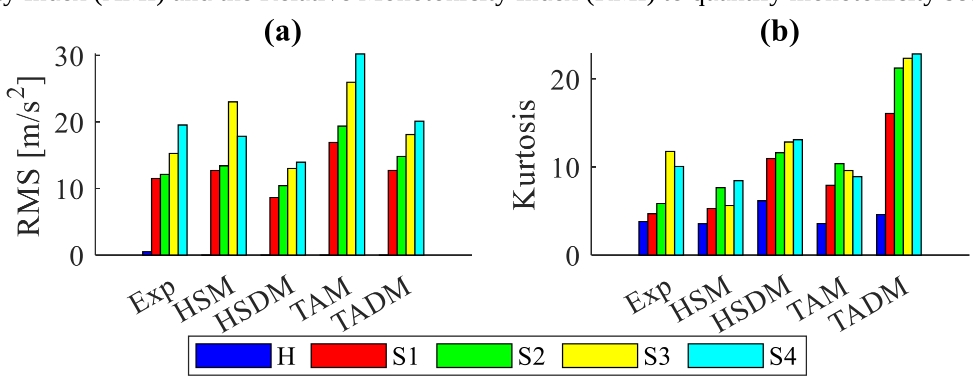

Figure 3. Defect size monitoring (at 1000rpm-3.5kN) (a) by RMS;(b) by Kurtosis ,for H-healthy, S1:1.3mm, S2:1.7mm, S3:2.3mm , S4:2.5mm.

The kurtosis, if damping is not considering the HSM scores for AMI = 0.5 and the TAM for AMI = 0.67 compared with the experimental results. The addition of damping makes possible to increase AMI to score 1 in both cases (HSDM and TADM) and RMI to 0.75. Regarding the RMS, the experimental is monotonic, the HSM is for the first levels monotonic, the contribution of the damping corrects the deviations and the tendency. The observation of the TADM profile having corrected the trends and the global deviation for the four severities. The speed trend observation is monotonic for the damped models, despite more deviation in the kurtosis observation, which requires more consideration of nonlinearities in the speed contribution.

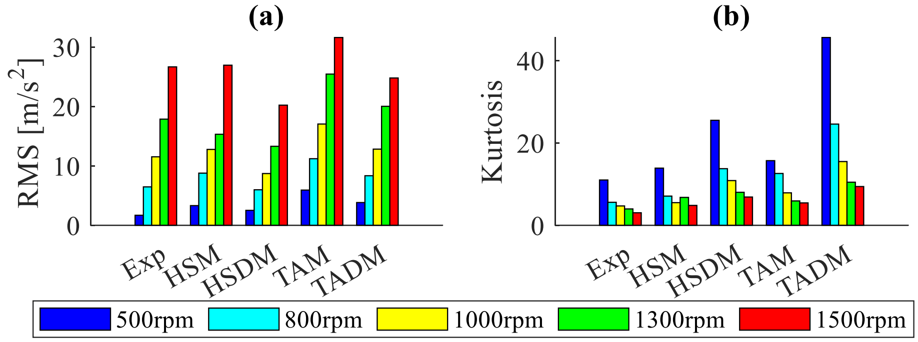

Figure 4. Speed Monitoring for defect size 1.3mm an Load 3.5kN (a) by RMS (b) by Kurtosis

3 Conclusion

It has been shown that considering damping improves fault tracking in the model and allows monitoring with the RMS and Kurtosis indicators under various speed conditions. This approach answers the question of trend monitoring, however some improvements are recommended, such as recalibrating the model parameters to compensate for any deviations and considering other phenomena, such as lubrication.

Acknowledgments – Funding

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References

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A unified framework for nonlinear vibrations of cables

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Abstract

A slender structure that resists due to its internal axial force is coined as cable [1]. We propose here a unified framework that spans from Lagrangian mechanics to nonlinear dynamics. General cable equations read

$$\rho \ddot{\mathbf{R}} + 2\mu \dot{\mathbf{R}} = EA \left((\|\mathbf{R}'\| - 1) \frac{\mathbf{R}'}{\|\mathbf{R}'\|} \right)' + \mathbf{b} \tag{1}$$

ρ : mass density, $\mathbf{R}$: cable position, μ : damping coefficient, EA : axial stiffness, $\mathbf{b}$: external forces

The latter are used to derive static equilibrium, modal analysis and dynamic computation in a compact manner [2]. Historical results [3, 4] are recalled and used to depict a general methodology that allows a wide scope of cable applications using reduced-order models obtained from Ritz-Galerkin procedure as

$$\mathbf{M}_{jk} \ddot{\varphi}_k + \mathbf{C}_{jk} \dot{\varphi}_k + \mathbf{K}_{jk} \varphi_k + \mathscr{Q}_{jkl} \varphi_k \varphi_l + \mathscr{C}_{jklm} \varphi_k \varphi_l \varphi_m = \mathbf{f}_j \quad , \quad 1 \leqslant j \leqslant N \tag{2}$$

φ_k : k^{th} modal coordinate, $\mathbf{M}$: mass operator, $\mathbf{C}$: damping operator, $\mathbf{K}$: linear stiffness operator, $\mathscr{Q}$ quadratic stiffness operator operator, $\mathscr{C}$: cubic stiffness operator, $\mathbf{f}$: forcing vector

Eventually some comparisons with finite element simulation [5] will be presented to conclude on the validity of the approach.

Keywords: Cable mechanics, Cable nonlinear dynamics, Modal projection

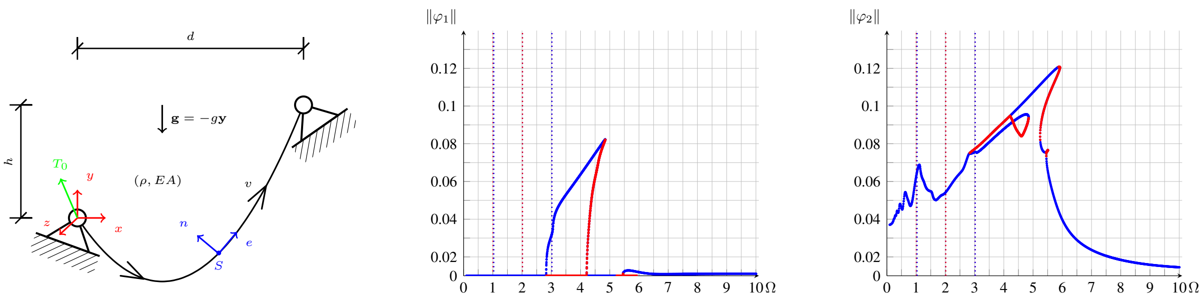

Figure 1: Frequency response of the 1st and 2nd modes of a translating cable (·····) Stable and (·····) Unstable solutions

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Bistable unit-cell, from the characterization of a single element to a lattice
SURVISHNO Conference 2025

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Abstract

Multistable systems, such as buckled beams, are attracting growing interest in the field of elastic metamaterials. At the scale of a bistable unit cell, we generally observe a double-well potential characterized by an unstable state between two stable regions. This intrinsically non-linear potential induces amplitude-dependent stiffness, which can be negative. Assembled in a network, these cells form a medium favourable to the propagation of nonlinear waves, such as solitons or transition waves. While the propagation of transition waves has been successfully studied, the response of these flexible metamaterials to periodic or sustained excitations remains less explored.
In the context of the ANR project ExFLEM (Exploiting Extreme Wave Events in Nonlinear Flexible Elastic Metamaterials), we are studying the mechanical behavior of an array of bistable cells to analyze and exploit wave phenomena localized in time and space. Initially, we focus on the study and characterization of a single cell under quasi-static and dynamic loading, with a particular focus on losses. The quasi-static response is measured by tensile-compression tests coupled with displacement field analysis, in relation with the Euler-von Kármán beam model. The dynamic response, marked by Duffing-type softening in a weakly non-linear regime, is analysed via a frequency response function using a shaker together with accelerometers.
In a second step, we extend the analysis to a network of bistable cells connected by linear springs, subjected to harmonic excitation. We first present a model/test comparison of the mechanical response of a system coupling two elementary cells, before showing some preliminary observations concerning the propagation of weakly non-linear waves in a periodic network containing a finite number of elements.

Keywords
Bistability, nonlinear, buckling, vibrations, metamaterial

May 21th, 16h30 - 17h15 : Session Experimentations in structural dynamics, Amphitheater N. BLANC

Robust camera-based vibration measurement in outdoor conditions using Line Segment Tracking **16h30**

Yunhyeok HAN[1], *Stefania LO FEUDO* [1], *Gwendal CUMUNEL*[2], *Franck RENAUD*[1]
[1] Quartz Laboratory (EA7393), ISAE - Supméca, France [2] Lab Navier, Gustave Eiffel University, ENPC, France

Versatile measurements tools for the dynamical characterization of a bridge assembly **16h45**

Nicolas LECONTE, Martin GHIENNE, Nicolas PEYRET
Institut supérieur de mécanique de Paris (ISAE-Supméca), France

Rotating Machine unstable operation detection using Dragonfly sensors **17h00**

Vincent BOUILLET[1], *Sylvain FUSARO*[2]
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Robust camera-based vibration measurement in outdoor conditions using Line Segment Tracking
SURVISHNO Conference 2025

Yunhyeok HAN[1*], Stefania LO FEUDO[1], Gwendal CUMUNEL[2], Franck RENAUD[1]

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Abstract

This research introduces and validates a camera-based vibration measurement technique called the Line Segment Tracking (LST) method, specifically designed for robust vibration measurement of large structures in complex and varying outdoor conditions. Traditional subset-based methods, such as Digital Image Correlation (DIC) and Lucas-Kanade Optical Flow (LKOF), are widely used to track feature points on an image sequence. However, these methods are often sensitive to noise due to disturbances within the image subset. Instead of analyzing all pixels in the subset, the LST technique estimates displacement by following the movement of points that are the intersection of tracked line segments. The main idea behind line segment tracking is the application of a modified LKOF algorithm to uniformly discretized points along the line segments detected by the line segment detector, in order to find the rigid body motions of the line segments in the image coordinates.

Synthetic images are used for error quantification and parametric analysis to understand the sensitivity of the method to key parameters. Subsequently, an experimental validation is carried out under controlled laboratory conditions. The LST method is further validated through a field study by measuring the displacement of a tower crane under real outdoor operating conditions. The tower crane test presented challenges due to disturbances near a feature point where a 3-axis accelerometer was also installed. A comparative analysis is conducted with the results of established methods such as DIC and LKOF. Finally, the results obtained from the proposed method are validated with the data collected from the 3-axis accelerometer.

Keywords

Line Segment Tracking; Digital Image Correlation; computer vision; vibration measurement;

Versatile measurements tools for the dynamical characterization of a bridge assembly

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Abstract

Experimental characterization remains essential for both the analysis of existing crossing structures (Structural Health Monitoring, maintenance, damage detection, etc.) and the development of new technologies (connectors, wooden structures, etc.). However, setting up such experiments is often complex, particularly for large structures [1]. This study is part of the ANR-PRCI project between France and Taiwan: NEMELIFT (Neutral Equilibrium Mechanisms and Smart Lightweight Footbridges for Urban Ecomobility). The project aims to develop innovative technologies dedicated to urban mobility, temporary installations, and disaster relief operations.

This work presents a methodology for the efficient characterization of an assembled bridge structure based on experimental measurements. This study considers an experimental setup made of two 15-meter steel beams connected using a non-standard joint for a total of 22 tones (Figure 1). Different load cases are considered: static tests, hammer impact tests and drop tests to induce higher amplitude responses. This approach is particularly advantageous for weakly damped structures, in temporal analysis with displacement measurement as it enhances temporal data accuracy due to the high magnitude of excitation. Measurements are recorded using accelerometers, lasers, and finally, a set of cameras, providing a full-field displacement analysis, a significant improvement over conventional methods. The results demonstrate that drop tests are applicable for large and heavy structures with low-frequency modes and high stiffness. The applicability of this non-destructive method testing method to structures heavier than the one studied remains an interesting question.

By offering a cost-effective and practical alternative, this methodology provides new possibilities for the characterization of slender lightweight large-scale structures. Its adaptability makes it particularly relevant for bridges and similar infrastructures, where accurate dynamic assessment is critical for design validation, maintenance, and long-term monitoring.

Keywords: Assembled structure, bridge, drop test, experimental characterization

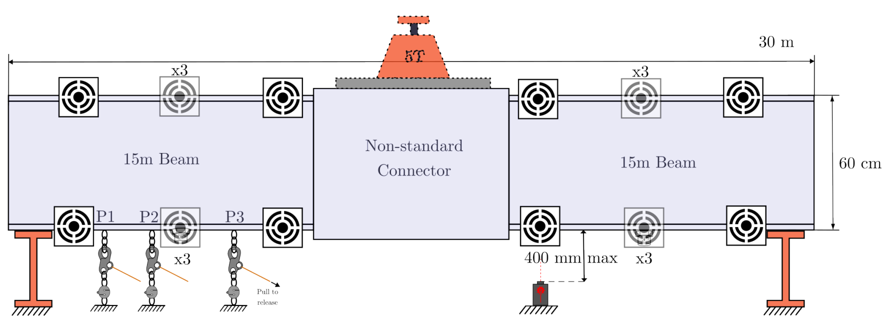

Figure 1: Assembly model and drop test setup

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Rotating Machine unstable operation detection using Dragonfly® sensors
SURVISHNO Conference 2025

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Abstract

This document details a case study of a 1936 600 MVA Shock Moto Generator equipped with hydrodynamic bearings known for their ability to handle high radial forces. The main objective is to analyse and resolve an instability encountered during an attempt to increase the rotating speed, leading to "oil whirl" and "oil whip" phenomena. The study highlights the use of Dragonfly® sensors for precise deformation measurements, and compares the performance of Dragonfly® sensors with conventional methods, emphasizing their ability for monitoring hydrodynamic bearings, particularly at low frequencies. It is demonstrated that Dragonfly® sensors are capable of diagnosing whirl and whip, and could therefore be used for early warning or machine shutdown, using a picture of stress instead of a picture of shaft or bearing displacements.

Keywords

F-Lab, Hydrodynamic bearings, Strain, Deformation, Oil whirl & Whip, Motogenerator

May 21th, 16h30 - 17h15 : Session Nonlinear Dynamics, Amphitheater G. INGLEBERT

Flutter of Flexible Wings: A High-Speed Video Investigation **16h30**

Florian MAETZ [1,2], Franck RENAUD [1], Jean-Luc DION[1], Benjamin CHOUVION[2], Annie LEROY[2]

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Optimisation and performance comparison of direct and parametric piezoelectric energy harvester with geometrical nonlinearities **16h45**

Hugo FAYOLLE[1], Christophe GIRAUD-AUDINE[2], Olivier THOMAS[1]

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Phase resonance measurement of conservative nonlinear modes of highly flexible structures and damping estimation **17h00**

O. Thomas[1], M. Debeurre[1], C. Giraud-Audine[2], A. Grolet[1] and S. Benacchio[1]

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Flutter of Flexible Wings: A High-Speed Video Investigation

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Abstract

The aerodynamic flutter of flexible wings presents a significant challenge in the design of High Altitude Long Endurance (HALE) drones. These vehicles typically feature large wingspans to facilitate sustained flight at high altitudes and maximize endurance. However, this increased wingspan makes the wings more susceptible to aeroelastic flutter, a dynamic instability that can be both detrimental and potentially destructive.

To gain a deeper understanding of this phenomenon, the objective is to develop a metrology capable of measuring large three-dimensional displacements, enabling the identification of nonlinear modes associated with limit cycle oscillations and, ultimately, the extraction of the aerodynamic forces responsible for the flutter. This metrology integrates data assimilation obtained from high-speed video recordings, combined with a beam model that accounts for geometric nonlinearities related to moderate rotations.

Data acquisition is conducted using a Kalman filter, which leverages the underlying physics of the model to estimate quantities from the measured data. The initial step involves evaluating various models to determine their fidelity in representing real-world behavior. Two models of particular interest are the first, a beam model with approximately 20 unknowns designed to accurately describe the wing, and the second, a multibody system that models beam compliance via torsion springs, but with a higher number of unknowns. A finite element model is used as a reference to compare these models. Establishing a reliable model is crucial for accurately estimating 3D displacements, which is essential for tracking purposes. Notably, tracking patterns exhibit significant displacement between consecutive frames, even when utilizing high-speed cameras operating at 160 Hz. This discrepancy is attributed to the frequency and amplitude of the flutter. An accurate model will aid in improving the Digital Image Correlation (DIC) tracking algorithm.

Wind tunnel experiments were conducted on a scaled-down slender beam, capturing the beam's responses to various angles of attack and wind speeds through video sequences. Modal analysis was performed on the static responses, providing insight into the evolution of modal frequencies and shapes. The dynamic response induced by flutter was also recorded, though post-processing remains challenging. It is anticipated that preliminary results will be presented in the near future.

Keywords:

Nonlinear dynamic, Video analysis, Data assimilation, Flutter

Optimisation and performance comparison of direct and parametric piezoelectric energy harvester with geometrical nonlinearities
SURVISHNO Conference 2025

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Abstract
Comparison of behaviors and performances between large amplitude nonlinear direct and parametric shunted piezoelectric energy harvesters (PEH) is carried out. A model of geometrically exact piezoelectric laminated beam with parametric excitation is proposed and simplified with Euler-Bernoulli and inextensible assumptions, Taylor series expansion of transverse displacement and truncation, and first-mode Galerkin expansion. A cantilever beam with two collocated patches is then considered and patches placement and geometry are computed based on coupling-factor optimization. Analytical and numerical resolution methods are compared. PEH behaviors and performances are compared regarding the dissipated power in the resistor at resonance. Three cases are considered: linear-direct, nonlinear-direct and nonlinear-parametric. Results show a great influence of nonlinearities for a parametric PEH and that harvested power under parametric excitation cannot compete the one under direct excitation.

Keywords:
piezoelectric energy harvester, geometrical nonlinearities, laminated structure, piezoelectric transducer, large rotation, parametric excitation, pertubation methods

Phase resonance measurement of conservative nonlinear modes of highly flexible structures and damping estimation

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We address in this communication the use of phase resonance testing, practically realised by phase lock loop experimental continuation of periodic solutions, to measure the conservative backbone curves of a geometrically nonlinear structure. We focus on highly flexible structures, such as cantilever elements, for which the transverse stiffness is related only to bending, without additional nonlinear stretching effects such as in plates, shells or axially restrained 1D structures. In this case, the geometrical nonlinearity is weak and noticeable only at very large amplitude. The communication will show that phase resonance testing is a way of measuring the nonlinear modes of a structure independently of damping effects and their nature (linear, nonlinear etc.), provided it is smooth. Then, by monitoring the input forcing, it is possible to estimate the damping law as a function of the amplitude of the motion [1].

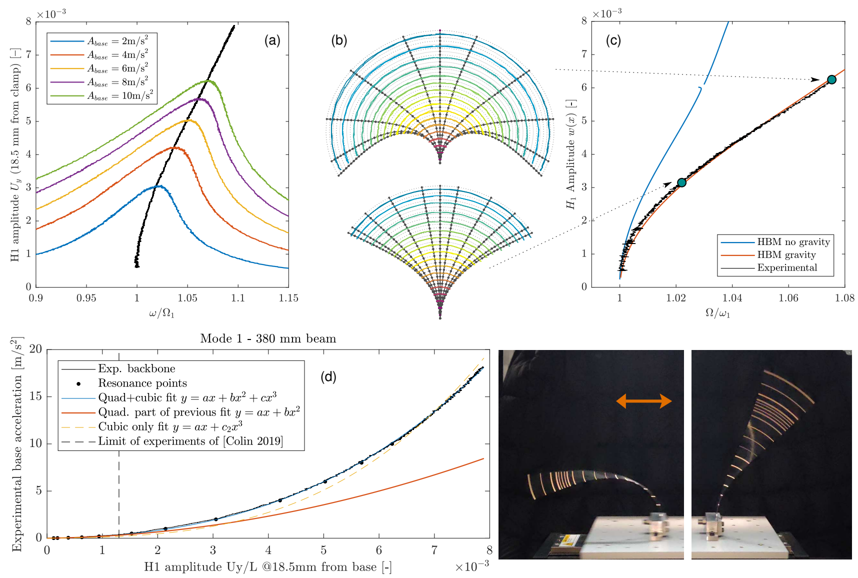

Figure 1: (a) Experimental frequency response of the first mode of a cantilever beam, obtained by phase lock loop. (b,c) Theory vs. experiments for the backbone curve & nonlinear mode shapes. (d) Estimation of the damping evolution as a function of the amplitude along the backbone curve.

References

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May 22th

May 22th, 09h00 – 10h00

PLENARY 2, Amphitheater N. Blanc

From Noise to Insight: Turning Instantaneous Angular Speed Variability into Diagnostic Power)
Hugo ANDRÉ
Laboratoire d'Analyses des Signaux et Procédés Industriels (LASPI)

May 22th, 10h00 - 11h00 : Session Rotating Machinery, Amphitheater N. BLANC

Towards Automated Gear and Bearing Fault Diagnosis Using Evolving Frequency Signatures — **10h00**
Anas Had, Mohamed Habib Farhat, Hugo André
Université Jean Monnet Saint-Etienne, IUT de Roanne, LASPI, UR, Roanne, France

Bearing Fault Diagnosis Based on IAS-LSTM Neural Networks Model — **10h15**
Djihene DJEGHLOUD, Jean-Paul DRON
Université de Reims, France

Cyclicity restoration of bearing signature in vibration-based condition monitoring: the case of the rolling elements — **10h30**
Adrien MARSICK, José-Luis GOMEZ CHIRINOS, Julien GRIFFATON
SAFRAN, France

Predictive Maintenance of Bearings Based on Damage Modeling and Vibration Data: Interest of a Phenomenological Damage Law — **10h45**
Teddy KAYALA[1,2], Xavier CHIEMENTIN[1], Fabrice BOLAERS[1], Hubert KAZADI[2], Bovic KILUNDU[3,4]
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Towards Automated Gear and Bearing Fault Diagnosis Using Evolving Frequency Signatures

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Abstract

Timely and accurate detection of mechanical faults in rotating machinery, such as gears and bearings, is crucial for effective predictive maintenance and ensuring reliable operational performance. Diagnostic methods typically fall into two main categories: time-domain indicators, which utilize statistical metrics extracted directly from vibration signals, and frequency-domain analyses, which concentrate on specific frequency characteristics. Time-domain techniques are particularly useful to evaluate the overall machinery's condition when faults significantly impact vibration signals, while frequency-domain methods typically used to identify fault-specific frequency patterns, enabling precise localization and characterization of faults such as gear tooth damage or bearing defects. However, it requires detailed knowledge of frequency signatures associated with specific faults. This study introduces a novel diagnostic approach aimed at reliably associating frequency components observed in vibration signals with specific mechanical defects. Initially, the proposed method evaluates long-term spectral data (LTSD) to pinpoint frequency channels exhibiting evolving trends over time. After statistically identifying these evolving frequencies, they are systematically matched to established fault-frequency models available in literature, which outline the characteristic frequencies associated with gear and bearing defects. Considering the complexity introduced by overlapping frequency signatures from multiple mechanical faults. The proposed method incorporates a frequency-affiliation process that assigns probabilities, explicitly linking evolving frequency components to the most likely mechanical faults. Additionally, to address frequency shifts caused by non-synchronous defects, such as those typically found in bearings, the strategy employs adaptive tracking techniques. These techniques dynamically adjust to frequency shifts, thereby ensuring consistently accurate fault detection despite operational variability. Comprehensive experimental validation using real-world data demonstrates the robustness and practical effectiveness of this proposed approach. By ensuring accurate fault identification and ease of interpretation, this diagnostic method significantly enhances reliability in predictive maintenance practices.

Keywords

Rotating Machinery, Predictive Maintenance, Bearings

Bearing Fault Diagnosis Based on IAS-LSTM Neural Networks Model

SURVISHNO Conference 2025

Djihene DJEGHLOUD[1], Jean-Paul DRON[2]

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Abstract

This research presents a novel approach using Long Short-Term Memory (LSTM) neural networks for fault diagnosis in rotating machinery by classifying Instantaneous Angular Speed (IAS) signals. IAS signals are highly sensitive to mechanical changes and are particularly effective in low-speed conditions where traditional vibration signals face challenges due to low energy levels. While all the existing ML and DL models adopt vibration signals. Our study demonstrates the significant advantages of deep learning models, specifically LSTM networks, in utilizing raw IAS signals without extensive feature extraction, thereby preserving critical signal information. High-resolution IAS signals are experimentally obtained using an optical encoder under various operational conditions (speeds, loads, and defect sizes). These raw signals, analyzed in both time and frequency domains, are treated as time series data, and used to train and test the proposed LSTM model particularly suited for time-sequential data. multiple classification scenarios are designed: binary, three-class, and multi-class. Initial experiments achieved a fault detection accuracy of 100% for scenarios with same operational parameters. When evaluating six defect severity levels, the classification accuracy was 97.06% with raw signals, compared to 71.86% for 1mm faulty bearings, and using traditional statistical feature extraction methods. These findings underscore the effectiveness of LSTM model for anomaly detection and classification in raw time-series sensor data, demonstrating the transformative potential of DL in machine condition monitoring. This opens new avenues for research on AI techniques leveraging IAS signals.

Keywords

Bearing fault diagnosis; LSTM; Instantaneous Angular Speed; rotating machinery; Raw Data; IAS signals; time-series data; Low Rotation Speed; Deep learning.

Acknowledgments – additional information

This research is financially supported by the university of Reims Champagne Ardenne.

Cyclicity restoration of bearing signature in vibration-based condition monitoring: the case of the rolling elements SURVISHNO Conference 2025

Adrien MARSICK[1], José-Luis GOMEZ CHIRINOS[2], Julien GRIFFATON[3]

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Abstract

Rolling element bearings are critical components in rotating machinery. Vibration-based diagnosis is often based on the cyclostationary properties of the fault signature, whose periodicity is modelled by well-known characteristic frequencies (BPFO, BPFI, FTF and BSF). To account for variable speed, the analysis is usually performed in the angle frequency domain with respect to the rotation of the shaft. However, it is well known that the signature cyclicity is often desynchronised from the shaft rotation due to slippage. This effect can severely limit the performance of diagnostic methods.

Recently, it has been shown that the cyclic properties of outer and inner ring fault signatures can be restored using cage rotation as an angular reference. Indeed, rings signatures are linked to the relative motion of the train of rolling elements with respect to the rotation of the rings. However, this is not the case for rolling element defects as their spin frequency is not trivially related to the cage rotation due to slippage.

There is a need to develop methods dedicated to restoring the cyclicity of the vibration signature associated with defective rolling elements. As with all angular approaches, the method depends on the availability of an estimate of a reference rotation to restore the cyclicity. An approach to estimate the appropriate ball spin frequency is presented. The estimation does not require additional sensor. The differences between the cage and rolling elements rotation references are highlighted. The case of multiple defective rolling elements is addressed, highlighting the different synchronicity of each rolling element rotation. With the knowledge of appropriate ball spin frequencies, condition indicators can be derived allowing a previously impossible automatic monitoring. The method is applied to industrial signals from a commercial jet engine with damaged rolling element.

This original approach allows automatic early detection of defective rolling elements, opening up perspectives for further investigations into the complex kinematics of rolling element bearings. While particularly severe in jet engine applications, the adverse effects of slippage are common for nonstationary operating rotating machinery and the proposed method is of interest for other applications.

Keywords

Vibration, condition monitoring, cyclostationarity, slippage

Predictive Maintenance of Bearings Based on Damage Modeling and Vibration Data: Interest of a Phenomenological Damage Law

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Abstract

An accurate estimation of the remaining useful life (RUL) of bearings is critical, as their failure is one of the main causes of breakdowns in rotating machinery. This study introduces a phenomenological spalling law for prognostics based on a model that integrates vibration data. Using an Extended Kalman Filter (EKF), the trajectory of the vibration indicator is dynamically adjusted. Data from the PRONOSTIA platform validated this approach, particularly under the influence of added Gaussian and gamma noise. The results demonstrate a significant improvement in accuracy compared to a conventional exponential modeling approach.

Keywords

Bearings, Prognostic, Damage law, Vibrations

1 Introduction

Bearings account for 40–50% of rotating machinery failures [1]. Among their failure modes, fatigue-induced spalling is the most prevalent [2]. Methods for predicting the Remaining Useful Life (RUL) of bearings rely on data-driven approaches, physics-based models, or their combination [2]. Purely data-driven methods [3] are adaptive but may lack precision. In contrast, physics-based models offer higher accuracy but involve greater complexity [4]. A hybrid approach combines the strengths of both [5].

This study integrates a phenomenological damage model with adaptive techniques using the Extended Kalman Filter (EKF) [6]. The goal is to improve RUL prediction accuracy while evaluating robustness under varying noise levels. Validation is conducted using data from the PRONOSTIA platform [7]. The bearings have a 0° contact angle. The first digit of their designation denotes the test condition, while the second represents their sequence number. Spalling in the bearings occurred naturally.

The method relies on a degradation model derived from Paris' theorem [8] and Hertz theory [9]. The degradation equation (Eq. 1) incorporates the equivalent stress σ_{eq} and the number of rotation cycles N. The health indicator (HI), linked to spall size, follows a power-law model with three parameters ϵ, η, and ζ, where HI_0 denotes the initial indicator level. An EKF dynamically updates the model parameters using vibration measurements. The equivalent stress is calculated based on the maximum normal stress σ_{max} and shear stress τ at the Hertz critical depth (Eq. 2). A slope detection criterion determines when tracking the remaining useful life becomes relevant. To test the robustness of the approach, Gaussian and gamma noise were added to the PRONOSTIA platform data at different signal-to-noise ratios (SNR).

$$HI = \epsilon {\sigma_{eq}}^{\eta} N^{\zeta} + HI_0 \tag{1}$$

$$\sigma_{eq} = ({\sigma_{max}}^2 + 3\tau^2)^{1/2} \tag{2}$$

2 Results

Figure 1 illustrates the effects of additional noise on the prognostic for Bearing 1_5. The impact of the initial values of parameters ϵ, η et ζ on prognostic accuracy is evaluated in Figure 2.

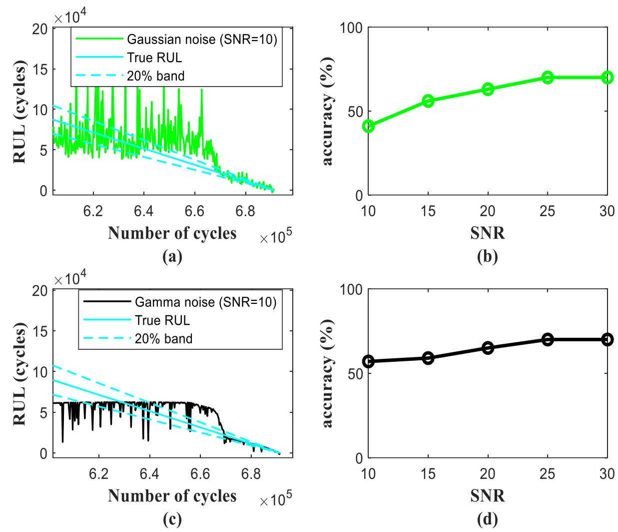

Figure 1: Additional noise effect: (a) and (b) Additional gaussian noise; (c) and (d) Additional gamma noise

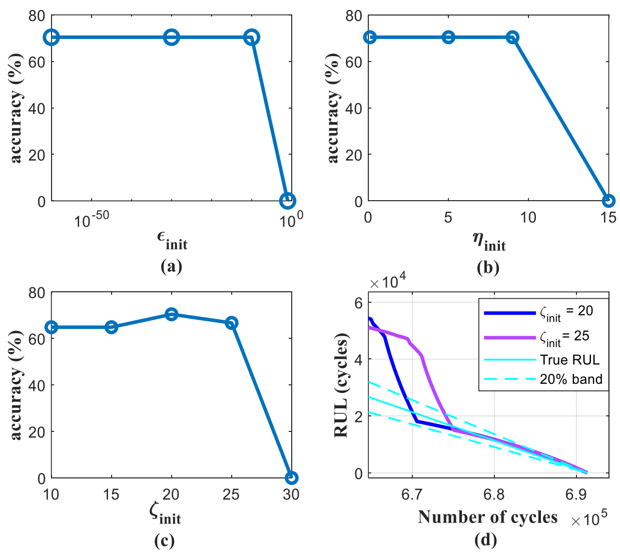

Figure 2: Effect of initial values on RUL accuracy (bearing 1_5): (a) Case of ϵ; (a) Case of η; (a) Case of ζ; (c) RUL predictions for ζ=20 and ζ=25

The model's performance was compared (Table 1) to a classical exponential law approach for bearings 1_3, 1_4, 1_5, 1_6, 1_7, and 3_3 **[10]**. Prediction accuracy is the ratio of predictions within ±20% of the exact RUL to the total predictions in the last 500 seconds.

Bearing No.	Proposed approach	Classical exponential approach
1_3	99 %	96 %
1_4	88 %	100 %
1_5	70 %	46 %
1_6	74 %	54 %
1_7	61 %	40 %
3_3	79 %	56 %

Table 1: Comparison of Prognostic Accuracies

3 Analysis

Figures 1(a) and 1(c) show that fluctuations caused by additional noise diminish as predictions align with the exact RUL. Figures 1(b) and 1(d) indicate that accuracy decreases on average by 2.39% per dB with additional Gaussian noise and by 0.99% per dB with additional gamma noise. Table 1 highlights an improvement in accuracy in all cases except for bearing 1_4. This case reflects a trade-off between a smaller data volume and a less steep HI trend. Results in Figures 2(a), 2(b), and 2(c) suggest setting the initial values as follows: $\epsilon_{init} \ll 0.1$, $\eta_{init} < 10$, and $\zeta_{init} \leq 25$. Within these ranges, accuracy remains stable for ϵ_{init} and η_{init}. However, variations in ζ_{init} impact accuracy, as depicted in Figures 2(c) and 2(d).

4 Conclusion

The results show significant improvements in Remaining Useful Life (RUL) prediction accuracy compared to the classical model based on exponential degradation. The model's robustness against additional noise, whether Gaussian or gamma, highlights its potential. However, a decrease in accuracy under high noise levels emphasizes the need for future developments to enhance the resilience of the approach.

In the future, this approach could be extended to variable operating scenarios, given that the damage model accounts for loading through equivalent stress and rotational speed through the number of cycles. Furthermore, the integration of new vibration indicators and the assessment of defect size could further enhance this method and broaden its application in predictive maintenance.

Acknowledgments – additional information

The authors wish to express their sincere gratitude towards French embassy in DRC for funding this study through French government scholarship program within T.K PhD thesis.

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May 22th, 10h00 - 10h45 : Session Digital Twin, Amphitheater G. INGLEBERT

Real-time digital twin for vehicle dynamics **15h00**
André BUCKENMEYER[1,2], Jean-Luc DION[1], Frank RENAUD[1], Laurent ROTA[2]
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A neural network based model of a yaw damper for nonlinear multibody simulations **15h15**
Betty AUZANNEAU[1,2], Emeline SADOULET-REBOUL[1], Emmanuel FOLTETE[1], Guillaume HAM-LIVET[2], Scott COGAN[1]
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Digital twin of a vibrodriver to estimate the force transmitted on the test bench **15h30**
Antonio BALDASSARRE, Jean-Luc DION, Franck RENAUD
1Laboratoire Quartz ISAE-Supméca, Saint-Ouen, France

REAL-TIME DIGITAL TWIN FOR VEHICLE DYNAMICS

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Abstract

The accurate estimation of wheel center forces is essential for durability assessment, predictive maintenance, and chassis control strategies. Current methods rely on instrumented test vehicles with expensive and intrusive sensors, such as Wheel Force Transducers (WFTs), which are prohibited on public roads. This limits real-world data collection. A real-time embedded approach is needed to enable continuous monitoring under real driving conditions. It would improve the characterization of driver usage patterns and refine the definition of a representative driver for specification documents, leading to better vehicle design. Previous work reconstructed wheel forces using nonlinear multi-body models with Augmented and Constrained Extended Kalman Filters (ECKF) [1]. These methods, while effective in controlled environments, are too computationally intensive for real-time execution on embedded vehicle architectures. A more efficient solution relies on detecting and characterizing vehicle life situations, where simplified models can provide accurate force reconstructions. Earlier research classified obstacles using extracted variables and threshold-based systems, as well as identified characteristic road behaviors through multi-sensor analysis. Recent studies explored Finite Impulse Response (FIR) models combined with Ridge Regression, using onboard accelerometers and suspension travel sensors to estimate vertical wheel forces [2, 3]. This research builds on these models, introducing a dual-prediction approach: force estimations are validated against both predicted values and measured signals to determine the current vehicle life situation. Beyond validation, this research aims to improve force prediction accuracy by detecting hyperparameter variations. Factors such as onboard mass, center of gravity shifts, and suspension aging influence wheel center forces. Integrating adaptive correction schemes will enable a self-calibrating real-time digital twin that continuously adjusts its models to account for these evolving parameters. The final goal is to deploy and test this estimation framework on an embedded computing platform, ensuring compatibility with edge-computing constraints.

Keywords:

Digital Twin, Vehicle Dynamics, Real-Time Processing, Edge Computing, Signal Estimation, Wheel Center Loads

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A neural network based model of a yaw damper for nonlinear multibody simulations

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Abstract

In the railway industry, digital twins based on nonlinear multibody simulations are developed to provide decision-making support for bogie design. A recurring question in implementing these simulations concerns finding an acceptable compromise between model complexity and computational burden for the different bogie components so as to guarantee a sufficiently accurate representation of the global dynamic behavior of train. Commercial codes implementing physics-based approaches generally rely on rheological models, with more or less complex assemblies of basic elements such as stiffness and damping. However, this type of model may not accurately represent the components behavior if part of the physics is thus left out of the modeling process, because the model's characteristics do not account for magnitude or frequency dependencies. The work presented here explores the viability of using a purely mathematical black-box model in place of a rheological model as a subcomponent of a complex structure during the simulation phases. Since the excitation at the component's interface is presumed to be unknown, this constraint forces us to define a model that is completely independent of it. The approach adopted is based on multi-layer perceptron (MLP) neural networks. This kind of model has the advantages of low computation costs and full consideration of the behavior physics. In a first step, we determine a MLP neural network architecture based on the displacement, velocity and acceleration at the component's interface, which are determined at the current time step, and allowing to calculate the interface forces. The limitations of this model lead us to modify the inputs to this network by adding data from the previous time step, thus transforming the MLP network into a nonlinear autoregressive exogenous model (NARX). Both approaches have been applied to a real yaw damper mounted on the motor bogies of high-speed trains, for which a set of experimental measurements with multiple configuration test data is available.

Keywords

Data driven model, nonlinear multibody simulations, railway application

Digital twin of a vibrodriver to estimate the force transmitted on the test bench

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Abstract

Vibrodrivers are huge machines used to drive into the soil or extract a wide range of civil engineering construction elements by making them vibrate vertically. This vibration is produced by unbalanced hydraulic motors, thanks to the rotation of paired eccentric weights. The digital twin architecture consists of the 3-DOF nonlinear dynamic model of the machine, an augmented state extended Kalman filter and several sensors: two accelerometers and two inductive proximity sensors as revolution counters of the eccentrics. These sensors are essential for the proper functioning of the entire architecture. The torque of the hydraulic motors and the force transmitted by the vibrodriver are the unknown physical quantities of the model.

In this research work, the machine operation on the test bench is investigated. The vibrodriver dynamic model is completed by adding the 2-DOF dynamic model of the test bench, and by developing a simulator to reproduce the behavior of the sensors. These numerical tools are used to simulate the system dynamics under several operating conditions, and to generate virtual (synthetic) measurements. The digital twin effectiveness is then tested by feeding the Kalman filter with these virtual measurements. Numerical validation of the digital twin's performance is an essential prerequisite for experimental testing and must be carried out before using the real measurements acquired by the on-board sensors.

The digital twin can monitor the system in real time. The dynamic model and the Kalman filter are connected in a data assimilation process that provides information on system states and the force transmitted to the test bench by the machine, without any prior knowledge of the mentioned bench model. Following the numerical validation, the digital twin can be implemented by processing the actual signals recorded by the sensors during experimental tests. The correct estimation of the force exchanged with the bench is of fundamental importance to enable the application of the technique when the machine is working in the construction site. In fact, this work is part of a wider project, which focuses on developing a soil force identification tool to determine the nature of the soil layers crossed during pile driving.

Keywords

Digital twin, extended Kalman filter, multi-body systems, force estimation

May 22th, 11h45 - 12h45 : Session Rotating Machinery, Amphitheater N. BLANC

Exploring Innovative Ordinal Pattern-Based entropies for Multimodal Time Series Analysis in Bearing Diagnostics **12h00**

Elga Ossonemane-Asseko[1], Meryem Jabloun[2], Emmanuel Attal[1], and Philippe Ravier[2]
Orleans University, Signal Team of PRISME Laboratory (ER 4229), [1] IUT de Chartres, Chartres, France [2] Orleans, France

Operational Modal Analysis Improvement Through Operational-Based Normalization and Reconstruction of Nonlinear Cyclic Excitations in a Gearbox **12h15**

Mojtaba AHANI, Adeline BOURDON, Didier REMOND
Univ Lyon, INSA Lyon, CNRS, LaMCoS, Villeurbanne, France

Investigating Roller Bearing Faults Using Phase Permutation Entropy Applied to Acoustic-Vibration-Electrical modalities **12h30**

Elga Ossonemane-Asseko[1], Philippe Ravier[1], Emmanuel Attal[1], and Meryem Jabloun[2]
Orleans University, Signal Team of PRISME Laboratory (ER 4229), [1] IUT de Chartres, Chartres, France [2] Orleans, France

Physics-Informed Few-Shot Learning for Accurate Gear Wear Monitoring in Digital Twin Systems **12h45**

Roee Cohen, Lior Bachar, Jacob Bortman
BGU-PHM Laboratory, Department of Mechanical Engineering, Ben-Gurion University of the Negev, Israel

Exploring Innovative Ordinal Pattern-Based entropies for Multimodal Time Series Analysis in Bearing Diagnostics

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Abstract

The diagnosis of rolling element bearings (REBs) is essential for ensuring the safety and efficient monitoring of rotating machinery in industrial applications [2, 3]. This research investigates the potential of innovative ordinal pattern (OP)-based entropy measures to extract fault indicators from real multimodal REB signals. Specifically, acoustic and vibration data were acquired using microphone and accelerometer sensors placed in close proximity and direct contact with an engine test bench. Three types of roller bearings were analysed: one without faults and two others with varying degrees of faults. The study was conducted under noisy environmental conditions and across different rotating machine speeds.

We first examined the efficacy of local polynomial modelling-based permutation entropy (LPPE) in detecting bearing defects. Two polynomial bases, Legendre [4] and Laguerre, were compared, both yielding indicators highly correlated with bearing faults, even under varying speed and noise conditions. Notably, LPPE demonstrates sensitivity to both frequency bandwidth and amplitude changes while effectively avoiding aliasing. In addition, a comparative analysis was conducted with other multiscale permutation entropy (MPE) variants already applied to REB diagnosis, including refined composite downsampling (rcDPE) [9], amplitude-aware MPE (AAMPE) [5, 11], multiscale dispersion entropy (MDE) [7, 10, 12], and multiscale bubble entropy (MBE) [6, 8]. Among these, rcDPE proved particularly effective in identifying optimal downsampling rates for accurate fault detection. AAMPE and MDE, though sensitive to aliasing, were capable of detecting noise bandwidth and amplitude changes, while MBE demonstrated insensitivity to parameter settings.

Our findings underscore the superior effectiveness of polynomial-based PE methods in extracting reliable and interpretable fault indicators for REB diagnosis, offering a robust approach for condition monitoring under challenging conditions.

Keywords:

Fault diagnosis, Acoustic and vibration analysis, Experimental bench, Multiscale permutation entropy, Feature extraction, Laguerre and Legendre polynomial bases.

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Operational Modal Analysis Improvement Through Operational-Based Normalization and Reconstruction of Nonlinear Cyclic Excitations in a Gearbox

Mojtaba AHANI, Adeline BOURDON, Didier REMOND

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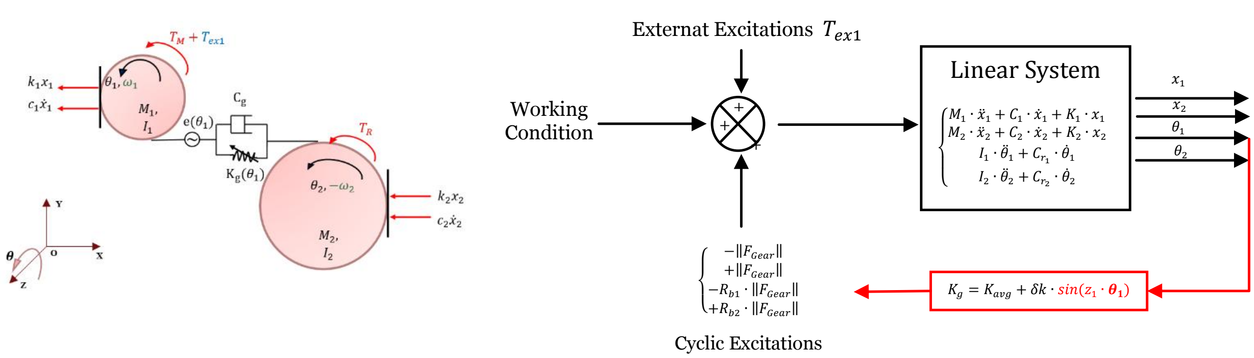
Abstract. Since as rotating machinery, the gearbox is an important source of vibration, the identification of signals and parameters of the component content of the gearbox is necessary for the monitoring of the system. Inside this mechanism, the rotation of elements with periodic discrete geometries (bearings, gears, turbines, ...) is the origin for potential excitations which are commonly cyclic. These excitations are therefore characterized by frequencies that evolve with rotation speed, that reconstructing them is equivalent to an inverse problem or an identification problem that can be treated using advanced techniques of operational modal analysis. The main problem is to separate the temporal and cyclically-periodic phenomenon, also to find the right external excitation conditions to reveal behaviors that are either resonances (a well-known linear problem and treated by identification) or internal cyclic excitations (less known and less well treated). The difficulty lies effectively in non-stationary operating conditions in the presence of the nonlinearity due to cyclic phenomena or coupling through rotating speed of the machine.

To describe the angle-related cyclic meshing due to gear a non-linear feedback function, $sin\left(f_{ev/rev} \cdot \theta(t)\right)$, the coupling of all the degrees of freedom is introduced through the gear mesh stiffness. A detailed comparative analysis of cyclic and harmonic excitation is presented in [2]. Figure [1] illustrates the academic model of one-stage transmission system considered to simulate the nonlinear dynamics of system in non-stationary operation. This academic system is composed of two discs linked together by a meshing stiffness and presenting two degrees of freedom in rotation and a linear stiffness-damping support on each disc offering two additional degrees of freedom in translation. The coupling between all the degrees of freedom is assumed by the meshing forces along the line of action of gears. In Figure [1], F_{Gear} is the cyclic gear mesh force as below, which is meant to be estimated:

$$F_{Gear} = K_g \cdot (R_{b1} \cdot \theta_1 + R_{b2} \cdot \theta_2) + C_g \cdot \left(R_{b1} \cdot \dot{\theta}_1 + R_{b2} \cdot \dot{\theta}_2\right) + K_g \cdot (x_1 - x_2) + C_g \cdot (\dot{x}_1 - \dot{x}_2) \tag{1}$$

$$K_g = K_{avg} + \delta k \cdot sin(z_1 \cdot \theta_1) \tag{2}$$



a) **b)**

Fig. 1. Block diagram of the system under consideration

Our research investigates non-stationary operating conditions to enhance identification performance. During various non-stationary operation scenarios, the system accelerates from an initial state to a high-speed level, causing the rotational frequency of the meshing order to sweep across a broad frequency range, from very low to high values (in Hz). This range encompasses all resonance frequencies of interest.

To capture temporal phenomena and system modal behavior, we employ a conventional Operational Modal Analysis (OMA) technique based on the Least Squares Complex Frequency (LSCF) estimator using a discrete-time z-model. The OMA is performed on the Order base of the system response [3]. However, the inherent nonlinear cyclic excitation and autoparametric effects introduce additional super-harmonics, as well as angle-periodic and time-periodic components in the system dynamics. Moreover, the presence of nonlinearity and signal non-stationarity violates the assumptions required for reliable performance of both the discrete Fourier transform (DFT) and the OMA technique.

To address these challenges, we develop a methodology that combines the Short-Angle Fourier Transform within an angular approach [1], along with proper normalization based on the governing operating regime. This approach enhances the estimated modal model of the structural dynamics of the rotating machine. Furthermore, by leveraging information on cyclic parameters—such as orders (e.g., number of gear teeth, ball pass frequency, etc.) and their locations—derived from the system structural design and geometry, we achieve a more accurate estimation of pure cyclic excitations. In Figure [2], the improvement of the normalized OMA, based on the spectrum of the order of a rotating system, is compared with the conventional OMA implementation using the Auto-power spectra obtained via DFT.

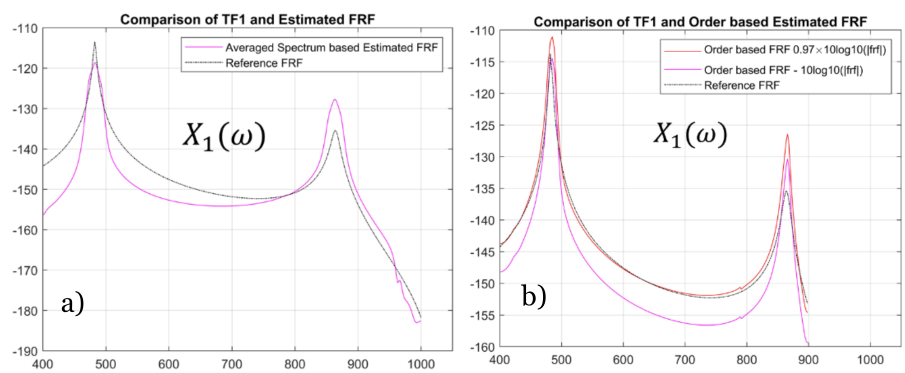


Fig. 2. OMA estimation of FRF to the first state X_1: a) Conventional implementation, and b) Normalized based on operation regime on the Order based

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Investigating Roller Bearing Faults Using Phase Permutation Entropy Applied to Acoustic-Vibration-Electrical modalities

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ABSTRACT

Reliable detection of common incipient faults in rotating machinery under varying speeds is essential for ensuring operational safety. To this end, this study investigates three signal modalities—acoustic, vibration, and electrical signals—using a complexity measure known as Phase Permutation Entropy (PPE). The three modalities were jointly acquired: acoustic and vibration signals were recorded using microphone and accelerometer sensors, respectively, placed in proximity and direct contact with an engine test bench. The electrical stator current was measured using current sensors on the three stator phases. The study was conducted under noisy environmental conditions and across varying rotating machine speeds.

The motivation for employing PPE to analyze these three modalities is based on two key aspects. First, it is commonly acknowledged that faults induce torque variations, causing nonlinearities to propagate from the fault source to the sensors, manifesting differently across each signal modality. Classical signal processing techniques, such as the Hilbert transform-based envelope detector, highlight fault-related information in the modulation bands of these signals. These modulations consist of oscillating multicomponent signals with nonlinear, time-varying phases. In this context, PPE—an extension of permutation entropy (a well-known ordinal-based complexity measure) to analytic signal phases extracted using the Hilbert transform —offers a dedicated tool for capturing and quantifying signal phase structures. Furthermore, evaluating PPE across the three modalities allows for a more comprehensive understanding of their relevance in distinguishing different types of faults.

By processing signals recorded from six types of roller bearings—one without faults and five with varying degrees of faults—the results show that PPE effectively differentiates and better characterizes fault severity compared to conventional methods. The defaults are damage on the outer race, on the inner race, on the rolling element, on the three previous defaults and a used rolling.

Keywords

Phase Permutation Entropy, Acoustic Emission, Stator Current, Vibration analysis, Roller Bearing Fault, Acoustic-Vibration-Electrical modalities.

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Physics-Informed Few-Shot Learning for Accurate Gear Wear Monitoring in Digital Twin Systems

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Abstract

Digital twins have the potential to revolutionize gear health monitoring by utilizing dynamic modeling and AI advancements to deliver real-time insights and support proactive maintenance. Wear is one of the most critical fault mechanisms in gears; however, vibration-based gear diagnosis has traditionally focused on localized tooth faults, as distributed wear presents significant challenges. This study introduces a novel approach for estimating gear wear severity using few-shot-learning, a methodology suited for applications with limited labeled data. The proposed method integrates machine-learning with physics-based models to enable accurate estimation of gear wear severity, even without extensive real-world data.

By leveraging simulated datasets generated through a validated dynamic model of gear vibrations, the few-shot-learning algorithm predicts gear wear severity across various machines and operating conditions. A key contribution of this study is the combination of data-driven and physics-informed models to enhance fault severity estimation in gear systems. The methodology is validated using a unique controlled-degradation test-rig, where wear-induced faults in spur gears propagate under controlled conditions. Experimental data, including vibration signals from gears under multiple wear severities, assesses the performance of the proposed algorithm. The simulated dataset is enhanced through domain-adaptation techniques, which address discrepancies between real and simulated data, reducing the simulation-to-reality gap and providing a robust training set.

The results demonstrate the few-shot-learning-based approach effectively predicts gear wear severity, achieving performance comparable to fully supervised regressors trained on abundant labeled data. The proposed model generalizes across different levels of gear wear and offers reliable severity estimation using minimal labeled data. Additionally, the anomaly detection stage, based on unsupervised health indicators, distinguishes healthy from faulty gears, enhancing the prediction model's robustness. This hybrid approach advances digital-twin development in gear systems, integrating synthetic with measured data for improved condition monitoring.

This work addresses challenges in condition-based maintenance, including the scarcity of labeled faulty data and the complexity of generalizing across different operating conditions. The findings suggest that learning offers a scalable solution for real-world gear wear monitoring.

Keywords

spur gear; wear; fault severity estimation; digital twin; few-shot learning; physics informed machine learning.

May 22th, 11h45 - 12h00 : Session Dynamics of NEMS and MEMS, Amphitheater G. INGLEBERT

Design and optimisation of a bioinspired Nano Air Vehicle with resonant vibrating wings **11h45**

Marguerite DE LA BIGNE[1,2], *Éric CATTAN*[1], *Sofiane GHENNA*[1], *Sébastien GRONDEL*[1], *Olivier THOMAS*[2]

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Design and optimisation of a bioinspired Nano Air Vehicle with resonant vibrating wings SURVISHNO Conference 2025

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Abstract

This work presents a new design and microfabrication of a bioinspired flapping-wing nano-aerial vehicle (NAV). Its basic structure is composed of two wings that are driven independently in vibration by coil magnet systems. Each wing is composed of two ribs, the leading edge and the trailing edge, connected by compliant links to the free end of a central beam, which acts as a motor. A very thin membrane is deposited between the leading edge and the trailing edge to create the lifting surface. To achieve a bioinspired kinematics, we need to create a combination of flapping and twisting movements with a quadrature phase shift. Our method is to optimise the geometry and elastic characteristics of the artificial wings in such a way as to tune the natural frequencies of two resonance modes very close and to drive the system with a single harmonic signal. As compared to previous fully flexible designs, we localize the compliance in small elastic regions connected to rigid bodies, which enable to model the complete structure as a three degrees of freedom (0D) mass / spring system, which facilitates the optimisation process. It also enables to obtain very high vibration amplitude without damaging the structure. Finally, it is found that the aerodynamic force produced by a rigid wing attached to a compliant link is greater than that of a fully flexible wing. The result is prototypes, manufactured using microfabrication technologies, capable of producing large-amplitude wing motions of the order of 40° angle, but also able of being driven in their flapping and twisting modes independently or in phase quadrature. Finally, excellent correlation with theory is achieved, with less than 10% error on resonance frequencies and equivalent deformations. This validates the new used design strategy for a NAV weighing less than 40 mg and with a wingspan of less than 3 cm.

Keywords

Resonant motion, Micro/Nano electromechanical system (M/NEMS), Modal combination, Design of structural vibration, Optimization, compliant links

Acknowledgments – additional information

This work was supported by ANR-ASTRID NANOFLY (ANR-19-ASTR-0023), and the French AID (Defense Innovation Agency).

May 22th, 12h00 - 12h15 : Session Model system and parameter identification, Amphitheater G. INGLEBERT

Parameter identification of dynamic behavior of high timber building **12h00**

Layla KORDYLAS, Franck RENAUD, Jean-Luc DION

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Parameter identification of dynamic behavior of high timber building
SURVISHNO Conference 2025

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Abstract

The construction industry faces significant challenges today due to rapid population growth and environmental concerns. To address these issues, building with wood instead of concrete offers a more sustainable alternative. As a result, there is a growing interest in increasing the height of timber structures. However, current building standards for such constructions are not well adapted. This may be due to complexity of this material, which has high variability in its behavior parameters and strong sensitivity to environmental factors, which makes it challenging to study [1].

To ward these difficulties off, the DynaTimberEyes project aims to develop a more effective method for studying wooden structures. On the experimental side, it utilizes camera-based measurements [3] to minimize intrusion, simplifying testing on buildings that generally require accessibility and cost. On the digital side, the project focuses on developing a method to model and identify dynamic behavior. This approach integrates data assimilation techniques, such as Extended Kalman filter [2], with experimental data. This method is particularly valuable for structural health monitoring, allowing the detection of potential changes in the structure and facilitating the determination of wood's dynamic parameters, which are notoriously difficult.

We propose a method able to estimate stiffness and damping of a mass-spring-damper system. This work is applied on a 1:10 scale wooden structure of the post-construction type, with metal pin type joints respecting rules from European Standard - Eurocode 5 [4]. The measurement use accelerometer and high speed camera acquisition. This structure is loading using a vibrating table.

Keywords:

Dynamic parameters identification, Extended Kalman Filter (EKF), Scaled-down timber building

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May 22th, 12h15 - 12h45 : Session Active and passive control of vibrations, Amphitheater G. INGLEBERT

Experimental Investigation of the Periodic Core Sandwich Structure: Shape of the Vibration Modes **12h15**

Guillaume ROBIN, El Mostafa DAYA

Université de Lorraine, CNRS, Arts et Métiers ParisTech, LEM3, Metz, France

Herschel-Quincke filters for vibrations : physical understanding and industrial-inspired numerical demonstrations **12h30**

Adrien PELAT[1], Stepan AVETISOV[2], Lionel MORIN[1], Davide FRANCHI[2], François GAUTIER[2], Sergey SOROKIN[3]

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Experimental Investigation of the Periodic Core Sandwich Structure: Shape of the Vibration Modes

SURVISHNO Conference 2025

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Abstract

The sandwich structure allows to shearing the viscoelastic core layer and increase passive damping. This study focuses on an investigation of the modal behavior of the sandwich structures with homogeneous cores and periodic cores. Two polymers are selected for its adhesion properties to metal surfaces and for their viscoelastic properties. A numerical approach is presented to solved to vibration problem and determined the response curve. Periodic sandwich beams are elaborated with two viscoelastic polymers which are chosen for these characteristics. Scanning vibration allows to measure the deflection shapes of the fourth mode. The results are compared to the numerical ones. The deflection shapes in the case of a periodic core sandwich show discontinuities localized at the interfaces of the periodic structures. These irregularities in the deflection shapes can be predicted and localized by our numerical model. The results show the importance of considering the impact of the behavior of the mode using a periodic core sandwich.

Keywords

Modal shape, periodic core sandwich, band gap, filtering properties

Herschel-Quincke filters for vibrations : physical understanding and industrial-inspired numerical demonstrations

SURVISHNO Conference 2025

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Abstract

The work presented in this paper concerns the adaptation of so-called Herschel-Quincke filters, originally developed for the attenuation of sound waves in tubes, to the case of elastic waves in thin structures. The technique consists in locally spliting the host structure into two parallel substructures of different wave propagation properties, so as to induce a phase shift that gives rise to a significant, albeit frequency-selective, filtering effect. The presentation summarizes a progression of recent work aimed initially at wave-model analysis and experimental validation of the phenomena for academic beam- and plate-type structures. Based on this physical understanding, ideas of applications involving industrially-inspired systems are then illustrated.

Keywords

notch vibration filters, thin split structures, wave-based modeling, experimental demonstration

May 22th, 14h45 - 15h45: Session Rotating Machinery, Amphitheater N. BLANC

Improvement of cyclic spectral coherence map with the use of non-Gaussian signals transformation **14h45**

Daniel KUZIO[1], Radosław ZIMROZ[2], Agnieszka WYŁOMAŃSKA[3]

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A numerical application of modal accelerometer placement techniques to geared transmission monitoring **15h00**

Arthur BUREL[1,2], Jeanne MONGIN[1], Didier REMOND[1]

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Influence of the Number of Rolling Elements on Signatures of Radial Bearings in Instantaneous Rotational Speed Signals **15h15**

Adeline BOURDON, Didier Rémond

Univ Lyon, INSA Lyon, CNRS, LaMCoS, Villeurbanne, France

Improving Blade Tip Timing Accuracy Under Rotational Speed Variations **15h30**

Khadija EL KHABBAZI[1,2], Jérôme ANTONI[1], François GIRARDIN[1], Arnaud Talon[2], Bruno VAN RUYMBEKE[2]

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Improvement of cyclic spectral coherence map with the use of non-Gaussian signals transformation

SURVISHNO Conference 2025

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Abstract

Currently, cyclostationary analysis is one of the most common approaches for extracting diagnostic features from raw signals. Furthermore, cyclic spectral coherence (CSC) is highly developed for this purpose. The bi-frequency domain representation of the signal, called the CSC map, is one of the best ways to detect cyclic behavior in the signal that corresponds to faults. Unfortunately, the classical approach to deriving the CSC map is not sufficient when the signal is corrupted by highly impulsive non-cyclic impulses. Several approaches can be used to address this problem. One option is to select only specific parts of the signal where the influence of large observations is limited. Another option is to remove outliers or filter the signal to increase the signal-to-noise ratio. Moreover, in recent years, robust versions of CSC map have been developed, where the classical estimator of the autocovariance function (based on the Pearson correlation coefficient) has been replaced by robust estimators (such as Spearman or Kendall correlation coefficients). There are also approaches that use alternative dependence measures, designed for heavy-tailed distributed signals, instead of the classical autocovariance function. One disadvantage of these methods is their computational complexity.

In our research, we propose simplifying the procedure and reducing complexity through prior signal transformation. The raw signal is first multiplied by a scaling factor that accounts for variations in the signal. Then, one of three considered functions is applied to transform the signal: arc tangent, sigmoid, or logarithmic-based. These signal processing methods help reduce the impact of outliers and improve the classical CSC map derivation. The proposed approaches are demonstrated on simulated signals. In our study, we analyze the adopted model of the signal with α-stable distributed noise. We demonstrate the effectiveness of the proposed methods for different α parameter, which is responsible for the impulsive behavior of the signal. Furthermore, our approach is also applied to data from a test rig to validate its usefulness in a real-world environment. Lastly, a comparison with the classical CSC map is presented.

Our proposal can be considered a crucial step in signal preprocessing to reduce the impact of large observations that significantly affect the classical methods used in cyclostationary analysis.

Keywords
Fault detection, cyclostationary analysis, CSC map, Monte Carlo simulations, α-stable distribution

A numerical application of modal accelerometer placement techniques to geared transmission monitoring

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Abstract

Mechanical gear transmissions, widely used across various industrial sectors, are subjected to significant loads throughout their lifespan. Monitoring critical components such as rolling bearings and gears is essential, as their degradation affects system dynamics and can lead to severe failures. Vibration measurements, typically taken from the casing, are commonly used for this purpose, by performing spectral analysis focused on the characteristic frequencies linked to potential faults.

A way to optimize vibration sensing is to link the frequencies of interest with the casing eigenmodes they are the most likely to excite. Campbell diagrams are instrumental in visualizing the possibilities of gear tooth and bearing frequencies matching the structure's natural modes of resonance, which could emphasize the spectral peaks linked to a given fault. Identifying the modes of interest of the structure at specific rotational speeds opens the way to strategic sensor placements for monitoring.

The present study investigates two methods for placing a minimal number of accelerometers on the casing while maximizing useful measured information. The first method involves computing the modal kinetic energy (MKE) across the structure to estimate the dynamic contribution of candidate sensor locations to a set of target mode shapes, prioritizing positions with large amplitudes. The second method employs an algorithm based on the effective independence (EI) principle to select positions that maximize the linear independence of vibration measurements, thereby avoiding redundancy: the Fisher information matrix, weighted by a mass matrix, is used to iteratively exclude nodes or degrees of freedom that contribute least to effective independence.

The effectiveness of sensor placement is confronted to the dynamics of the whole transmission using a semi-analytical finite-element model with time integration. The shaft, modelled by Timoshenko beam elements, interacts with gears and bearings thanks to a nonstationary angular dynamic model based on a Hertz contact law. The loads from the rotating parts are conveyed to the casing by a penalty force bearing-bore contact, which excites the casing condensed using Component Mode Synthesis (CMS). The transfer path from source to sensor is thus reconstructed, allowing one to estimate the detection potential of each sensor position for a given damage.

Keywords

Sensor placement, finite element analysis, condition monitoring, rolling element bearings

Influence of the Number of Rolling Elements on Signatures of Radial Bearings in Instantaneous Rotational Speed Signals

SURVISHNO Conference 2025

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Abstract

The presented work falls within the context of rotating machinery monitoring, specifically focusing on the behavior tracking of bearings through the analysis of instantaneous rotational speed signals. This study considers the case of bearings under radial load (ball bearings or cylindrical roller bearings) as an illustrative example.

The core of this contribution is based on previous research that explained the relationship between the contact forces between the rolling elements and the races, and the speed variations observed experimentally. These variations primarily and naturally stem from fluctuations in the torque T_{bear}, associated with rolling resistance. In this work, the models derived from earlier studies will be simplified to develop a phenomenological model, enabling an analytical expression of this torque. This formulation will clearly highlight the influence of the number Z of rolling elements on this torque, and thus on the "signature" of the bearing—whether healthy or defective—in the instantaneous speed signal.

These changes are not limited to the modification of the bearing's characteristic frequencies. It will be demonstrated that the parity of Z alters the number of loaded rolling elements during rotation. In the case of a healthy bearing, this will lead to different "shapes" of the torque T_{bear}, explaining why frequency analysis of the speed signal may reveal one or two harmonics of the BPFO (Ball Pass Frequency Outer). For a bearing with a defect on the outer race, specifically localized in line with the radial load direction, it will be shown that Z influences the position and shape of the resulting perturbation compared to the healthy configuration.

Moreover, this analytical formulation of the differential equation formally demonstrates the cyclic dependence of the inertial term, leading to the introduction of a self-parametric excitation.

These findings must be considered alongside the fact that, depending on the manufacturer, two bearings deemed identical according to standards may have different numbers of rolling elements. Consequently, they will exhibit different signatures, which must not be mistakenly attributed to the emergence of a defect. It is therefore crucial to establish a healthy reference state for each machine, especially if the specific bearing installed on the monitored machine is unknown.

Keywords

Instantaneous rotational speed signal, Radial bearing, Signatures

Improving Blade Tip Timing Accuracy Under Rotational Speed Variations

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Abstract

Blade tip timing (BTT) is a non-intrusive technique used to measure blade vibrations in turbomachinery. Using fixed measurement probes in the casing, BTT provides information about the dynamic behaviour of all blades, which offers a valuable complement to strain gauges during turbomachines certification.

Conventional BTT methods rely on the assumption of a constant rotational speed over one revolution to simplify data processing. This assumption fails under real-world conditions, where turbomachines are tested during speed run-up and speed fluctuations are inevitable.

These variations in rotational speed create discrepancies when converting blade passage times into deflection measurements, leading to errors that degrade the accuracy of the analysis. As a result, the deflexion spectrum is distorted by additional artifacts, which conceal the true vibration characteristics of the blades.

To address this limitation, alternative methods for directly calculating the blade's deflection in the angular domain are studied, offering a more accurate representation of blade dynamics under varying rotational speeds. These methods eliminate the reliance on the constant speed assumption, allowing for precise analysis.

The effectiveness of these angular approaches is examined through simulations as well as experimental data, to ensure their robustness and accuracy in real-world conditions.

Keywords

Blade Tip timing, Blade vibration, Variable speed, Estimation error, Angular domain

May 22th, 14h45 - 15h45: Session Active and Passive Control of Vibrations, Amphitheater G. INGLEBERT

Performance of a periodic absolute vibration filter in a sandwich structure — **14h45**

Theo BONNEVAL[1], Rémy TANAYS[2], Maxime LANOY[3], Guilhem MICHON[1], Adrien PELAT[3]
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Modeling vibrations damping in composite beams with a viscoelastic core — **15h00**

Mahdi ESSID[1,2], Antoine FAULCONNIER[1], Benoit NENNIG[1], Julien BROCAIL[2], Jean-Baptiste CASIMIR[1], Stéphane JOB[1]
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Hybrid nonlinear energy sink for structural protection from high vibration levels — **15h15**

Louis MESNY, Guilhem MICHON
Université de Toulouse - ICA, CRNS, ISAE-SUPAERO, Toulouse - France

Advanced Suspension Technologies for Vibration Control — **15h30**

Johann ROBERJOT[1,2,3], Emeline SADOULET-REBOUL[1], Gaël CHEVALLIER[4], Nicolas PEYRET[3], Charles ARNOULD[2], Eric COLLARD[2], Emmanuel BACHY[2]
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Performance of a periodic absolute vibration filter in a sandwich structure

SURVISHNO Conference 2025

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Abstract

A current challenge in the aeronautics and aerospace industries is to limit the impact of low- and broadband vibrations considering lightweighting challenges. These two objectives are often contradictory, as improving one generally tends to worsen the other. One promising approach is the development of multifunctional materials that are both load-bearing and capable of filtering elastic waves. There are several works in the literature on periodic lattice structures that exploit Bragg interference to design lightweight vibration filters. However, their adoption in industrial applications remains limited due to their low structural rigidity. This study explores the geometrical parameters of Bragg-band vibration filters, positioned on either side of a lattice structure, with the aim of creating a sandwich structure. The goal is to preserve the vibration filtering properties of the filters while improving the bending stiffness. The mass of the structure is also analyzed in order to demonstrate the advantages of this solution in an industrial context. The conclusions are based on the results of an analytical model that enables the filtering, stiffness, and mass of different designs to be evaluated at low computational cost. In addition, experimental measurements are carried out on a prototype manufactured by additive metal printing in order to validate the theoretical results.

Keywords

Forbidden band, Vibration filter, Periodic, Elastic waves

Modeling vibrations damping in composite beams with a viscoelastic core

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Abstract

The primary objective of our research is to investigate an approach for damping bending waves and transverse vibrations in beams, by taking advantage of the dissipative properties of granular media [1]. Our solution consists in a layer of non-cohesive particles confined between two elastic beams, similar to the thin viscoelastic patches used in automotive and aeronautic applications for structural damping. In this configuration, inter-particles contacts are intrinsically dissipative due to solid friction, which efficiently works under shear. In practice, the mechanical response of such a composite multilayer structure follows Hertz contact mechanics, thus likely conferring confining pressure dependent elasticity and dissipation.

In this presentation, we will introduce a comparative study of three models developed to analyze the mechanical behavior of a three-layered beam with a compliant core. The first model is based on Timoshenko's theory, which accounts for both bending and shear deformations. The second follows Guyader's approach [2], specifically addressing shear effects in the compliant core. Finally, we present a numerical implementation of Guyader's model using the Dynamic Stiffness Method, making it a meshless approach for improved analysis of the beam's dynamic response [3]. This study highlights the influence of shear effects and modeling assumptions on the vibrational behavior of the beam.

Keywords

Damping, Shear effects, Composite beams, Numerical modeling, Dynamic Stiffness Method

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Hybrid nonlinear energy sink for structural protection from high vibration levels.

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Abstract

Nonlinear energy sinks (NES) consist of a mass, a cubic non-linear stiffness and viscous damping. The advantage of these absorbers, unlike tuned mass dampers (TMD), lies in their frequency robustness [1]. The non-linearity of this type of absorber causes a targeted energy transfer when a certain amplitude level is exceeded. This property results in the transition from a periodic response to a strongly modulated response (SMR), and protects the main structure from excessive vibration levels. However, at very high amplitude levels, the NES becomes inactive, its response becomes periodic again and the structure is no longer protected. To overcome this problem, this study proposes to combine passive NES with active structure control in order to improve the amplitude robustness of these absorbers. These are known as hybrid nonlinear absorbers (HNES). The HNES is the composition of linear hybrid absorbers [2] i.e. the incorporation of active control which, with a control law and a sensor/actuator pair, enables the dynamics of the structure to be modified in real time, and the nonlinear passive control provided by the NES. Designed to overcome the limitations of passive absorbers [3], the HNES also benefits from the fail-safe aspect, which guarantees the system's vibration damping, despite the active part stopping. Thanks to active control, it is possible to modify nonlinearities in real time or to introduce a complicated nonlinearity that would be very difficult to achieve mechanically. In this paper, active control will be used to generate a piecewise cubic nonlinearity as a function of the amplitude of the primary system. This particular nonlinearity will be used to improve the protection of structures even at high vibration energy levels by creating multiple activation thresholds in order to provide SMR, i.e. vibration damping over several vibration levels. An initial analytical study using the multiple time scale method will be carried out to define the virtual piecewise nonlinearity and validate the desired behaviour of the absorber. Finally, a proof of concept will be carried out by positioning the HNES on a free embedded beam in order to control its first bending mode.

Keywords:

Hybrid nonlinear energy sink, Active control, Piecewise nonlinearity, Multiple time scale method

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*Speaker

Advanced Suspension Technologies for Vibration Control

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Abstract

This study investigates the design and validation of innovative stiffness control systems for vibration control, focusing on two distinct approaches: thermo-driven Shape Memory Polymers (SMPs) and mechanically tunable stiffness devices. The objective is to develop adaptive suspension systems capable of changing stiffness to address diverse operational challenges, such as in-flight stabilization and payload protection under extreme vibration loads.

For SMP-based systems, a comprehensive numerical framework has been established to model the temperature-dependent stiffness variation. Experimental validations have demonstrated the significant potential of SMPs, showing eigenfrequency shifts and a notable capacity to transition between soft and rigid states. This adaptability enables these systems to provide high-static and low-dynamic stiffness properties, ensuring effective vibration attenuation across a wide range of operational conditions.

In parallel, mechanically tunable stiffness devices have been explored as an alternative approach for precise control of vibration isolation. Numerical studies have identified critical design parameters and operational thresholds for efficient stiffness adjustment. Ongoing experimental efforts aim to validate these findings and assess the performance of such devices under varying loads and excitation scenarios.

This research highlights the potential of these two approaches to address critical vibration control requirements. By leveraging their distinct capabilities, SMPs and mechanical tunable stiffness devices present promising solutions for optimizing suspension behavior while ensuring reliability and protection for sensitive payloads.

The integration of numerical and experimental results underscores significant progress toward achieving a technology readiness level suitable for industrial applications. These findings pave the way for deploying advanced vibration control systems in aeronautical, automotive, and industrial sectors, addressing key challenges in dynamic and high-performance environments.

Keywords
Vibration control, Adaptive suspension system, Shape Memory Polymer.

May 22th, 17h00 - 18h00: Session Rotating Machinery, Amphitheater N. BLANC

Improvement of cyclic spectral coherence map with the use of non-Gaussian signals transformation **14h45**

Daniel KUZIO[1], *Radosław ZIMROZ*[2], *Agnieszka WYŁOMAŃSKA*[3]
[1] Faculty of Geoengineering, Mining and Geology, Wroclaw University of Science and Technology, Poland [2] Faculty of Geoengineering, Mining and Geology, Wroclaw University of Science and Technology,Poland [3] Faculty of Pure and Applied Mathematics, Hugo Steinhaus Center, Wroclaw University of Science and Technology, Poland

A numerical application of modal accelerometer placement techniques to geared transmission monitoring **15h00**

Arthur BUREL[1,2], *Jeanne MONGIN*[1], *Didier REMOND*[1]
[1] LaMCoS, INSA Lyon,Villeurbanne, France [2] Safran Helicopter Engines, Bordes, France

Influence of the Number of Rolling Elements on Signatures of Radial Bearings in Instantaneous Rotational Speed Signals **15h15**

Adeline BOURDON, Didier Rémond
Univ Lyon, INSA Lyon, CNRS, LaMCoS, Villeurbanne, France

Improving Blade Tip Timing Accuracy Under Rotational Speed Variations **15h30**

Khadija EL KHABBAZI[1,2], *Jérôme ANTONI*[1], *François GIRARDIN*[1], *Arnaud Talon*[2], *Bruno VAN RUYMBEKE*[2]
[1] INSA Lyon, France [2] SAFRAN

Condition monitoring based on simultaneous FBG sensor measurements on the inner and the outer race of a rolling element bearing

Panagiotis Mantas[1,2], Alex Ricardo Mauricio[1,2], Damilare Samuel Ojo[3,4], Sidney Frans Goossens[3,4], Francis Berghmans[3,4], Konstantinos Gryllias[1,2]

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Abstract

Condition monitoring of rolling element bearings is crucial for ensuring the reliability and efficiency of rotating machinery. This study explores the use of fiber Bragg grating (FBG) sensors for real-time bearing condition monitoring, leveraging their high sensitivity, immunity to electromagnetic interference, and capability for multiplexing multiple sensing points along a single fiber. To achieve direct measurement at the inner race, FBG sensors were installed by modifying the transmission shaft and integrating a fiber optic rotary joint (FORJ). This approach allows for continuous signal acquisition from the bearing's inner race, extending the research field compared to conventional monitoring techniques, that are focused on measuring on static components of a rotating system. At the same time, measurements were acquired with FBG sensors on the outer race of the bearing, allowing for a direct real time comparison of measurements on the inner and outer race. Experimental results demonstrate the effectiveness of the proposed setup in capturing critical strain variations, highlighting its potential for early fault detection in rotating machinery. Based on the acquired signals from both the inner and outer race of the bearings, basic condition monitoring indicators are computed, and are able to successfully detect faults on the inner race of the bearing.

Keywords
Condition Monitoring, Diagnostics, Health indicators, Anomaly Detection, Rolling Element Bearing, FBG sensors, Fiber Optical Rotary Joints

A Health Indicator Study For Early Fault Detection For Rolling Element Ball Bearings

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Abstract
Rolling element bearings are key components in rotating machinery. Early detection of faults in bearings is often based on vibration analysis and is essential in order to prevent unexpected failures, reduce maintenance costs, and enhance system performance. Vibration-based fault detection generally relies on health indicators which represent the health state of bearings. Various health indicators have been proposed for condition monitoring but depending on the target they should present different characteristics. For instance, health indicators targeting to early fault detection should be sensitive to the incipient faults of bearings while those targeting to prognostics, they should have high trendability and high correlation with the trend of the fault growth. Various methodologies have been proposed in order to estimate the remaining useful life of rolling element bearings, but still prognostics is considered as an open challenge. The goal of this paper is the investigation of the influence of different choices in the steps of a prognostics methodology in the estimation of the RUL. Different prognostic indicators are considered and their performance based on the time of detection and their trendability is investigated. The indicators are further combined with an anomaly detection approach and loaded at a Kalman based prognostic methodology. The proposed methodology is applied, tested and evaluated on a dataset captured during 10 accelerated life tests performed at the KU Leuven Bearing Prognostics Test Rig.

Keywords
Condition Monitoring, Prognostics, Health indicators, Anomaly Detection, Rolling Element Bearing

Integration of multi-scale simulation, contribution to vibration monitoring

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Abstract

Thrust bearings are essential components in mechanical systems, providing rotational or pivot connections between parts and ensuring the proper functioning of numerous machines, such as tunnel boring machines, generators, and turbomachinery. Their reliability is critical, as any failure can lead to costly downtime or significant malfunctions. However, bearings are exposed to various types of degradation, particularly defects on contact surfaces, which influence their overall dynamic behavior. This study proposes a multi-scale approach to analyze these phenomena, combining finite element simulations in Abaqus and analytical methods based on Hertzian contact theory to calculate contact forces and validate the results. To balance accuracy and computational efficiency, a simplified geometry was adopted, and defects were modeled as rounded cylinders to study their impact on both local and global scales. Over the years, various models have been developed to better understand the degradation process in bearings. Some studies focus on critical contact zones between balls and rings using numerical simulations to identify defect initiation mechanisms. Other research takes a more systemic approach by analyzing the impact of a degraded bearing on the overall machine behavior. Additionally, simplified analytical models consider bearings as mass-spring-damper systems, providing a general overview but lacking precision in describing local interactions. Despite these advances, few models simultaneously address both microscopic interactions at contact points and their macroscopic implications on the global system's behavior. The objective of this study is to bridge this gap by proposing a multi-scale model of a thrust bearing with an artificial defect. This approach establishes a connection between local degradation phenomena and their global effects on the system, thereby improving predictive maintenance by enhancing the monitoring and reliability of industrial machines.

Keywords
Multi-scale modelling, Thrust bearings, Finite element simulation, Static defect

Anomaly Detection in Wind Turbines under Operational Variability via SCADA and Residual Analysis

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Abstract
The rapid growth of wind energy demands reliable predictive-maintenance strategies to minimize premature failures. Nowadays, many methods can be employed for fault detection, and the quality of data remains a critical aspect in guaranteeing their success and satisfactory performance. Over the last decade, data collected by the Supervisory Control and Data Acquisition (SCADA) system has become a common solution, particularly due to its readily accessible data and cost-effective nature. This work proposes a method that exploits a regression model to compute residuals, which are subsequently employed for anomaly detection. This approach combines a physical analysis based on the Betz model with a machine learning method, that is Support Vector Regression, to distinguish normal behavior from potential faults.

1 Introduction
Anomaly detection methods are widely used to identify deviations in data from normal operating conditions [1–3], helping reduce maintenance costs and prevent premature equipment failures. Machine learning techniques play a crucial role in enabling predictive maintenance by identifying incipient mechanical or electrical faults before they lead to failure [4]. Modern wind turbines produce large volumes of SCADA data [5,6]. While this data offers significant diagnostic potential, its high dimensionality and inherent noise complicate accurate and robust anomaly detection [7,8]. A notable example is the work proposed by Dhiman et al. [9], who applied different methods based on Support Vector Regression (SVR) to gearbox-temperature monitoring, using feature selection and statistical tests on the residuals. Taking this work as reference, a physics-inspired SVR approach focused on detecting anomalies through nacelle vibration analysis is proposed. The methodology begins by establishing a physical correlation between inputs and outputs via a 2-input-1-output regression model, aimed at capturing the aerodynamic influence of wind speed and power output on nacelle vibration. Based on this insight, an SVR model is trained using the selected input set, including wind speed cubed to reflect the aerodynamic power relationship, and two output signals: vibration nacelle and active power. An extensive SCADA dataset [10] has been analyzed. It comprises time series features - recorded every 10 minutes and containing power output, wind speed, nacelle temperature, and vibration signal - from 36 turbines across three wind farms [1]. The proposed method - summarized in Fig. 1 - is based on the final computation of the residuals starting from the SVR model trained and validated exclusively on a dataset representing normal operating conditions (WT53), while a second dataset (WT35) contains a scheduled pitch failure, is used to evaluate its anomaly detection capability.

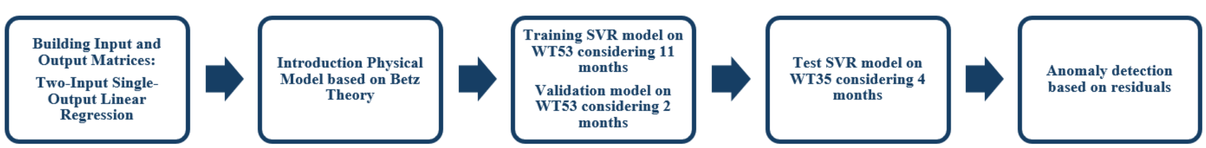

Figure 1: Workflow followed in this study

2 Analysis
The main idea is to identify the input variables that influence nacelle vibration using 2-input/1-output regression, so that the relationship can be exploited during the training phase of our SVR model. A Gaussian

kernel function, optimized using Sequential Minimal Optimization (SMO), has been employed in the SVR. In addition, the Betz model [11], which describes how a turbine extracts wind kinetic energy by reducing wind velocity and widening the flow (see Fig. 2), has been incorporated to integrate physical-related information. The physical model helps inform the regression by emphasizing the dependency of the turbine power output on wind velocity. The power output is expressed in Eq. (1).

$$P_t = \frac{1}{2}\rho A C_p c_0^3 \tag{1}$$

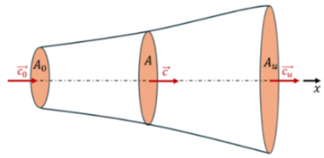

Figure 2: The tube flux is generated because of the presence of a wind turbine in the middle (with section A), so that a discontinuity in wind speed is reached and used to favor the power production.

The input features and output variables are defined as shown in Eq. (2), (3), as a result of the 2-input/1-output regression. The final SVR is trained to predict both nacelle vibration and power output.

$$[X] = \left[\{c_0^3\}\,\{T_a\}\,\{\alpha\}\,\{T_{oil}\}\,\{\beta\}\,\{\omega_g\}\,\{T_{inb}\}\,\{\omega_r\}\right] \in \mathbb{R}^{nx8} \tag{2}$$

$$[y] = [\{a_x\}\,\{P_t\}] \in \mathbb{R}^{nx2} \tag{3}$$

Please refer to the Nomenclature for complete variable definitions. Standard performance metrics, such as RMSE and R^2 are computed to evaluate the quality of the regression during training, validation and test phases.

3 Results

Considering one month of SCADA data during the winter period, when nacelle vibration levels are typically higher, the dataset has been filtered to include only data exhibiting normal behavior. The results indicate that the power turbine is controlled by the wind velocity, which remains between the cut-in (at least 2 m/s) and cut-off (20 m/s) value. Due to the large turbine size, it is evident that power control is achieved through the regulation of the pitch angle. This regulation likely contributes to reducing nacelle vibration during power production, especially as wind velocity increases (Fig. 3).

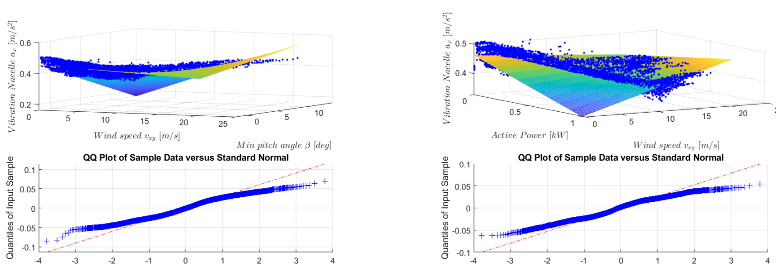

Figure 3: Two-Input and Single-Output regression. Power control through pitch regulation reduces nacelle vibrations at increasing wind speeds

From these effective controls, turbulence can be reduced through aerodynamic optimization. Fig. 4 illustrates how the regression model, informed by physical parameters, obtains a well-fitted regression plane during the winter period. Additionally, the residuals shown in the Q-Q plot appear to follow normal distribution without obvious anomalies under canonical operating conditions.

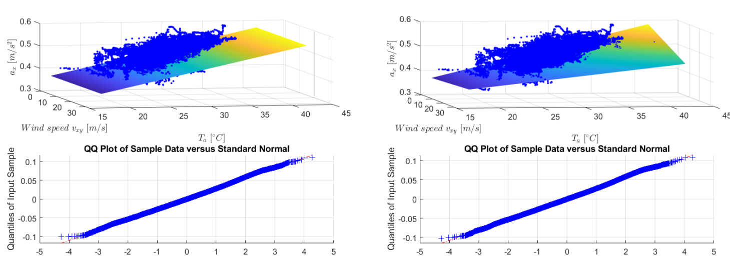

Figure 4: Vibration nacelle. On the left side, the dependency c_0^3 is considered

The goal of our regression is to predict outputs accurately, with significant deviations in residuals exceeding training thresholds serving as early indicators of potential failures. Table 2 shows how the regression performance diminishes when residuals surpass the thresholds defined based on the training data, confirming its ability to detect abnormal patterns. Both power and nacelle vibration residuals exceed thresholds simultaneously in Fig. 5, with power residuals appearing to anticipate vibration anomalies.

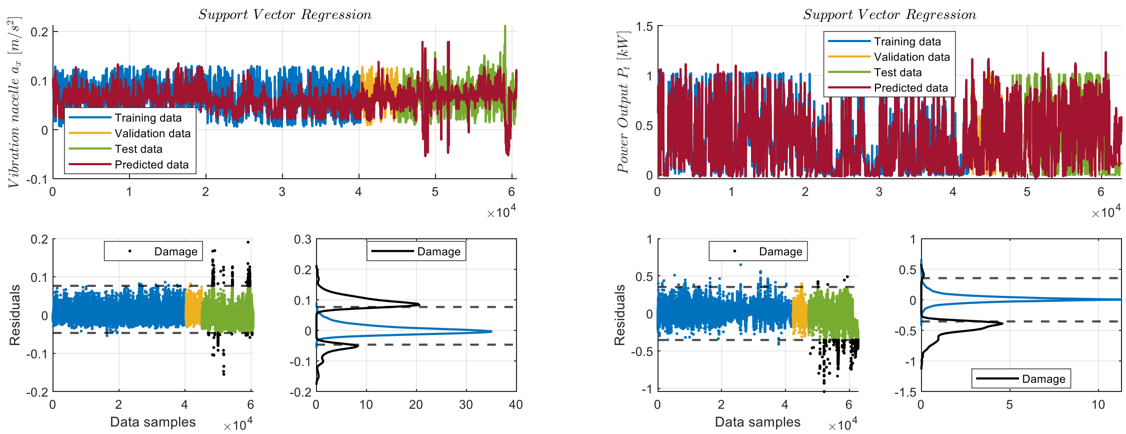

Figure 5: SVR model results. Upper plots show the predicted and measured output, while lower plots represent the resulting residuals. Left plots represent Vibration results, while Power output is shown on the right

Table 2: Comparison between model performance metrics computed for training, validation and test datasets

SVR output	Performance Coefficients	Training	Validation	Test
Nacelle vibration	R^2	0.62	0.55	−0.18
	$RMSE$	0.02	0.01	0.02
Power	R^2	0.91	0.92	0.05
	$RMSE$	0.08	0.08	0.22

Table 3: Comparison of accuracy, false-alarm and missed-alarm rates for the anomaly detection models

SVR output	**Accuracy** [%]	**MA** [%]	**FA** [%]
Vibration residuals	88.05	11.71	0.24
Power residuals	74.77	10.63	14.60

It is worth noting that the RMSE values remain consistently low across all datasets, although the R^2 value drops significantly in the test set, particularly for nacelle vibration. This suggests that the predicted values do not diverge drastically in absolute terms. As reported in Table 3, the model achieves an accuracy of 88.05 % in identifying faults through vibration monitoring, with false-alarm rates below 0.3 %, confirming the effectiveness of the method. While power residuals show lower accuracy in fault detection and may be less useful for diagnostic classification purposes, they could still provide valuable information about the state of the wind turbine and may be exploited in the future as part of a multivariate anomaly detection framework.

4 Conclusion

This work demonstrates that the integration of physical analysis with traditional machine learning methods can create a powerful tool for anomaly detection in wind turbines. The SVR model, particularly with its nonlinear Gaussian kernel, delivers satisfactory results and is well-suited for modelling complex operational behaviors. By integrating physical insights from the Betz model with data-driven regression, the method accurately distinguishes normal behavior from potential faults. Although the training process demands large amounts of data and careful parameters to avoid overfitting, the approach shows promise for predictive maintenance applications. Future work may involve incorporating deep learning, real-time monitoring, and multivariate anomaly detection using more features to refine the anomaly detection process further.

Nomenclature

Symbol	Meaning
c_0	Wind speed
T_a	Ambient Temperature
α	Pitch Angle
T_{oil}	Gearbox Oil Temperature
β	Position Rotor Blade Axis
ω_g	Rotor Speed
T_{inb}	Axis Rotor Bearing Inner Ring Temperature
ω_r	Rotor Speed Gearbox Main Shaft
a_x	Nacelle Vibration Longitudinal
P_t	Power Output
WT53	Wind Turbine 53
WT35	Wind Turbine 35

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May 22th, 17h00 - 17h45: Session Session Active and Passive Control of Vibrations, Amphitheater G. INGLEBERT

Active Control with a Robust Hybrid Tuned Mass Damper **17h00**
S. CHESNE and J. RODRIGUEZ
INSA Lyon, CNRS, LaMCoS, UMR5259, Villeurbanne, France

Damping cable-driven parallel robot vibrations using active vibration control method **17h15**
Thibault GARCIA1, Didier REMOND, Simon CHESNE
INSA Lyon, CNRS, LaMCoS, UMR5259, Villeurbanne, France

Influence of Temperature on the Stability of Electroacoustic Absorbers **17h30**
Leonardo FERREIRA[1], Rafael TELOLI[1], Emanuele DE BONO[2], Morvan OUISSE[1]
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Active Control with a Robust Hybrid Tuned Mass Damper

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Abstract

The integration of feedback control with tuned mass dampers (TMDs) offers an effective solution for mitigating structural vibrations, particularly due to their fail-safe properties in aeronautical applications. Recent advancements in hybrid mass dampers have introduced control strategies targeting multi-mode vibration control, sky-hook synthesis, and nonlinear regulation [1].

This study proposes a novel approach to designing control laws that ensure system stability. By analyzing mechanical impedance at the interface, we derive an equivalent mechanical dynamic behavior, inherently guaranteeing the passivity of the active system. This methodology has been successfully demonstrated in recent works [2,3].

Our focus is on enhancing the robustness of the closed-loop system under high uncertainties. To achieve this, we explore the Multiple Tuned Mass Damper (MTMD) concept. Using the original TMD as an inertial actuator, we simulate an active force equivalent to seven optimally tuned parallel TMDs. The resulting system delivers excellent vibration attenuation, even with significant variations in the dynamic properties of the primary structure, such as changes in modal frequencies.

Simulation results highlight the proposed system's superior vibration control performance and its ability to maintain robust stability under dynamic uncertainties. The robustness and stability margins are evaluated and benchmarked against conventional systems, demonstrating significant improvements.

Keywords

Active Tuned Mass Damper, Multiple Tuned Mass Damper, Electromagnetic actuators

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Damping cable-driven parallel robot vibrations using active vibration control methods
SURVISHNO Conference 2025

Thibault GARCIA[1], Didier REMOND[1], Simon CHESNE[1]

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Abstract

A cable-driven parallel robot (CDPR) is a manipulator characterized by its end-effector (EE) being connected to the frame by cables. An electric motor/winch system enables the adjustment of each cable length and tension. The primary drawback of cables lies in their low stiffness, resulting in EE vibrations along the trajectory. For applications requiring high accuracy, such as additive manufacturing for instance, this issue presents a significant obstacle to the development of high-precision CDPRs. There is thus a need in damping these EE vibrations.
Active vibration control can be defined as a method or system designed to mitigate or suppress undesirable vibrations in structural systems by using sensors, actuators, and control algorithms. This approach involves the detection of vibrations through sensors, the processing of this information via a control unit, and the generation of counteracting forces or displacements through actuators to minimize or eliminate the vibrations.
These methods can thus be applied to CDPRs. Nevertheless, the CDPR modal properties can fundamentally change depending on the EE position, requiring careful consideration in vibration control algorithms. This study, therefore, focuses on presenting different approaches to damp EE vibrations along trajectories using active vibration control methods, while also taking into account the evolution of modal properties to ensure accuracy without any loss of performance.

Keywords

Vibration, Robotics, Control, Cables

Influence of Temperature on the Stability of Electroacoustic Absorbers
SURVISHNO Conference 2025

Leonardo FERREIRA[1], Rafael TELOLI[2], Emanuele DE BONO[1], Morvan OUISSE[1]

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Abstract
Reducing low-frequency noise in constrained environments is a challenge for passive control strategies due to the physical limitations imposed by the one-quarter wavelength rule. To address this limitation, electroacoustic absorbers (EAs) have been developed as active alternatives, offering adaptable acoustic impedance control through loudspeaker-based systems. The performance of EAs depends, among other factors, on the electromechanical properties of their loudspeakers. These properties are commonly described by the Thiele-Small parameters, which are used in the definition of the control law of the EAs. However, environmental factors, such as temperature, may affect the mechanical properties of the viscoelastic materials used in loudspeaker construction. This study investigates the impact of temperature variations on EAs performance by measuring the acoustic impedance of an EA over a wide temperature range (-10°C to +50°C) and analyzing the variations in the mechanical properties of the loudspeaker. To model these variations, a Generalized Maxwell model is employed to describe viscoelastic temperature-dependent changes in stiffness and damping. This model is fitted using master curves derived using the Williams-Landel-Ferry law, enabling temperature-frequency characterization of the loudspeaker viscoelastic material. Additionally, this work evaluates the stability of an EA under different control strategies. Traditional control approaches assume constant loudspeaker properties, which can lead to instability when temperature variations affect mechanical parameters. To address this, an adaptive control strategy incorporating temperature-dependent adjustments is proposed. Comparative experimental validation demonstrates that adaptive tuning significantly improves the stability and efficiency of the EAs, reducing performance degradation caused by temperature fluctuations.

Keywords:
Electroacoustic absorbers, Impedance control, Viscoelastic materials , Generalized Maxwell model, Temperature effects

May 23th — Morning Presentations

May 23th, 9:00 – 10:00

09h00 - 10h00 : PLENARY 3, Amphitheater N. Blanc

Survival Guide to Vision-based Vibration Measurements

Stefania LO FEUDO / Yunhyeok HAN

ISAE-Supméca - Institut supérieur de mécanique de Paris / Laboratoire QUARTZ

May 23th, 10h00 - 11h00: Session Session Active and Passive Control of Vibrations, Amphitheater G. INGLEBERT

Design of a vibration isolator based on magnetorheological elastomer **10h00**

Emre CAVDAR[1,2], Emeline SADOULET-REBOUL[1], Gaël CHEVALLIER[3], Laurent HIRSINGER[1], Eric COLLARD[2], Charles ARNOULD[2], Emmanuel BACHY[2]

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Electromagnetic Shunt for Reducing Torsional Vibrations in a Rotating Elastic Structure Using an Electrical Machine as an Electromechanical Transducer **10h15**

Guillaume HAY[1], Hervé MAHÉ[3], Christophe GIRAUD-AUDINE[2], Olivier THOMAS[1]

[1] LISPEN, Arts et Métiers Institute of Technology, Lille, France [2] L2EP, Univ. Lille, Arts et Métiers Institute of Technology, Centrale Lille, Junia, URL 2697, Lille, France [3] VALEO, NeMo (New Mobility Center), Amiens, France

Vibration optimization of a fiber optic interferometer **10h30**

Eliott BRETON[1], Cyril DESJOUY[1], Patrick O'DONOUGHUE[2], Charles PÉZERAT[1], Adrien PELAT[1], Pierre BROCHARD[2]

[1] Laboratoire d'Acoustique de l'UniversitÉ du Mans, Le Mans, France [2] Silentsys, Le Mans, France

Design of a vibration isolator based on magnetorheological elastomers

Emre CAVDAR[1,2], Emeline SADOULET-REBOUL[1], Gaël CHEVALLIER[3], Laurent HIRSINGER[1], Eric COLLARD[2], Charles ARNOULD[2], Emmanuel BACHY[2]

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Abstract
Magnetoactive elastomers (MAE) are smart materials composed of an elastomer matrix and ferromagnetic particles with field-dependant mechanical properties. MAEs synthetized with magnetically hard NdFeB particles allow for field-induced deformation also known as magnetostriction. On the other hand, composites with soft carbonyl iron particles exhibit field-dependant elastic moduli and damping, referred as magnetorheological elastomers (MRE). The instant and reversible magneto-mechanical response of MREs is leveraged to develop an adaptative vibration isolator to control a single degree of freedom. The designed device features MREs separately excited in shear and compression modes in order to achieve a greater range of magnetorheological effect while ensuring load bearing capacity. The real-time stiffness and damping of the isolator are controlled by the input current in the coil. Current research includes the fabrication of the composites, the design of isolators, the experimental results and introduces the various modeling approaches for MAE-based devices.

Keywords
Vibratory Control, Magneto-Active Materials, Numerical and Experimental Design

Electromagnetic Shunt for Reducing Torsional Vibrations in a Rotating Elastic Structure Using an Electrical Machine as an Electromechanical Transducer

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Abstract

The electrification of the automotive industry has introduced new challenges, particularly high-frequency torsional vibrations originating from the gearbox. These vibrations propagate through the drivetrain, generating a whining noise. Moreover, the bandwidths achievable with mechanical devices are incompatible with the vibration spectrum. This presentation proposes reducing these vibrations using an electromagnetic shunt, implemented with an electric machine acting as a transducer to couple the vibrations to electronic circuits. A capacitor placed across the transducer terminals takes advantage of the inductive nature of the machine to create a resonant circuit. The electrical circuit's resonance induces an anti-resonance in the mechanical structure's frequency response, which can be tuned to a specific frequency by adjusting the capacitor value. A first approach involves using a direct current (DC) machine as a transducer. In this configuration, the rotation of the mechanical structure induces an electromotive force generated by the transducer. In steady-state conditions, this voltage is balanced by the DC component of the voltage across the capacitor, so the current flowing through the transducer is solely due to the vibrations experienced by the structure. The study establishes a merit criterion for the transducer, optimizing the electromagnetic shunt. An anti-resonance in the torsional response function has been experimentally observed on a rotating structure, where the transducer used for the shunt implementation is a low-inertia DC machine. Experimental validations have revealed technological challenges related to contact resistance at the brush-collector interface within the machine. An electromagnetic shunt using a three-phase synchronous machine is currently under investigation, offering new perspectives.

Keywords:

Damping torsional vibrations, Electromagnetic shunt damper, Resonant circuit tuning, Rotating Structure, Electrical machine

Vibration optimization of a fiber optic interferometer

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Abstract

This work focuses on the vibration optimization of a fiber optic interferometer whose detection performance may be compromised due to external mechanical or acoustic excitations. In such an interferometer, the optical path is split into two parallel arms, with one significantly longer than the other. Optimizing the interferometer involves minimizing the phase difference of light caused by mechanical deformations, particularly in the long arm, resulting from unintended external excitations. Building on the pioneering work of Hocker and Sirkis, a number of increasingly complex load cases are being studied, leading to the development of a generic numerical-analytical model. The results obtained with this model are then shown and compared with experimental data to verify its accuracy. Additionally, the impact of integrating fiber protection into the model is discussed. This evaluation will then enable the analysis of industry-inspired systems belonging to photonic technologies.

Keywords:

Fiber optic interferometer, Vibration optimization, Optical phase shift, External excitations

May 23th, 10h00 - 10h45: Session Electric Machines, Amphitheater N. BLANC

Characterization of the Dynamic Behavior of Laminated Electric Rotors **10h00**

Nour ABUHEMEIDA[1,2,3], Damien VAILLANT[1], Gaël CHEVALLIER[4], Morvan OUISSE[2],

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Projection of Magnetic Forces for the Calculation of Vibrations in Electrical Machines **10h15**

Raphaël PILE

Arts et Métiers Institute of Technology, LISPEN, F-59046 Lille, France

Measurement of dynamic loads at bearing interface of an electrical motor by inverse method using piezoelectric gauges **10h30**

Hugo SIWIAK[1], Pascal BOUVET[1], Wilfried RAGUENET[2]

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Characterization of the Dynamic Behavior of Laminated Electric Rotors

Nour ABUHEMEIDA[1,2,3], Damien VAILLANT[1], Gaël CHEVALLIER[4], Morvan OUISSE[2,3]

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Abstract

The accurate numerical modeling of sheet stacks in train rotors presents significant challenges due to the complex behavior of these structures. Unlike solid metal components, these stacks consist of numerous thin, tightly fitted metal sheets, resulting in anisotropic mechanical properties and complex lateral interactions. The waviness of the sheets introduces pressure concentrations rather than uniform distribution, and the ununiform friction coefficient between different sheets further complicates characterization. In contrast to previous approaches relying on characterizing local contact variables and generalizing these findings to predict global behavior, this study adopts a more experimental and global approach to address these challenges.

A prototype test setup has been developed, comprising two relatively thick metal plates with six bolt holes. Between these plates, sheets from the rotor under study are placed, and the structure is finally secured with six instrumented bolts to apply the required pressures with good precision. The structure is subjected to a series of vibration tests at varying pressure levels, with each pressure configuration altering the dynamic response of the stack. By analyzing the frequency response functions (FRFs) corresponding to each pressure setting, and updating the corresponding finite element model (FEM) accordingly, the material properties of the sheet stack, including their pressure-dependent behavior, can be characterized.

To ensure the reliability and robustness of the findings, the tests are repeated multiple times with the same tested sheets as well as with different groups of sheets. This iterative process aims to validate the repeatability of the results and provide a comprehensive understanding of the mechanical behavior of these sheet stacks.

The outcomes of this study will not only provide valuable insights into the stack pressure-dependent properties, but also improve the modeling accuracy for train rotor, paving the way for enhanced rotor performance and reliability in engineering applications, and widen the possibilities for future development of laminated motors.

Keywords
Homogenization, Rotor Stack, Lamination, Nonlinear Behavior.

Projection of Magnetic Forces for the Calculation of Vibrations in Electrical Machines

SURVISHNO Conference 2025

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Abstract

The analysis of the vibro-acoustic behavior of electrical machines has been extensively studied recently. The unresolved issue is exacerbated by the increase in mass and volume power densities, impacting vibration and noise levels. These phenomena must be considered from the design stage, with simulation being a key tool. A critical aspect of these simulations is the modeling of electromagnetic forces. The Maxwell Force (MF) method is commonly used, estimating an equivalent surface force in the air gap based on the magnetic field. The MF is compatible with analytical, semi-analytical, and Finite Element methods. Calculating magnetic forces with the MF involves defining a surface force in the air gap on a cylindrical surface. Consequently, this magnetic surface force depends on the angular position and time. The time and space harmonics can be obtained by Fourier decomposition. These harmonics can be linked to the properties of the magnetic field and the main design parameters of the machine, providing useful insight for understanding the electromagnetic source of vibration. The standard method integrates an angular portion of the magnetic surface force based on MF for each lamination tooth, resulting in MF lumped tooth force load vectors.

Another method is the Virtual Work Principle (VWP), which provides a nodal magnetic force resultant. The VWP is considered the reference method for calculating local forces on laminations.

This communication proposes to study the accuracy of MF lumped tooth force loading for predicting electrical machine vibrations. In particular, the modulation effect is highlighted by comparison with results from VWP loading. The consequences for the analysis of the origin of noise and vibration in electrical machines will be presented.

Keywords

Vibration, Noise, Electrical machines, Magnetic force, Maxwell Tensor, Virtual Work Principle.

Measurement of dynamic loads at bearing interface of an electrical motor by inverse method using piezoelectric gauges

SURVISHNO Conference 2025

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Abstract

The knowledge of dynamic loads at bearing interfaces of an electrical engine is the nerve of war to deal with noise and harshness problematics.

To perform such measurements inverse method approach is the only available option. To overcome the constraints in terms of accessibility and to enhance the approach by having a higher local sensitivity, the choice to use strains gauges as response sensors is made.

The interest of the study is on two aspects. The first one is on the use of simulation to define the best test procedure and estimates its sensitivity (virtual instrumentation). The second one is to use piezo electric strain gauges to be able to measure extremely low levels of strains during electrical motor operation.

With this approach we were able to measure axial and radial forces at eMachine bearing interface on each side of rotor shaft from 0 to 3500Hz using an hybrid approach of classical inverse method.

Keywords

Input loads, inverse method, strain gage, simulation.

May 23th, 12h00 - 12h45: Session Vibroacoustics and fluid/structure interaction, Amphitheater G. INGLEBERT

Characterization of the Dynamic Behavior of Laminated Electric Rotors **10h00**

Nour ABUHEMEIDA[1,2,3], Damien VAILLANT[1], Gaël CHEVALLIER[4], Morvan OUISSE[2],
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Projection of Magnetic Forces for the Calculation of Vibrations in Electrical Machines **10h15**

Raphaël PILE
Arts et Métiers Institute of Technology, LISPEN, F-59046 Lille, France

Measurement of dynamic loads at bearing interface of an electrical motor by inverse method using piezoelectric gauges **10h30**

Hugo SIWIAK[1], Pascal BOUVET[1], Wilfried RAGUENET[2]
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Vortex-induced vibrations mitigation of a cantilevered hydrofoil with resonant piezoelectric shunt

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Abstract

This work first investigates the ability of a two-degree-of-freedom coupled system model, derived from the Facchinetti, de Langre and Biolley model, to fit the vortex-induced vibrations (VIV) observed on a truncated hydrofoil in a hydrodynamic tunnel. A particular VIV area is scrutinized, for which the hydrodynamic excitation mechanism due to a Kármán-type vortex wake organization locks the first torsional mode of the hydrofoil. Coupling a structure oscillator with a van der Pol wake oscillator satisfactorily reproduces the amplitude response and the lock-in frequency. In order to build a low order model allowing to optimize control strategy, a third degree of freedom corresponding to the electric circuit of a piezoelectric resonant shunt has been added. Composed of an inductance and a resistance connected to a piezoelectric patch, the passive shunt was tuned to minimize the vibration amplitude in the frequency lock-in range. Model predictions are finally compared with experimental results.

Keywords:

Hydrofoil, Vortex-induced vibrations (VIV), Piezoelectric shunt, Low order model, Mitigation

Comparative vibro-acoustic analysis using FEM and IGA in combination with the projection of modal basis

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Abstract

The study of vibroacoustic problems is crucial in various fields, such as the automotive and aeronautic industries. Fluid-structure interaction plays a key role in analysing these problems, as it directly influences the system's behaviour [1].

This work aims to demonstrate the efficiency of Isogeometric Analysis (IGA) compared to the isoparametric Finite Element Method (FEM) in solving a coupled vibroacoustic problem involving a cylindrical cavity enclosed by a structural boundary. The primary variables under investigation are the vibroacoustic eigenfrequencies.

Furthermore, the IGA approach will be analyzed by increasing the polynomial order [2,3], whereas the FEM approach will be examined only at the second order [2,3]. Given the complexity of solving a fully coupled vibroacoustic problem, the Projection of Modal Basis (PROMs) method will be employed to reconstruct the vibroacoustic behaviour [4].

To achieve the final objective, three main steps will be followed: (i) the construction of structural and fluid bases, (ii) the reconstruction of vibroacoustic eigenfrequencies, and (iii) the evaluation of computational time and accuracy across different configurations.

Keywords

Isogeometric analysis, fluid-structure interaction, reduced order model

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Comparison of Vibro-Acoustic Characterization Methods Applied to Plasterboards SURVISHNO Conference 2025

BRAULE Théodore[1,2,3], GALLEZOT Matthieu[1], EGE Kerem[3], CHESNE Simon[2], LECLERE Quentin[3], BRAJER Xavier[1], BERGER Sylvain[1], MEILLE Sylvain[4]

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Abstract
Saint-Gobain develops and distributes various lightweight construction solutions based on plasterboard panels (partitions, linings, ceilings, etc.), which contribute significantly to enhancing the acoustic comfort of inhabited spaces. Ideally, such structures should be lightweight, rigid, and optimized to achieve high acoustic insulation performance. However, mechanical and acoustic requirements often appear contradictory, particularly in terms of stiffness and mass. In particular, the acoustic insulation of partitions made of plasterboards screwed onto metal studs tends to decrease when their mass is reduced. To maintain system performance, it is crucial to control the mechanical properties of its components, especially the plasterboards. In this study, several experimental vibro-acoustic identification techniques for structural characterization are applied and compared using plaster beams. On the one hand, the Mechanical Impedance Measurement (MIM) methodology, commonly used in industry (ISO 16940 and NF EN 16703 standards), relies on a modal approach. However, this method determines the equivalent global mechanical properties of the studied structure (dynamic Young's modulus, loss factor) at only a few discrete frequencies. On the other hand, the Corrected Force Analysis Technique (CFAT), initially developed at the LVA laboratory, provides localized information over a continuous broadband frequency range. This technique calculates the spatial derivatives of the structure's motion equation using a finite-difference scheme applied to the transverse displacement measured in a non-contact manner via a vibrometer. The study presented in this communication consists of two main parts. First, experiments are conducted on pristine samples to quantify the spatial and frequency variability of mechanical properties obtained using CFAT and compare them to the global values derived from the MIM approach. The representativeness of the global parameters is thus discussed. Second, the CFAT methodology is applied to beams subjected to controlled damage, enabling the localization of defects and quantification of the resulting local variations in mechanical parameters.

Keywords
Plasterboard, vibro-acoustic characterization, inverse problem.

May 23th, 12h00 - 12h45: Session Vibration-based Structural Health Monitoring, Amphitheater N. BLANC

Characterization of the Dynamic Behavior of Laminated Electric Rotors **10h00**

Nour ABUHEMEIDA[1,2,3], Damien VAILLANT[1], Gaël CHEVALLIER[4], Morvan OUISSE[2],
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Projection of Magnetic Forces for the Calculation of Vibrations in Electrical Machines **10h15**

Raphaël PILE
Arts et Métiers Institute of Technology, LISPEN, F-59046 Lille, France

Measurement of dynamic loads at bearing interface of an electrical motor by inverse method using piezoelectric gauges **10h30**

Hugo SIWIAK[1], Pascal BOUVET[1], Wilfried RAGUENET[2]
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Detection and classification of track defects using axlebox accelerometers
SURVISHNO Conference 2025

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Abstract

The detection of track defects is a crucial topic for infrastructure managers to efficiently drive the rail maintenance. For this, trains equipped with measuring devices allow to cover a complete network with a reduced number of sensors, compared to fixed sensors on the tracks.

In this context, Vibratec and RATP have developed a methodology to process the measurements of axlebox accelerometers, in order to detect track defects and to classify them in terms of defect nature (squats and other deteriorations of the rail surface, matted insulation joints, hanging sleepers, broken rails), and of defect severity. In this methodology, the vertical acceleration signals are double integrated to obtain displacement signals. A wavelet decomposition of the vertical displacement signals is then performed, providing a cartography indicating the amplitude of the displacement at each spatial position, for wavelengths between 0 and 5 meters. Data processing methods including machine learning techniques were used to distinguish and classify the different defects. In general, hanging sleepers generate high displacement amplitudes in high wavelengths, broken rails in medium wavelengths, and squats and joint matting (plastic deformation at the contact surface) generate high displacement amplitudes in low wavelengths.

The methodology was first developed using simulation results of a multi-body bogie model running on a finite-element track with several defects. It was then applied on measurement data performed on a test track with a broken rail, and on measurements collected on the RATP's RER A network. More recently, the suitability of the method for the detection of insulation joints and the classification of their health condition was investigated. The main outcomes of these development steps will be presented at the SURVISHNO conference.

Keywords

Rail Defects, Track Maintenance, Vibration Measurement, Wavelet Transform, Machine Learning

Dictionary Learning for Periodic Signals: Application to Rotating Machine Elementary Vibration Source Tracking

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Abstract

In this paper, we investigate a methodology for recovering periodic components from a nonlinear mixture. Accurate estimation of such components is crucial, particularly in vibration-based health monitoring, as it enables the isolation and analysis of individual source contributions. Traditionally, synchronous averaging has been a widely adopted technique due to its near-optimal estimation performance and simplicity. However, its applicability is restricted to (quasi-)stationary operating conditions, limiting its use in various applications, such as aeronautics. To address this limitation, we propose a dictionary learning approach for periodic signal recovery under variable-speed conditions, where the mixture function follows a multi-amplitude modulation model. Our method simultaneously updates the fundamental frequencies and the corresponding amplitudes of the different sources. At each iteration, the fundamental frequencies are refined, and the amplitude variations are tracked. The algorithm is initialized by first solving a linearized form of the mixture using a LASSO-like optimization problem. The proposed methodology is validated using synthesized and experimental data from a planetary gearbox, demonstrating its potential to meet the Cramèr-Rao bound for our problem.

Keywords:

Dictionary learning, source separation, vibration analysis, non-stationary regime, periodic signals, multi-modulation

Convolutional Neural Network Based Structural Health Monitoring for IASC-ASCE Benchmark

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Abstract

In the present research, we combine modal analysis and Convolutional Neural Networks (CNNs) for structural damage quantification. A Finite Element simulation provides damage scenarios, and a modal analysis is employed to derive a new damage index based on the normalized Modal Effective Factor (MEF). Numerical data for single and multiple damage scenarios validate the proposed index. Then, the CNN algorithm is trained using labeled data from the abovementioned numerical simulations and real accelerometer data collected from a benchmark structure.

The interpretability of CNN predictions is guaranteed by the integrated Introduction of Damage (IOD) equation. A four-level benchmark building by the IASC-ASCE Structural Health Monitoring Task Group is used as a reference structure. The results confirm that the suggested approach is effective for damage severity quantification.

Keywords

Convolution Neural Networks, Structural Health Monitoring, short time Fourier transform, wavelet transform, structural damage estimation

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Index