The 8th International Congress on Technical Diagnostics

ICTD 2026

23–25 September 2026, Gdańsk, Poland



Book of Abstracts

Institute of Fluid-Flow Machinery PAS

Polish Naval Academy

Polish Association of Technical Diagnostics

2026
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About the congress

The International Congress on Technical Diagnostics (original Polish name: *Międzynarodowy Kongres Diagnostyki Technicznej*) is a series of meetings for representatives of science and industry addressing issues related to the theory and practice of technical diagnostics. The Congress is held every four years in different Polish cities. The meeting provides an international platform for industrial partners and researchers to exchange ideas and share the latest concepts in the diagnostics of machines, vehicles, structures, materials, and industrial processes, as well as in the maintenance of all types of technical facilities.

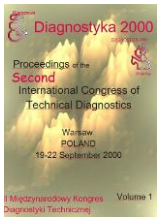
Congress topics

- theory of technical diagnostics
- experimental diagnostic tests of technical objects and manufacturing processes
- analytical, symptom and simulation models of technical objects
- algorithms, methods and devices used for monitoring, diagnosing and predicting the technical condition of machines
- artificial intelligence in diagnostics: neural networks, fuzzy logic systems, genetic algorithms and expert systems
- methods for detection, localisation and identification of damage
- structural health monitoring
- machine maintenance systems
- dynamics of machines and structures
- diagnostics of anthropotechnical systems
- medical diagnostics using signal processing techniques
- signal analysis and processing
- noise and vibration
- diagnostic issues in mechanical engineering and civil engineering
- economic and environmental aspects in technical diagnostics
- other topics related to technical diagnostics

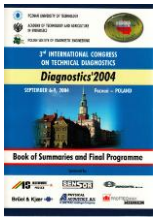
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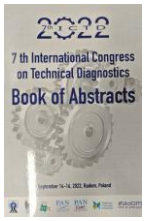
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From the organisers

The International Congress on Technical Diagnostics – ICTD 2026 is the eighth edition of this event. This year's edition is being organised in Gdańsk, Poland, by the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences, the Polish Naval Academy and the Polish Association of Technical Diagnostics. The Congress is held under the auspices of three committees of the Polish Academy of Sciences: the Machine Design Committee, the Acoustics Committee and the Transport Committee. It is co-financed by the Ministry of Science and Higher Education of the Republic of Poland.

The ICTD 2026 Congress offers a valuable opportunity to network and engage in discussions with many specialists, providing an excellent setting for establishing and maintaining long-term professional and personal connections among participants. The current edition of the ICTD Congress will feature three plenary sessions, eight technical sessions, and two poster sessions. The Congress includes 44 presentations, 31 posters, and seven sponsor presentations. Approximately 100 participants from Poland and abroad are expected to attend.

All abstracts approved by the Scientific Committee have been published in a Book of Abstracts. Authors interested in publishing a full paper could choose one of nine recommended international scientific journals. We also encourage authors of abstracts presented as oral presentations or posters to publish their full papers in the recommended journals after the Congress.

We sincerely thank everyone involved in organising the ICTD 2026 Congress. We thank all members of the Organising Committee and the Secretary. We also thank all members of the Scientific Committee for their valuable comments on the organisation of the event and for the time they devoted to reviewing abstracts. We also thank all abstract authors and conference speakers. This Congress could not take place without your participation.

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Chairs of the Organising Committee

Gdańsk, September 2026

General programme

Wednesday, 23 September 2026

11:00–11:30	Opening ceremony
11:30–13:00	Plenary session
13:00–14:00	Lunch
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15:30–16:00	Coffee break
16:00–17:30	Technical sessions
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Plenary lectures

Differences in the implementation of tasks of diagnostics of the state of acoustic hazards in the environment

Wojciech Batko[1,*], Adam Jablonski[2]

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Abstract: The implementation of diagnostic tasks regarding the state of acoustic hazards in the environment is focused on obtaining information that aids in the selection of technical and administrative solutions that minimize the harmful effects of environmental noise. It addresses the following tasks: identifying the causes of excessive acoustic impacts in the environment, assessing their condition, and forecasting their variability over a specific time horizon. Their implementation differs from the methodology of numerous diagnostic tasks used in practice due to the need to identify phenomena in a non-Euclidean metric space. Their results must reflect the conditions of their perception by people present in the environment, which result in their nuisance and health hazards, as well as their impact on the proper performance of human activities.

These results are quantified by a nonlinear decibel measure – sound pressure level – which is an expression of the Weber-Fechner psychoacoustic law, which links the effects of the relative energy of acoustic disturbances in the environment with the conditions of their perception by humans. This law is related to the axiom of adding two decibel values, currently used in environmental acoustic research. This axiom serves as the basis for defining other decibel processing operations for acoustic measurement results. These include summing n-decibel values, averaging them, subtracting them, multiplying them by a scalar, or dividing (relative to each other) two decibel values, which are used to develop a database of decibel measurement results. The axiom of adding two noise levels required a modification proposed by W. Batko to bring the decibel calculation into line with the axiomatics required for the algebra of operations on these numbers, making it a suitable new basis for modeling and identifying environmental acoustic hazards.

A discussion of this defined and modified tool for modeling environmental acoustic hazards is the subject of the case study analysis. It highlights the flaws of existing computational solutions in the process of developing decibel measurement results. In particular, the fundamental step in the identification process is the selection of a measure for comparing their variability, the interpretation of which must be consistent with the decibel algebra of the obtained result description – with the conditions of its human perception. This element significantly determines the different approaches to diagnostics, including the limitations in the application of standard identification tools – appropriate for research tasks in the Euclidean space of their description.

The paper's presentation focuses on the requirements of the process of correct hazard identification, as well as on the differences in the implementation of quantification

of exceedances of standard values. It highlights the crucial role of choosing an estimator of exceedances and the averaging of decibel variability of measurement results, i.e., choosing a method for integrating monitored noise level variations. It considers the advisability of using the Lebesgue integral as a method for integrating over signal values, which enables the correct and appropriate formalization of research tasks for a wide range of environmental noise variability. The raised issues are supplemented by the presentation of software developed by the authors for the diagnosis of acoustic hazards, as well as a presentation of the validity of modelling the sought diagnostic relations, using the example of selected research objectives, in the modified decibel algebra of processing the results of environmental acoustic measurements.

Keywords: noise control, decibel algebra, acoustic hazard modelling.

Information and time as determinants of quality in technical diagnostics

Zbigniew Dąbrowski[1, *], Rafał Burdzik[2, *]

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Abstract: The objective of technical diagnostics is the accurate identification of a system's condition and its proper contextual interpretation. State recognition involves the identification of its symptoms and their assignment to specific classes, while the definition of these classes follows from the assumed context. It is precisely the definition of context that determines what is considered useful information. In information theory, in a general sense, this is any recognition of a system state that can be distinguished from another state of the same system. If, within a given context, the statement of no change in the technical condition is demonstrated to be useful, it may also be regarded as information. A signal represents, in a mathematical space, any measurable quantity. Diagnostic signals, as measurement outputs, provide large volumes of data, the interpretation of which consists in extracting useful information. Diagnostic models define information as symptoms correlated with specific states (adopted classes). Thus, the diagnostic task includes the acquisition and interpretation of information about the condition of an object based on observations performed through measurement. The acquisition of satisfactory information from a measurement signal depends on its quality, which in turn is strongly related to the processes of measurement strategy, planning, and execution. Furthermore, due to increasing expectations placed on condition monitoring systems and the growing complexity of multi-component, interdependent machine structures, the speed of information acquisition is becoming increasingly important. This speed is determined by both the signal transmission time and the signal processing time. Consequently, the following question becomes relevant: *How can useful information of satisfactory quality be obtained within an appropriate time frame?*
The paper discusses criteria for assessing signal quality in the context of technical diagnostics and identifies the determinants of signal quality. Additionally, considerations are presented regarding the existence of a true value in the context of its measurability, with reference to the definitions of measurement error and measurement uncertainty. Above all, however, the fundamental role of time in measurement, signal processing, and result interpretation is emphasized. The concept of appropriate observation time is explained across different scales representative of various physical phenomena subject to observation, i.e., the act of recognition. In conclusion, it is demonstrated that the time required to obtain useful information becomes a new and critical parameter in technical diagnostics, constituting a current technical and scientific challenge. This speed is associated with the time required to obtain satisfactory information through measurement and signal processing. The time required for information acquisition and transmission depends on the signal medium, which is strongly influenced by the physical phenomena related to the measurand or by the

transmission technology. In contrast, the time required for information extraction from the signal depends on the complexity of the processing algorithm and the expected scope of information.

Keywords: time, information, signal, technical diagnostics.

Technical diagnostics - yesterday, today, tomorrow. The evolution from symptom observation to autonomous prescriptive systems

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Abstract: The author presents the evolution of diagnostic systems, spanning from simple symptom observation techniques to advanced systems for predicting the condition of an object, along with the assessment of its "lifeline". Special emphasis is placed on model-based diagnosis and inverse problems, which involve identifying the root causes of a machine failure based on observed symptoms.
The author outlines the results of his own research, as well as the findings of the research teams he has collaborated with. These results pertain to attempts at the mathematical description of dynamic states in both complex objects, such as high-power turbo-sets, and smaller ones, such as high-speed microturbines. The developed numerical models of these objects allowed for the assessment and diagnosis of their condition through the introduction of original concepts known as Adequacy Intervals and the Weight Function Concept. The author also provides examples of diagnostic assessments for such intriguing phenomena as multiple whirls, heuristics and prehistory in rotating machinery diagnostics, as well as the variability and randomness of input data. These are the elements of modern and future-oriented technical diagnostics. It is driven by Digital Twins, which establish new paradigms in the approach to technical diagnostics, while simultaneously defining an entire ecosystem of research tools supported and enhanced by AI.

Keywords: technical diagnostics, model-based diagnosis, inverse problems in technical diagnostics, the digital twin ecosystem in diagnostics, the role of AI in technical diagnostics, heuristics in rotating machinery diagnostics.

Nonlinear dynamics, design, and control for future rotating machinery

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Abstract: This presentation aims to review recent trends in the nonlinear dynamic analysis and design of rotating machinery across a wide range of applications and to discuss control strategies and electromechanical systems for controlling machine dynamics. Incorporating nonlinear dynamics into the design iterations of large turbomachinery and high-speed rotating systems requires advanced formulations and substantial computational resources. Consequently, nonlinear analyses are not yet routinely applied in standard industrial dynamic calculations. However, when implemented, they enable the assessment of stability, bifurcations, and the nature and quality of motion, phenomena that cannot be adequately captured by conventional linear dynamic approaches. This capability represents an important step towards operating closer to performance and stability limits while maintaining reliable dynamic designs. Examples of nonlinear dynamic analysis and design involving turbine-generator shaft trains, jet engines, turbochargers, turbopumps, and microturbines will be presented, incorporating basic design aspects like sensitivity analysis, optimization and uncertainty in the evaluation of dynamic characteristics.

Electromechanical systems are increasingly being embedded in rotating machines to actively control their dynamic behaviour. A range of control strategies has been investigated, while some have already evolved into established technological solutions. Examples include active magnetic bearings, actively controlled oil and gas bearings, active rolling element bearings, actuated rotor supports, active balancing devices, smart material actuators, and other mechatronic elements that provide control authority over rotor dynamics. The integration of sensors, actuators, power electronics, real time control, and tribological interfaces is creating multi-physical electromechanical-tribological systems that support the evolution from the passive rotating machine to the controllable machine, and further towards adaptive and autonomous machines.

At the highest level, intelligence emerges through a supervisory control layer that determines what should be controlled, when intervention is required, and how control objectives and machine properties should adapt as operating conditions and machine health evolve. A central objective of the presentation is to demonstrate that future rotating machinery will be designed using advanced physical models and nonlinear dynamics and will not merely be monitored during operation: its dynamic properties, stability margins, and response characteristics will increasingly become controllable and adaptable in real time.

Keywords: rotating machinery, dynamics, design, mechatronics, control.

Regular contributions

A unified device description format for Modbus RTU/RS485 sensors in machine condition monitoring systems

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Abstract: The Modbus RTU protocol, implemented over the RS485 serial interface, is among the most widely deployed communication standards in industrial automation, including machine condition monitoring and diagnostics systems. Despite its ubiquity, the Modbus specification defines no standard device description mechanism – there is no standardised format specifying register maps, data types, byte ordering conventions, physical units of measured quantities, or measurement ranges. Every sensor manufacturer provides proprietary documentation, precluding automated configuration and resulting in high integration costs. By contrast, newer industrial protocols such as IO-Link (IEC 61131-9) offer mature solutions – notably the IODD (IO Device Description) format, a mandatory standardised descriptor for every IO-Link device. A review of the literature confirms that the only academic standardisation initiative for Modbus remains the Modbus Definition Language (MDL, Oak Ridge National Laboratory, 2015), which has not achieved broad industrial adoption. The present work addresses this gap by proposing a unified, open-format JSON-based device descriptor for Modbus RTU/RS485 sensors, with particular emphasis on MEMS-based vibration transducers used in condition monitoring systems. The descriptor defines complete device metadata: manufacturer identification, communication parameters, a register map with data types, byte ordering, physical units, measurement ranges, and scaling coefficients. A software tool with a graphical user interface supporting descriptor file generation has also been developed. The proposed standard enables automated configuration of measurement data acquisition in monitoring systems, eliminating interpretation errors and reducing the time required to integrate new devices.

Keywords: machine condition monitoring, diagnostics, smart sensors, Modbus RTU, RS485, device description standards, IO-Link, IODD, vibration sensors, MEMS.

Research and diagnostics of the sealing performance of an ORC cogeneration microsystem

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Abstract: The article presents the research methodology, the results obtained, and an assessment of the sealing performance of an ORC cogeneration microsystem. ORC systems use organic working fluids, which are often low-boiling liquids, including refrigerants. This necessitates an assessment of the sealing performance of the installation in order to prevent leakage of the working fluid from the ORC system into the atmosphere. In the first stage of assessing the sealing performance of the installation, pneumatic tests were carried out at a compressed air pressure of 10 bar(a), during which the pressure in the installation was monitored. The tests showed that the pressure drop in the installation was 1 bar per hour, indicating significant leakage in the ORC system components. Therefore, in the subsequent test, a product called Micro Leak Detector by Big Blu was used, which made it possible to locate major sources of leakage in flange and threaded connections, among others, and eliminate them. After the subsequent pressure test, the pressure drop in the installation was determined to be approximately 0.01 bar(a) over 24 hours. The spectrometric method was used in the sealing performance tests. Helium was used as the test gas, and the installation was filled to a pressure of 5 bar(a). The helium diffusion time before the test was approximately 1.5 hours. Based on the measurements, sources of leakage were detected at welded joints, control valve seals, and the microturbogenerator, with the maximum helium leak flow rate exceeding the required leak-tightness level of 10^{-5} mbar l/s. Hence, in the next stage, after eliminating the identified sources of leakage, further tests were carried out, which showed that the helium leak flow rate in the ORC system was 2.6×10^{-6} mbar l/s, a level of tightness considered satisfactory for the cogeneration system.

Keywords: sealing performance tests, ORC system, cogeneration, experimental research, diagnostics.

Analysis of large datasets as a pre-requisite for reliable condition monitoring of rotating machines

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Abstract: The technical condition monitoring of rotary machinery in modern vibration diagnostics is typically a complex methodology involving the mechanical drive train (or the kinematic system), the vibration data acquisition system and the signal processing system as three vast individual sections. The vibration analysis of rotary machines involves the vibration data acquired from the machine elements and their corresponding working-speed data by using accelerometer sensors and phase markers respectively. In this paper, a state-of-the-art algorithm is developed as a data tracking system that serves as a pre-requisite for reliable condition monitoring of rotating machinery for analysing large vibration datasets (i.e., data management and data tracking) of the acquired vibration signals from the mechanical drive train in relation to the speed of the rotating machine. This novel methodology helps in determining and tracking the characteristic frequencies and characteristic orders of individual machine elements during run-up and run-down. This approach can be utilized as a datum for fault detection and diagnosis of rotating machines. This methodology also proves that the spectral accuracy depends on the acquired phase marker signals, playing a key role in the resampling, affecting the characteristic orders of the machine elements.

Keywords: frequency tracking, order tracking, speed response curve, advanced diagnostics, resampling, condition monitoring.

Diagnostic evaluation and numerical validation of interfacial adhesion in melt-impregnated continuous carbon fiber/PEI composites

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Abstract: The mechanical strength of additively-manufactured continuous carbon fiber (CCF) composites is primarily governed by the quality of the interfacial interface between the CCF tow and the thermoplastic matrix. To improve the interfacial adhesion between the CCF and high-performance Polyetherimide (PEI) a melt impregnation technology is developed.
A diagnostic method of determining the quality of interfacial adhesion between fibre tow (impregnated or non-impregnated) and polymeric matrix is established. It contains two steps: pull-out testing of fibre tows (non-impregnated and impregnated) and tensile testing of the composite samples. A numerical validation model developed in ABAQUS is used to establish the efficiency of this technique.
The adhesion force of the impregnated tow is five times higher than non-impregnated tow. The result exhibits that the melt-impregnation process facilitates good fiber wetting and a cohesive bond between the CCF and the PEI polymer, successfully transitioning from interfacial deboning to a stronger mechanical interlock. The numerical model successfully replicates experimental plots, accurately predicting the peak adhesion force and validating the underlying interfacial mechanics.
Furthermore, tensile testing the impregnated tow displays the linear response and high slopes indicate good fiber-matrix wetting and high tensile strength. This impregnated tow is utilised in Material Extrusion (MEX) process to produce composite structures with improved interlayer adhesion and high mechanical strength.

Keywords: continuous carbon fiber (CCF), adhesion testing, tensile strength, impregnated CCF, numerical modelling.

Spatiotemporal mapping of ultrasonic wave propagation for enhanced diagnostics of viscous media

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Abstract: This study presents an approach to ultrasonic diagnostics based on the spatiotemporal representation of wave propagation in a viscous medium. In contrast to conventional methods focused on pointwise signal parameters, the proposed methodology considers the wave process as a distributed structure evolving in both space and time. This representation enables visualization of wavefront propagation and provides access to additional diagnostic descriptors that are not readily available in standard time-domain analysis.

The approach is based on constructing the full wavefield $U(x, t)$ and analysing its structural organization by means of topological mapping. Such a formulation makes it possible to identify characteristic features of the ultrasonic process, including attenuation patterns, reflected components, interference regions, front dispersion, and locally disordered fragments of the wavefield. These features can be further expressed through quantitative descriptors related to signal energy distribution, spectral characteristics, entropy, and activation patterns in the mapped feature space.

The scientific novelty of the study lies in the transition from local signal interpretation to wavefield-oriented diagnostics, where the informative content is extracted from the spatial and temporal structure of the process itself. The proposed methodology broadens the diagnostic potential of ultrasonic measurements and creates a basis for developing non-destructive evaluation tools with extended sensitivity to the physical state and internal structure of viscous media. The method may be regarded as a promising framework for advanced diagnostics of lubricating liquids and other acoustically attenuating media.

Keywords: ultrasonic diagnostics, spatiotemporal wavefield mapping, viscous media, non-destructive evaluation, topological analysis, diagnostic descriptors.

Numerical modelling of hygrothermal diffusion and tensile response in additively manufactured composite laminates with embedded fibre Bragg grating sensors

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Abstract: Embedded fibre Bragg grating (FBG) sensors enable in situ strain monitoring in composite structures. But their presence may also alter local stress fields, moisture transport, and damage initiation, especially under combined environmental and mechanical loading. This work presents a numerical study of additively manufactured fibre-reinforced polymer laminates with embedded FBG sensors, focusing on the effects of hygrothermal exposure on tensile behaviour. A finite element framework is developed to simulate moisture diffusion, thermally induced strains and subsequent tensile loading. The environmental step predicts the transient distribution of the moisture absorbed through the laminate under hot and cold humid conditions. These results is then coupled with thermo-mechanical analyses to investigate swelling related deformation or residual stress development around the region where sensor is embedded. Particular attention is given to stress concentration zones around the embedded optical fibre and resin-rich zone, which may initiate matrix cracking, interfacial debonding, or delamination. This is also validated through SEM observations of fractured coupons under similar circumstances. The study is expected to provide a comprehensive framework for investigating the durability of smart composite laminates and support the design of structurally efficient composite systems that combine load-bearing capability with reliable sensing performance.

Keywords: finite element modelling, hygrothermal diffusion, thermo-mechanical behaviour, fibre bragg grating sensors, composite laminates, additive manufacturing.

Monitoring, diagnosing and identification of various rotor-shaft imperfections by means of the multi-fault model based vibratory inverse problem solution

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Abstract: Rotating machines are often affected by significant simultaneous imperfections usually caused by various manufacturing errors and operational defects. These imperfections excite more or less severe, mainly lateral vibrations of the rotor shafts of these machines, which on the one hand constitute a threat to their proper operation, and on the other hand these vibrations are a carrier of important diagnostic information allowing for the effective identification of faults and even their elimination. In order to identify the causes of these adverse effects on the basis of measured diagnostic signals recorded during a regular machine operation, it is necessary to obtain a theoretical knowledge regarding possible dynamic responses of the monitored machine to its most likely failures. For this purpose, advanced structural digital-twin models of the rotor-shaft systems have been built, which take into account the impact of various types of imperfections typical in rotating machines. These imperfections are represented by equivalent forces and moments that excite rotor shaft lateral vibrations. In such models, in addition to the impact of static unbalances, there is included simultaneous interaction of dynamic unbalances of the overhung rotors, parallel and angular misalignments of the adjacent shaft segments, inner anisotropy of the rigid couplings, transverse cracks in shaft cross-sections, pressure pulsation of the working medium caused by incorrect stagger angles of the rotor blades, electromagnetic pull of rotors of the electric motors or generators, and others. The contribution of these imperfections to the dynamic behavior of the system being tested will be identified by means of a multi-fault model-based identification method using the measured harmonic excitation signals and inverse problem solution, where vibratory motions are transformed into the space of modal coordinates, and malfunction effects are modelled by the use of the abovementioned equivalent external loadings. The operation of the proposed approach will be demonstrated on the example of identifying residual static and dynamic unbalances, and in consequence balancing the rotor-shaft of a low-power steam turbine. In the second example, results of monitoring recorded on a large blower applied in the mining industry will be used to examine the influence of a faulty setting of the stagger angles of the blower blades on lateral vibrations of the entire rotating system with the simultaneous impact of static and dynamic unbalances, parallel misalignments of the adjacent shaft segments, and inner anisotropy of the rigid couplings.

Keywords: machine condition diagnosing, vibration signals monitoring, rotor-shaft digital-twin model with imperfections, model-based multi-fault identification, inverse problem solution.

Metamaterial topology design with CLIP based learning

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Abstract: Metamaterials are engineered periodic structures whose exotic properties such as acoustic bandgaps and negative Poisson's ratios are influenced by the geometry of their unit cells. Traditionally, the topological design of these lattices presents a complex challenge, particularly at higher frequencies. This process typically demands computationally expensive finite element simulations and domain expertise. Furthermore, the relationship between numerous design parameters significantly influences material properties. In this work, we propose a novel approach to forward prediction in acoustic metamaterial topology design by leveraging a Contrastive Language-Image Pre-training (CLIP) architecture that integrates computer vision and natural language processing methodologies. We develop a framework utilizing images of metamaterial topologies paired with Run-length Encoding (RLE) textual representations to predict wave propagation vectors from a joint embedding space. Evaluated on a benchmark dataset, our results demonstrate that while the visual modality captures dominant geometric features, the multimodal approach leverages complementary textual representation to provide richer semantic context.

Keywords: acoustic metamaterials, acoustic bandgaps, forward prediction, topology optimization, multimodal learning, CLIP.

Diagnostics and control challenges in a large-scale forest CO_2 enrichment facility: technical upgrades from the BIFoR FACE experiment

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Abstract: The Birmingham Institute of Forest Research's (BIFoR) Free-Air CO_2 Enrichment (FACE) experiment is one of only two FACE facilities globally operating in mature woodland ecosystems. The facility enriches the tree canopy of 180-year-old oak trees to 150 ppm CO_2 above ambient levels, simulating atmospheric conditions projected ~30 years into the future and providing a platform for ecosystem research.

Maintaining a stable 150 ± 15 ppm CO_2 concentration above ambient levels in an open forest requires continuous response to rapidly changing wind fields, turbulence, canopy motion and weather-related variables. This demands a control system capable of high-frequency measurement, predictive adjustments and reliable actuation across a 25-metre-tall ring structure. The system must diagnose faults, correct instability and maintain target conditions while being fully automated.

Since CO_2 enrichment commenced in 2017, the facility relied on specialised DOS-based software written in Turbo Pascal in the late 1980's. This system originally enabled pioneering science, but over the years created operational challenges emerged, including reliance on outdated hardware and limited compatibility with modern computer operating systems.

In 2025, the program was redeveloped to operate on modern Siemens PLC architecture replacing the legacy Turbo Pascal system. This has allowed for integration of industry standard hardware, simplified development of features and has improved efficiency and adaptability, while reducing downtime. This newly developed control system is called the Next Generation FACE Control Program, or NG-FCP.

BIFoR is now collaborating with the UK Met Office to support the integration of NG-FCP into the Amazon FACE project in Brazil. The updated technology will operate a new long-term experiment aimed at understanding the ecosystem response of equatorial rainforests to rising global CO_2 levels.

This contribution highlights the engineering and diagnostic challenges of running a large, open-air environmental-control system and presents lessons relevant to technical specialists working with complex outdoor experimental infrastructure.

Keywords: BIFoR, FACE, PLC, environmental control systems, automation, CO_2.

A synergistic method for diagnosing the condition of a tribosystem operating under fluid lubrication

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Abstract: This paper presents an original approach to the functional diagnosis of the technical condition of lubricated tribosystems, integrating measurements of wear, energy losses, and lubricant film parameters. This method is based on empirical studies conducted on a test bench for examining friction assemblies in a sleeve-shaft configuration and the continuous recording of assembly operating parameters such as friction torque, friction force, and temperature. Discrete measurements include the geometric dimensions of the friction assembly and mass wear.

The empirical data form the basis for the developed diagnostic metrics covering energy and entropy-related issues such as the ratio of power pulsations to total friction energy, or the contact metric—describing the operating time of the joint under high-friction conditions. Based on the obtained data, a Sommerfeld characteristic was developed. A new technical degradation index was also proposed, based on the amount of heat generated by friction and its dissipation within the tribosystem, as well as the energy causing material wear.

The proposed method serves as an alternative for optimizing the control of the friction node's operating process under conditions of fluid and boundary lubrication, without a distinct extremum, and under operating conditions.

Keywords: entropy, tribosystem, sliding bearing, lubricant, degradation, diagnostic metrics.

Frequency-domain cointegration analysis for misalignment detection in rotating machinery

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Abstract: Rotating machines are fundamental components in industrial applications, where early detection of misalignment is essential to prevent excessive vibration, noise, and costly operational downtime. While cointegration has been developed as an effective approach for structural health monitoring (SHM) in non-stationary environments, applying it to vibration-based frequency-domain data remains a significant challenge.

This study proposes a novel approach to misalignment detection by applying cointegration to power spectra. The research specifically focuses on a multi-load blending methodology designed to better reflect the dynamic nature of industrial operations. Unlike traditional methods that analyze signals at single, constant loads, this approach blends vibration data from multiple operating loads (0.8, 1.6, 2.0, and 2.4 MPa). To ensure physically realistic load transitions, a Hann window is utilized to smooth the transitions between states, creating fifteen unique load profiles. The resulting power spectra serve as the input for a cointegration framework utilizing the Johansen method. To evaluate the effectiveness of the process, Augmented Dickey-Fuller (ADF) unit root tests were conducted on the data both before cointegration and subsequently on the residuals for comparison.

The proposed method was validated using experimental data from a laboratory test bench involving a motor-gearbox-pump system. The results demonstrate that the multi-load blending approach provides superior fault detection performance compared to single-load analyses. By capturing local spectral correlations across varying conditions, the method achieves significant improvements in damage-sensitive feature separation and classification accuracy. Furthermore, the multi-load approach exhibits a stronger signal-to-noise ratio, suggesting it is a more robust and practical tool for condition monitoring in machines operating under variable environments.

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Keywords: rotating machinery, misalignment detection, vibration measurements, varying load effects, cointegration, augmented Dickey–Fuller (ADF) test, condition-based maintenance, data analysis.

Blade fault diagnosis in wind turbines using a hybrid energy distance and permutation test method for vibration dataset analysis

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Abstract: This study introduces a new approach for wind turbine blade fault diagnosis based on vibration dataset analysis. Accurate prediction of wind turbine blade failures is of critical importance, as the inability to reliably detect such faults can result in substantial financial losses, prolonged downtime, and extensive repair activities, as well as increased operation and maintenance costs. In this study, a non-parametric diagnostic framework is proposed that combines energy distance metrics with permutation testing for the identification and characterization of blade faults in wind turbines. This method does not require the assumption of a normal data distribution, which is particularly important when analysing vibration signals, as such data often deviate from normality. In addition, the approach is robust to the presence of outliers. The proposed method is validated using experimental vibration datasets representing different blade conditions, including healthy, cracked, eroded, twisted, and unbalanced states. These datasets are analysed under varying wind speed conditions using energy distance combined with a permutation test for condition monitoring. The energy distance metric is employed to classify the blade condition of the wind turbine and to investigate subtle changes in blade behavior by comparing healthy and corresponding faulty states while considering the entire data distribution rather than simple summary statistics such as means. Furthermore, a permutation test is applied to statistically validate the energy distance results via p-values. The findings indicate that the combined use of energy distance and permutation testing effectively identifies and detects distributional changes between faulty and healthy blade behavior across different wind speed conditions.

Keywords: non-parametric method, blade fault diagnosis, wind turbine, condition monitoring, vibration measurement, statistical test.

Failure analysis of a tilting pad thrust bearing in a small back-pressure steam turbine

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Abstract: Tilting pad thrust bearings are critical components in steam turbines that ensure axial rotor support and minimise friction losses. Failures in such bearings can lead to severe operational disruptions and costly downtime, and may arise from subtle design or operational factors.
A premature failure was reported in a tilting pad thrust bearing of a small back-pressure steam turbine. This study investigates a potential cause of the failure, which was a design modification related to the thermocouple holes in the bearing pad. The holes were enlarged compared to the original design, and the distance between the hole axis and the bearing surface was reduced.
The axial load acting on the rotor was determined using computational fluid dynamics (CFD). The obtained load was subsequently applied in a thermo-hydrodynamic (THD) analysis of the thrust bearing to determine the pressure distribution, lubricant temperature, and thermal field within the bearing pad. The THD model solves the Reynolds equation for the oil film, the energy equation for the lubricant, and the heat conduction equation for the pad. The resulting operating conditions were then used in a Finite Element Method (FEM) analysis to evaluate the stress state in the bearing pad, including the local reduction in material cross-section caused by the modified thermocouple holes.
The results indicate the presence of shear stress concentration in the region between the pad surface and the thermocouple hole. The corresponding shear strain indicates that the bearing alloy is operating close to its yield limit. This local weakening of the bearing alloy layer occurs regardless of whether a thermocouple is installed in the hole. The results highlight the potential risk associated with the design modification.

Keywords: tilting pad thrust bearing, steam turbine, bearing failure analysis, bearing diagnostics, thermo-hydrodynamic analysis.

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Stages of maturity in condition-based maintenance: insights from urban rail, waste management and port logistics

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Abstract: This study examines the implementation process of Condition-Based Maintenance (CBM) systems across three heterogeneous machine categories, each defined by distinct operational characteristics, technical requirements, and resource availability.
The first case study focuses on a tram equipped with an extensive sensor network and a robust historical database, containing data on components failures and changes across seasons, but being the only monitored vehicle in the fleet it cannot be compared with other trams.
The second case involves refuse collection vehicles, where a large fleet allows for cross-vehicle comparisons and malfunction probability assessments, despite less granular sensor data. Although this implementation is in its nascent stages, it already delivers stakeholder value through continuous usage analytics.
The third category comprises port machinery, representing the earliest stage of CBM adoption. This segment serves as a pilot to demonstrate the initial challenges of system integration in a diverse equipment environment.
Ultimately, this work demonstrates the various stages of CBM development and adoption, highlighting how differing technical constraints dictate the primary focus, challenges, and return on investment (ROI) at each phase.

Keywords: condition-based maintenance, mobile machine, technical diagnostics, system implementation, maintenance analytics.

Comparative experimental identification of stiffness and damping in an active gas foil bearing using impulse and harmonic excitation

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Abstract: This study compares different experimental setups to determine the stiffness and damping of a novel active gas foil bearing with an adjustable three-segment sleeve. The proposed method compares results between two complementary identification paths applied to the same laboratory setup. In the first path, the compliant foil-support structure is examined under impact excitation on a non-rotating, vibration-isolated test stand, providing baseline effective modal parameters of the bearing assembly. In the second path, the setup is augmented with controlled harmonic excitation, in which the forcing frequency serves as a repeatable, frequency-indexed representation of the rotor's rotational speed.
The main goal is to compare the coefficients obtained from impulse-response measurements with those identified for specific harmonic excitation frequencies. Such a comparison enables the separation of structural baseline properties from excitation-frequency-dependent dynamic behaviour, while benefiting from the non-rotating setup, which eliminates the influence of the fluid film, unbalance excitation, gyroscopic coupling, and thermal transients. The measurement system combines force input (from the modal hammer and excitation shaker) with contactless displacement measurements, and the recorded signals are analysed using a reduced-order input-output model of the tested bearing structure.
The proposed methodology establishes a foundation for configuration-dependent maps of effective stiffness and damping in active foil bearings with adjustable geometry. It also supplies experimentally verified data for further rotordynamic modelling, technical diagnostics, and future control-focused studies of actively tuned bearing systems.

Keywords: active gas foil bearing, stiffness identification, damping identification, harmonic excitation, impulse excitation, technical diagnostics.

Application of Rice's frequency for the analysis of acoustic signals of the welding process

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Abstract: The growing automation of welding processes has increased the demand for reliable online quality monitoring systems for welded joints. Conventional quality control methods, based primarily on non-destructive testing performed after welding completion, are time-consuming and costly, and do not allow for real-time correction of process parameters. Among the available sources of diagnostic information, acoustic signals occupy a prominent position. The sound generated during arc welding is a natural carrier of information about the process state — research in this field has been published since 1979. Changes in workpiece geometry, surface contamination, fluctuations in material properties, arc length instabilities, and deviations in current and voltage parameters are immediately reflected in the spectral characteristics of the emitted sound. The non-contact nature of measurement, low instrumentation cost, high diagnostic information density, and ease of sensor installation make acoustic monitoring particularly attractive for industrial applications.

Effective detection and identification of welding discontinuities requires appropriate processing of the recorded signals. The literature describes numerous approaches, ranging from simple statistical methods and Fourier transform-based spectral analysis to advanced deep learning techniques. Due to the random and non-stationary character of the welding acoustic signal, not all methods exhibit sufficient sensitivity for detecting process instabilities.

In signal processing theory, a measure describing the weighted mean frequency of the signal spectrum is defined, known as Rice's frequency. This measure is applied in the condition monitoring of rotating machinery; however, despite its suitability for analysing non-stationary signals, its application to welding process diagnostics has not previously been reported. The present study assesses the applicability of Rice's frequency for detecting acoustic instabilities in the welding process that may lead to defects disqualifying joint quality. The obtained results demonstrate that Rice's frequency enables effective detection of selected types of welding process instabilities.

Keywords: arc welding, acoustic monitoring, Rice's frequency, defect detection, signal processing, process diagnostics.

The application of simulation and artificial intelligence methods in the diagnostics of main propulsion marine combustion engines

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Abstract: This article presents the application of artificial intelligence as a new method for diagnosing marine internal combustion engines. The limitations of traditional diagnostic methods for marine internal combustion engines are presented based on the current state of knowledge. Graded simulations of operating conditions were performed on a simulator provided by a leading main engine manufacturer. The basic algorithms used for machine learning and the selection of artificial neural networks, implemented and tested in MATLAB, are described.

Technological development necessitates the refinement of traditional diagnostic methods and the development of new ones. According to the authors, establishing a reliable diagnosis relies on the correct classification of simulated data on the Kongsberg simulator. The problem of classifying data collected based on changes in pressure waveform parameters in the cylinders of a marine internal combustion engine, which vary under the influence of various types of faults in the fuel and piston-crank systems of the simulated engine. The authors' contribution lies in applying at least a four-stage simulation of technical conditions (up to 60%) to the simulator and using condition classification.

The best classification model turned out to be an optimized network consisting of three hidden layers, where the training accuracy reached 94.1%, and the testing accuracy reached 97.3%.

Keywords: marine engine, diagnostic, simulation, machine learning, classification.

Trend identification in diagnostic time series using a hierarchical reasoning neural network model for machine condition monitoring

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Abstract: Effective assessment of machine technical condition requires reliable methods for trend prediction in diagnostic signals, which are characterised by discontinuities, measurement noise, and variable dynamics. Continuous monitoring systems depend on proper analysis of large volumes of heterogeneous sensor data and on the formulation of accurate diagnostic insights supporting maintenance decision-making.

Time series representing the evolution of diagnostic features are difficult to interpret directly due to random variations caused by changing operating conditions, process parameter modifications, and production schedule variability. The dynamic nature of these signals hinders both trend detection and degradation forecasting. Classical forecasting methods exhibit limited effectiveness for complex, non-periodic signals, which motivates the development of more flexible, data-driven approaches.

This study proposes the application of a Hierarchical Reasoning Model (HRM) for trend prediction in diagnostic time series. The hierarchical architecture processes data at multiple abstraction levels — from local short-term patterns to global long-term trends — enabling simultaneous modelling of transient fluctuations and the dominant signal trend. This capability is particularly relevant for machine operational data, where signal components of different time scales are superimposed.

Due to limited availability of labelled industrial data, the training dataset was generated synthetically while preserving representativeness with respect to real operating conditions. The generation process incorporated diverse trend function classes and realistic disturbances, including additive noise with variable amplitude, cyclic interruptions representing planned downtime, and random interruptions simulating unplanned failures.

Model effectiveness was evaluated using standard prediction error metrics and compared against selected reference methods. The results confirm that the hierarchical structure significantly improves trend estimation accuracy in the presence of discontinuities and noise, demonstrating the potential of the proposed approach for practical application in machine condition monitoring and predictive maintenance.

Keywords: time series prediction, hierarchical reasoning model, trend estimation, condition monitoring, predictive maintenance, artificial neural networks.

Fatigue life prediction for naval polymeric shock absorbers

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Abstract: Marine machinery operating in demanding hydrometeorological conditions is subjected to harmonic loads characteristic of rotating machinery, quasi-harmonic or stochastic loads related to rough sea, impact loads, and environmental conditions within the ship's hull. Highly humid, saturated-hydrocarbon atmospheres significantly shorten the service life of polymer shock absorbers. These changes involve degradation of stiffness and damping parameters, which, in the long term, can lead to the development of resonances that may not have been analysed during the design process due to the lack of reliable rheological analyses. This paper proposes and tests Maxwell (Prony) and Kelvin–Voigt/Maxwell simulation models for three types of materials commonly used in marine shock absorbers to determine their durability for a specified number of cycles. The proposed fatigue life prediction methodology integrates a numerical rheological model written in MATLAB code with experimentally derived material characteristics from laboratory tests. The simulation results were verified in the laboratory using laboratory stands to examine the effect of fatigue loading on changes in shock absorber stiffness. This approach reduces the need for costly experimental studies and facilitates numerical modelling of shipboard machinery shock absorption to improve operational safety.

Keywords: elastomeric mounts, shock absorbers, viscoelasticity, fatigue degradation, simulations.

Verification of the Johnson–Cook model in finite element analysis through 3D scanning of 316L specimens manufactured by WLMD

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Abstract: This study presents a combined numerical and experimental investigation of flat 316L stainless steel specimens manufactured by Wire Laser Metal Deposition (WLMD), a process classified within Directed Energy Deposition (DED) technologies. The main objective was to validate the Johnson–Cook constitutive model implemented in finite element simulations by comparing the numerical results with static tensile test data and the actual post-fracture geometry of the specimens obtained through 3D scanning.

The first stage of the study focused on mesh convergence analysis for six finite element discretization levels, with characteristic element sizes ranging from 0.0025 m to 0.0005 m. The evaluation considered maximum normal stress, average stress within the gauge section, and computational time. The results showed that, up to the ultimate tensile strength, the predicted material response was largely insensitive to mesh density. In contrast, clear differences between mesh variants appeared in the necking and failure stages. A global seed size of 0.001 m was identified as the most effective compromise between numerical accuracy and computational efficiency. The agreement between numerical predictions and experimental results reached 99.52%.

In the second stage, the fractured specimens were digitized using a Revopoint METROX 3D scanner. The resulting point clouds were filtered, aligned, and compared with the finite element results. Deviation analysis enabled both qualitative and quantitative assessment of the agreement between the simulated and real geometries, particularly in the fracture zone and its immediate vicinity. The results confirm that combining finite element analysis, the Johnson–Cook material model, and 3D scanning provides an effective framework for evaluating deformation and failure mechanisms in WLMD-manufactured components.

Keywords: 316L stainless steel, wire laser metal deposition, WLMD, directed energy deposition, DED, finite element method, FEM, Johnson–Cook model, tensile test, mesh convergence, 3D scanning, fracture analysis.

Hybrid game-theoretic decision models for non-probabilistic diagnostics of computational systems under uncertainty and incomplete information by irregular faults

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Abstract: A hybrid game-theoretic decision model for diagnostics of computational systems (CSs) under uncertainty is proposed, when CS faults are irregular. The diagnostic process is modeled as a non-probabilistic game between the diagnostic system and uncertain CS states representing faults, where $S$is the set of diagnostic strategies, and Θ is the set of possible CS states. A strategy $s \in S$ maps observed signals X(e. g., CPU load, memory usage, network traffic) to decisions $D = s(X)$. For example, a rule may classify a CS as overloaded when CPU usage exceeds a threshold. Another rule may combine CPU/GPU and network indicators.

The performance of a strategy depends on the true CS state $\theta \in \Theta$, such as normal operation, overload, hardware fault, or network anomaly. This is described by a payoff function $U(s,\theta)$ reflecting detection inaccuracy, false alarms, and computational cost. For instance, missing a hardware fault leads to a high penalty, while a false alarm increases maintenance cost. Uncertainty arises because different faults may produce similar signals. For example, high CPU usage may be caused by legitimate workload growth or by a hidden malfunction. Incomplete information occurs when not all CS parameters are observable. For instance, internal hardware degradation may not be directly reflected in available logs. Instability appears when different criteria lead to different optimal strategies. For example, a minimax rule may prefer conservative thresholds, while an average-based rule may favor more aggressive detection, resulting in conflicting decisions.

Instead of using a single decision criterion, hybrid decision criteria are applied for selecting optimal strategies. In particular, min-max and regret-based evaluation criteria

$$V_{\min}(s)=\min_{\theta\in\Theta}U(s,\theta),\quad V_{\max}(s)=\max_{\theta\in\Theta}U(s,\theta),\quad R(s,\theta)=U(s,\theta)-\min_{t\in\Theta}U(t,\theta)$$

are combined into a hybrid rule:

$$H(s)=\alpha V_{\min}(s)+\beta V_{\max}(s)+\gamma\max_{\theta\in\Theta}R(s,\theta)\ \text{ by }\alpha>0,\ \beta>0,\ \gamma>0,\ \alpha+\beta+\gamma=1,$$

whereupon $s^{*}\in\arg\min_{s\in S}H(s)$. In general, this is a minimultimax-type criterion:

$$s^{*}\in\arg\min_{s\in S}\max_{\theta\in\Theta}\max_{\lambda\in\Lambda}U_{\lambda}(s,\theta),$$

where Λ denotes a family of payoff transformations.

Genetic algorithms are employed to optimize diagnostic strategies by encoding each $s \in S$ as a chromosome and evaluating its fitness via the hybrid criterion as $\psi_{\text{fitness}}(s)=-H(s)$ to maximize it. The evolutionary process iteratively applies selection, crossover, and mutation to generate improved strategies, when vector X is too long.

The proposed approach allows non-probabilistic refinement of diagnostic strategies beyond classical minimax or single-criterion solutions. It reduces instability and improves robustness

in diagnostics of servers and distributed systems under uncertainty and incomplete information by irregular faults.

Keywords: computational systems, diagnostic strategy, game-theoretic decision model, non-probabilistic game, minimultimax-type criterion, genetic algorithms.

Comparative analysis of entropy-based methods for diagnostics of water-lubricated plain bearings

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Abstract: Modern diagnostics of water-lubricated plain bearings require advanced signal analysis methods capable of identifying subtle changes in system dynamics. One approach gaining increasing attention is the use of entropy-based measures as indicators of the complexity and instability of dynamic processes.

Numerous entropy estimation methods have been proposed in the literature, differing in their theoretical foundations as well as sensitivity to noise, signal length, and data characteristics. Commonly used approaches include approximate entropy, sample entropy, and dispersion entropy, along with their modifications. Despite their widespread application, clear guidelines for selecting an appropriate method for a specific diagnostic task are still lacking.

The aim of this study is to perform a comparative analysis of selected entropy estimation algorithms in the context of diagnosing water-lubricated plain bearings. Particular attention is given to their ability to detect changes in dynamic behavior, robustness to noise, and sensitivity to input parameters. The analysis is based on both numerically generated signals and experimental data obtained from dedicated test rigs.

It is hypothesized that the effectiveness of entropy-based methods strongly depends on signal characteristics and operating conditions of the bearing, which necessitates a careful selection of the algorithm for a given application. The expected outcome is to improve the understanding of the applicability of different entropy measures in bearing diagnostics.

Keywords: water-lubricated plain bearings, entropy measures, signal analysis, condition monitoring.

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A stochastic signal model for distributed faults in rolling bearings

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Abstract: The scientific literature on the diagnosis of rolling bearings largely focuses on localized faults. Such local defects of the raceway cause the vibration signal from a damaged bearing to contain a series of pulses, resulting from the interaction of successive rolling elements with the point of structural discontinuity. The clearance between the cage and the rolling element, and the slippage of the cage itself, make subsequent impact times not perfectly periodic. For a signal originating from a faulty bearing, a cyclostationary model is therefore adopted – one that accounts for the cage clearance in the form of normally distributed jitter – or a pseudo-cyclostationary model, which accounts for random cage slip.
Diagnostic methods for rolling bearings based on this type of impulse signal model account for the majority of the methods described in the literature. These methods are most commonly validated using experimental datasets of bearing measurements in which localized damage has been induced. Such isolated faults clearly show the nature of the analyzed signal, but in industrial practice, bearing faults may occur in the form of distributed faults. In the case where bearing damage takes the form of generalized roughness of the raceway, a model assuming that the damage manifests itself as a series of pulses is insufficient.
The presentation introduces a new model of a faulty bearing signal, which allows for any damage profile of the raceway to be adopted. By modeling the angular velocity of the rolling element as a stochastic process, this approach extends the traditional cyclostationary impulse model to effectively describe generalized roughness. Furthermore, the model also allows for describing the angular velocity of the bearing cage with a stochastic process, thus extending its application to a pseudo-stationary or mixed cases.
Finally, different variants of outer and inner raceway damage are presented. The resulting synthetic signals were analyzed using standard rolling bearing diagnostic methods to validate the proposed model's ability to accurately represent the vibration signatures of distributed faults.

Keywords: rolling bearing diagnostics, distributed faults, generalized roughness, stochastic process, signal modelling, cyclostationarity.

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Infrared thermography for in-process TIG welding supervision using anomaly detection with a convolutional autoencoder

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Abstract: Thermographic monitoring is increasingly applied to welding supervision, yet robust in-process quality assessment remains challenging due to the highly dynamic nature of thermal signatures and their dependence on multiple interacting factors, including heat input, surface condition, emissivity variation, reflections, shielding, and viewing geometry. An anomaly-detection workflow for infrared thermography (IRT) sequences recorded during TIG (Tungsten Inert Gas) welding, aimed at early detection of atypical thermal behaviour to support operator feedback, reduce scrap, and complement conventional post-process inspection was elaborated.

A controlled experimental trials were conducted in which a radiometric IR camera observed the weld pool and adjacent heat-affected zone during welding under diverse operating conditions. Multiple parameter settings were explored to capture the natural variability of nominal runs and transient disturbances. Each recording was linked to the specimen and process metadata to ensure traceability between IR data and the physical outcome.

The pipeline converts the radiometric stream into temp. maps and selects a region of interest around the arc–pool area to suppress background effects. Normalization and temporal alignment reduce sensitivity to absolute temperature changes and highlight structural thermal patterns. Alongside deep learning, interpretable indicators are computed as baselines and diagnostics, including average temp. evolution, inter-frame temp. changes, and the relative extent of high-temp. zones obtained through adaptive thresholding.

For annotation-light detection, a convolutional autoencoder is trained exclusively on thermograms representing stable, acceptable process behaviour. The network learns a compact representation of expected spatial temperature distributions and reconstructs incoming frames. During inference, reconstruction error serves as an anomaly score: frames that cannot be adequately reconstructed are flagged as potentially abnormal. A post-verification step examines additional symptoms to confirm deviations and provide coarse qualitative categorization.

Results demonstrate that reconstruction error peaks align with visible thermal irregularities and unstable bead formation. The workflow combines physics-informed preprocessing, transparent thermal indicators, and unsupervised deep learning, offering a practical route toward scalable IR-based TIG welding supervision where labelled defect data are limited.

Keywords: anomaly detection, infrared thermography, TIG welding monitoring.

Properties enhancement for gas foil bearings via application of smart materials

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Abstract: The application of smart materials opens new perspectives regarding the control and observation of the dynamic behavior for a wide range of mechanical and mechatronic systems. These materials offer advantageous capability of coupling between various physical domains. Therefore, using them, both actuating and sensing tools can be developed to effectively track and modify the operation regimes of the controlled systems.
Amongst others, gas foil bearings (GFBs) are the systems that are subjected to the continuous development due to their undeniable advantages. They are fluid film supports readily used in modern high-speed and preferably lightly loaded machinery. The coexistence of the two adjacent layers found in these slide bearings, i.e., the structural one composed of thin metallic foils and the fluidic one developed as an air film, makes it feasible and convenient to control the bearing's elasto-damping characteristics and the resultant load capacity. The main drawback of GFBs, however, is their sensitivity to the high temperature gradients that may rapidly lead to the loss of desired hydrodynamic conditions necessary to maintain the air film and contactless operation.
The presented work discusses the applications of smart materials to assure effective control of the GFB's thermomechanical characteristics and their operation over a wide range of rotational speeds. Specifically, the use of thermoelectric modules, thermocouples, shape memory alloys (SMAs) and piezoelectric transducers (PTs) remains within the scope of the authors' interest. There are reported various techniques that extend the bearings' capabilities and their operational regimes via applications of the electrically and thermally activated excitations within both mechanical and temperature domains.
Finally, the use of the selected smart material-based control techniques for GFB operation is illustrated with the results of experimental tests. As shown, installation of SMA components and PTs in an inspected bearing allows for an effective and advantageous modification of its dynamic properties. The publication was financed by a subsidy to maintain the research capacity of the Faculty of Mechanical Engineering and Robotics, AGH University of Krakow.

Keywords: gas foil bearing, rotor dynamics, turbomachinery, smart material, dynamic properties, properties control.

Modular program for modelling dynamic phenomena occurring in selected types of toothed gearboxes

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Abstract: The aim of the research described in this article was to develop a set of algorithms for simulating the dynamic phenomena occurring in selected types of gear transmissions. Two types of transmissions, selected based on their popularity, were analysed. The first type consists of spur gears, and the second of planetary gears.
Simulations performed in the developed program account for the impact on gear operation of factors originating both within the gear itself and those caused by the operation of other components of the drive system. The results of own work were preceded by a literature review presenting previous achievements in the analysed area, concerning both model construction and the analysis of the causes and effects of the phenomena occurring.
It is widely recognized that the use of dynamic transmission models can help reduce the design time for both the toothed gearboxes themselves and entire power transmission system. Using these models also enables design optimization efforts that could not be carried out experimentally to the same extent. As a result, it becomes possible to better adapt the final gear design to actual operating conditions and user needs.
The developed program can serve as a useful tool for assisting in the diagnosis of gearboxes. The close cause-and-effect relationship between the technical condition of a gearbox and its vibrations and noise - which forms the basis of vibroacoustic diagnostics - leads to the use of dynamic models to determine vibrations numerically by simulating various technical conditions of the analysed objects. Since all working components in gearboxes are subject to wear, primarily gears and bearings, the entirety of these wear processes ultimately leads to randomness in the amplitude and frequency of the sequence of elementary events resulting from gear rotation. As wear increases, the intensity of vibration and acoustic phenomena also increases. Emerging malfunctions and damage also influence the vibration profile in the time and frequency domains. Investigating these relationships through simulation studies is therefore advisable and justified from an application perspective.
Regardless of how gear dynamic models are used, the value of a developed program is always determined by its correctness, the assumptions made, the specified constraints, its identification, and finally its tuning. For this reason, this work focuses not only on describing the phenomena occurring within the gearboxes themselves, but also demonstrates how to model the most important components of the drive system.

Keywords: toothed gear, power transmission system, dynamic model, design, optimization, diagnostics.

The condition monitoring system for rotating machinery with training under industrial conditions

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Abstract: The paper presents a condition monitoring system for rotating machinery operating under variable conditions, implemented on an industrial controller running a real-time operating system. The system incorporates a diagnostic method trained on a healthy machine under industrial conditions.
During the training process, relationships between the components of the order spectrum and rotational speed are determined, where speed variations result from changing load conditions. These relationships are represented as sets of polynomial curves. The resulting sets of curves are determined for different temperature ranges. It should be emphasised that the training process requires only data obtained from a healthy machine.
The characteristics determined during training are used as reference functions in the diagnostic process. During diagnosis, distances between the current and reference curves are calculated and expressed as normalised *RMSD(order, temperature)* parameters. The *RMSD(order)* parameters, averaged over temperature for each order, form the components of a new order spectrum that is insensitive to variations in operating conditions. The interpretation of this new spectrum is analogous to that of a spectrum obtained under steady operating conditions.
The system's performance was tested on two laboratory setups designed for diagnosing cylindrical and planetary gearboxes. The system was tested for its ability to diagnose basic faults, such as misalignment and imbalance. The method also proved effective in detecting the early stages of degradation in a two-stage cylindrical gearbox. The obtained spectrum revealed degradation processes of individual gears as well as damage to the rolling bearing of the gearbox input shaft. The method was compared with a conventional order-spectrum-based approach that does not account for the influence of varying operating conditions on spectral component amplitudes.

Keywords: condition monitoring system, variable, variable operating conditions, order analysis, real-time operating system.

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Hydrogen-powered vehicles in vehicle technical inspections

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Abstract: This study analyses current methods of conducting technical inspections of vehicles that use compressed hydrogen as an energy source. The current legal regulations regarding the scope and methods of testing do not keep pace with technical progress in the design of modern means of transport. The study proposes changes and an extension of the scope of technical inspections to include the detection of hydrogen within hydrogen system pipes and connections using portable point-detection sensors. The results of the analysis and testing using the Vehicle Inspection Station's test bench enable safer vehicle operation and improve the effectiveness of diagnosing leaks and mechanical damage to hydrogen supply systems fitted in vehicles. The tests were carried out using a city bus manufactured by the Polish company NesoBus.

Keywords: hydrogen-powered vehicles, hydrogen car technical inspection, vehicle inspection station, fuelcell bus technical inspection, hydrogen leak detection, car technical inspection.

Integration of fast- and slow-varying phenomena in multiscale diagnostic models of technical systems

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Abstract: Modern technical diagnostic systems operating in industrial environments enable the processing of data characterized by diverse temporal dynamics, including both fast- and slow-varying phenomena. The first group includes high-frequency signals, such as vibrations or acoustic emission, primarily used for event detection and identification of machine component faults. In contrast, slow-varying phenomena, represented for example by temperature, wear indicators, or changes in operational parameters, reflect degradation processes and enable long-term condition assessment of the object. In industrial practice, these data are often analyzed separately, which leads to the loss of important diagnostic information and limits the effectiveness of decision-making processes.

The aim of this paper is to present an approach integrating fast- and slow-varying phenomena within multiscale diagnostic models of technical systems. The proposed concept is based on a model in which fast-varying data are responsible for event detection and anomaly identification, while slow-varying data enable trend analysis and assessment of degradation levels. A key element of the proposed approach is an integration layer that incorporates the operational context of the system, including working conditions, load, and environmental variability, allowing for proper interpretation of data across different time scales.

The proposed approach is validated based on several experiments conducted both on a test industrial line and during studies involving air pollution monitoring using unmanned aerial vehicles. The collected data made it possible to consider both fast-varying fluctuations of selected parameters and slow-varying changes in the environmental background resulting from ambient conditions, including atmospheric factors. The aim of the study is to demonstrate that the integration of multiscale data and the inclusion of measurement context significantly improve the reliability of diagnostics and enable more accurate anomaly detection.

Furthermore, the paper discusses the role of artificial intelligence methods in the integration of multiscale data, with particular emphasis on hybrid models combining signal analysis, statistical models, and machine learning. The proposed approach provides a basis for the development of modern diagnostic systems in Industry 4.0 environments, supporting predictive maintenance and the analysis of complex environmental processes.

Keywords: technical diagnostics, multiscale models, fast- and slow-varying phenomena, operational context, artificial intelligence.

Different approaches for using unsupervised deep learning in fault diagnosis of rotating machinery operating under variable conditions

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Abstract: To address the challenges of diagnosing machines under variable operating conditions, this study proposes three different deep neural network architectures that use, as input data, the relationships between orders amplitudes as a function of machine operating parameters (rotational speed, motor current, and temperature).
The first method, an ensemble model, used a set of 12,000 models to construct a virtual diagnostic parameter for machine health assessments by independently modelling each order in the analysed spectrum.
The second model used the regression of operating condition and the specialised input-influence analysis to determine which part of the spectrum is responsible for damage-alarm generation.
The last proposed method was based on the autoencoders and spectrum reconstruction error, which allows for assessing the type of detected damage.
All presented deep learning methods allow for the detection as well as the identification of the type of damage based on the analysis of anomalies in spectral component relationships. As they are trained in an unsupervised paradigm, they do not require signals recorded on an undamaged machine for model training.
All proposed models were verified on laboratory test benches for diagnosing planetary and helical gearboxes. In the experiments conducted, the diagnosed objects were subjected to variable loads simulating those encountered in industrial conditions. In addition, signals were recorded during the object's warm-up to assess the methods' effectiveness at varying temperatures.
Diagnostic methods based on deep neural network models demonstrated effectiveness in detecting shaft imbalance, misalignment of a planetary gearbox or degradation of a two-stage helical gearbox, while generating no false alarms.
The project was financed by the Polish Ministry of Science and Higher Education [project No. 10 000-501.00-130 000].

Keywords: rotating machinery diagnosis, deep learning, order analysis, unsupervised learning.

From signal processing to decision support: multiscale diagnostics for predictive and prescriptive maintenance

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Abstract: Modern technical diagnostics in industrial systems increasingly relies on advanced signal processing and data-driven methods to support maintenance strategies. The growing availability of high-resolution measurement data enables continuous monitoring of machine operation and creates the need for effective integration of heterogeneous signals characterized by different temporal dynamics. In this context, diagnostic systems must process both fast-varying signals, such as vibration or acoustic emission, and slow-varying parameters related to degradation processes, including temperature and operational trends.

The aim of this paper is to present a multiscale diagnostic framework that integrates signal processing and artificial intelligence methods to support predictive and prescriptive maintenance. In the proposed approach, fast-varying signals are analyzed using feature extraction and anomaly detection techniques, while slow-varying data are used for trend analysis and degradation modeling. The integration of these data streams enables consistent condition assessment and supports the transition from prediction-oriented diagnostics toward decision-oriented maintenance.

The methodology is based on a processing chain that includes signal acquisition, preprocessing, feature extraction, model identification, and decision support. Attention is given to the role of multiscale data fusion and the incorporation of operational context, which allows for improved robustness and reliability of diagnostic models under varying working conditions.

Experimental studies are conducted on a test production line, where multiple sensor signals are collected and analyzed. The experiments demonstrate how the integration of fast- and slow-varying data improves fault detection, enhances prediction accuracy, and supports the generation of maintenance recommendations. The results highlight the importance of combining signal-based features with contextual information in practical diagnostic applications.

The paper also discusses the application of artificial intelligence techniques, including machine learning and hybrid models combining signal processing with physics-based approaches. Key challenges include feature selection, data quality, model interpretability, and integration with industrial systems. The proposed framework provides a basis for the development of advanced diagnostic systems in Industry 4.0 environments, bridging the gap between signal analysis and decision support.

Keywords: signal processing, technical diagnostics, predictive maintenance, prescriptive maintenance, multiscale data.

Model-based diagnostic of fuel injectors

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Abstract: The continuously increasing requirements and restrictions regarding the emission of harmful substances in exhaust gases are driving the development of fuel supply systems in modern internal combustion engines. In spark-ignition engines, the application of TSI direct injection technology enables precise control of the fuel mixture formation and combustion process. A key component of this system is the electromagnetic fuel injector, whose operation determines both the accuracy of fuel dosing and the timing of injection initiation.
The injector system can be divided into three interconnected subsystems: electrical, mechanical, and hydraulic. Phenomena occurring in one subsystem influence the operation of the others. This work proposes a nonlinear mathematical model of a TSI electromagnetic injector that takes into account the couplings between these subsystems. The model is formulated as a system of nonlinear differential equations describing both the current changes in the coil and the motion of the injector needle.
Based on the mathematical model, a simulation model was developed in the Matlab–Simulink environment using Simscape libraries, enabling the reproduction of injector operation. A peak-and-hold control strategy was applied, characterized by a rapid rise in current during the injection initiation phase, followed by its reduction to a level sufficient to maintain the needle in a position that allows fuel flow after the injector is opened. This approach enables a realistic representation of real injection system operating conditions.
The developed system serves as a tool for analyzing changes occurring in the injector. It allows investigation of the influence of electrical parameters, such as winding resistance or inductance characteristics, on the current waveform and the generated electromagnetic force. Current-related quantities determine the moment of needle motion initiation, the duration of fuel flow, and the stability of its position during operation. At the same time, it is possible to analyze the impact of mechanical parameters, such as spring stiffness and damping, on the dynamic response, including delays and fluctuation phenomena. The model also accounts for hydraulic parameters (fuel pressure) acting on the needle, making it possible to study the relationship between engine operating conditions and the course of the injection process.

Keywords: fuel injector, injector diagnostics, model-based diagnostics.

Chatter onset detection in high-speed micromilling by recurrences

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Abstract: Chatter instability is a critical limitation in high-speed micromilling, leading to deteriorated surface quality and reduced tool life. This study presents an experimental investigation into chatter onset under continuously varying cutting conditions. Full immersion micromilling experiments are performed on Ti6Al4V using a 500 μm diameter tool, where the axial depth of cut is gradually increased from 0 to 200 μm within a single machining pass to induce instability. Spindle speeds of 20k, 60k, and 100k RPM and a feed rate of 3 μm/tooth are considered. Cutting forces and acceleration signals are acquired using a dynamometer and a high-bandwidth accelerometer to capture the dynamic response of the process. The gradual variation of depth of cut within a single pass provides a controlled framework to capture the transition from stable cutting to chatter.

The analysis combines recurrence plots, RQA analysis, wavelet-based time–frequency decomposition, and entropy measures to characterize the evolving dynamics of the process. The results indicate that recurrence representations reveal clear structural transitions associated with the emergence of periodic chatter vibrations. Wavelet analysis captures localized transient features and the development of dominant frequency components, while entropy measures reflect changes in signal complexity preceding instability.

The proposed methodology will be validated through examination of the machined surface, where the predicted chatter onset is correlated with the actual appearance of chatter marks. The combined approach provides a consistent and complementary description of chatter initiation under non-stationary machining conditions. The findings demonstrate the potential of integrating nonlinear dynamics and time–frequency analysis for reliable chatter detection, with implications for real-time monitoring and adaptive control in micromilling processes.

Keywords: micromilling, chatter, recurrence plots, wavelets, multiscale entropy.

Simulation-experimental identification of internal flow parameters of a Savonius turbine for predictive diagnostics purposes

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Abstract: This paper addresses the issue of predictive diagnostics of vertical-axis Savonius wind turbines in the context of identifying internal rotor flow parameters. Savonius turbines, due to their simple design, low manufacturing costs and the ability to operate at low wind speeds, are used in microgeneration. At the same time, their low aerodynamic efficiency and significant torque fluctuation pose both design and operational challenges. Changes in rotor geometry parameters, particularly blade spacing, affect the internal flow structure, which directly translates into measurable turbine operating characteristics.

An approach combining experimental tests carried out in a wind tunnel with numerical flow modelling (CFD) is presented to develop diagnostic indicators enabling the assessment of rotor technical condition under operating conditions. Experimental tests included measurements of rotor torque and rotational speed as a function of wind speed and angle of rotation, performed in both dynamic and quasi-static modes, for three blade spacing variants of a two-blade Savonius turbine. In parallel, numerical models were developed to reproduce the velocity and pressure fields in the inter-blade area of the turbine.

A comparative analysis of experimental and simulation results enabled the identification of characteristic internal flow structures and their correlation with torque waveforms as a function of rotor rotation angle. Deviations between the reference model results and measurement data were proposed as potential diagnostic indicators, which changes under operating conditions may signal rotor geometry degradation, such as blade deformation, inter-blade gap alteration or casing damage. The possibility of using spectral analysis of torque waveforms as a complementary diagnostic tool was also indicated.

The proposed approach fits within the concept of predictive diagnostics, enabling early detection of changes in turbine technical condition based on a comparison of current operating parameters with a reference model. The results may find application in monitoring systems for wind microinstallations operated under conditions of limited technical supervision.

Keywords: Savonius turbine, predictive diagnostics, CFD simulation, torque fluctuation, wind tunnel testing, blade spacing.

Autonomous systems incidentally supported by a remote operator

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Abstract: Autonomous systems play an increasingly important role in modern applications. Their advanced and responsible operation is typically governed by intelligent software that relies on knowledge accumulated in a dedicated Knowledge Base. However, in rare cases the system may be unable to make an appropriate decision regarding its continued operation in a dynamically changing environment or under rapidly evolving circumstances. In such situations, a remote operator can temporarily support the system by taking control, resolving the complex task, and subsequently returning control to the autonomous system. This remote-operation process can be enhanced through the use of a Virtual Teleportation (VT) approach.

Virtual Teleportation (VT) is a capability of innovative user interfaces that enables full immersion of a user into an environment located far from their physical position. It creates the sensory impression of being physically present in that remote environment and allows the user to perform both passive and active tasks there.

The first research in this field involving the author was initiated by K. Cyran in 2013 and conducted at SkyTech Research sp. z o.o. (currently AuRoVT sp. z o.o.). K. Cyran and W. Moczulski submitted two project proposals under FP6 and FP7. Although the projects introduced bold concepts—such as unmanned cargo aircraft that could optionally be controlled by pilots operating from centralized control centres—the reviewers deemed these ideas too futuristic at the time. The first successful implementation of VT took place in the TeleRescuer project (Research Fund for Coal and Steel, 2014–2017), which developed a virtual teleportation system enabling mine rescuers to be virtually present in areas of a coal mine impacted by catastrophic events. Virtual Teleportation has since become a valuable component of the company's know-how.

The paper will present the technical implementations of VT and its further applications in monitoring, supervision, diagnostics, and control of facilities and processes.

Keywords: virtual teleportation (VT), remote human–machine interaction, autonomous systems control, immersive user interfaces, teleoperation and supervision, dynamic environment decision-support.

Context-aware diagnostic modeling in technical systems: toward reliable decision support in industrial environments

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Abstract: The rapid development of industrial systems and the increasing integration of measurement technologies have led to a significant growth in the volume and diversity of diagnostic data. Despite this progress, diagnostic approaches remain largely focused on signal analysis without sufficient consideration of the conditions under which data are generated. In many practical cases, identical signal patterns may correspond to different technical states depending on operating regimes, environmental influences, or system-level interactions. This ambiguity highlights the necessity of incorporating contextual information into diagnostic processes.

This paper introduces a context-driven approach to technical diagnostics, in which the interpretation of measurement data is explicitly linked to the operational environment of the system. The proposed concept assumes that diagnostic reasoning should be treated as a context-dependent process, where signal features are complemented by additional descriptors representing system conditions, external influences, and operational constraints. Such an approach enables a more accurate mapping between observed data and underlying technical states.

A structured framework for context representation and integration is proposed, supporting the transformation of raw measurement data into meaningful diagnostic knowledge. Attention is given to the relationship between observable signals and technical states under varying contextual conditions, as well as to the impact of context on anomaly detection, condition assessment, and prediction tasks. The framework emphasizes the role of context in shaping the relationships between signals, anomalies, and system behavior. To validate the proposed concept, experimental studies are conducted on a test production system, enabling controlled variation of operating conditions and systematic analysis of their influence on diagnostic signals. The experiments explicitly demonstrate context-aware diagnostic reasoning, illustrating how the inclusion of contextual information affects the interpretation of signals, improves the consistency of condition assessment, and supports more reliable inference about system states under different operating scenarios.

The paper also addresses the application of artificial intelligence methods within context-aware diagnostics. Machine learning and hybrid approaches combining data-driven and knowledge-based models are considered as tools for capturing complex relationships between signals and context variables. The inclusion of context information is shown to improve model adaptability, reduce uncertainty, and enhance the interpretability of diagnostic results.

The presented approach contributes to the development of advanced diagnostic systems capable of operating effectively in complex and dynamic industrial environments, forming a foundation for context-aware, intelligent maintenance solutions in Industry 4.0.

Keywords: technical diagnostics, context-aware systems, operational context, artificial intelligence, decision support.

A method of controlling the head of a longwall shearer using the acoustic effect generated during the mining of a coal seam

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Abstract: Hard coal remains an important energy resource in global economies, providing a relatively cheap and stable fuel for electricity generation. To maintain competitiveness in terms of both price and product quality, hard coal mining companies are increasingly required to implement innovative technologies. Implementing such technologies contributes to optimizing production processes, reducing operating costs, and improving occupational safety.

The goal of our approach is to minimize the amount of sandstone extracted with the coal. To achieve this, the shearer head should not cross the boundary between the coal seam and the sandstone. The operating principle is based on the difference in acoustic effects caused by mining coal and sandstone. The acoustic effect of mining the coal face is separated from sounds from other sources using a suitable set of microphones located near the operating shearer head.

The processed data was then used to build a classification database using the k-nearest neighbor (k-NN) method and a support vector machine (SVM). The STFT analysis results are presented in the form of waterfall graphs and spectrograms, while the classification results are summarized in tabular form.

The experiments were conducted in a real coal mine. A simple measurement system based on a digital sound recorder was used to record acoustic effects. Offline analyses were then conducted, and the results were compared with coalface profiles determined by official geological surveys. The boundary between coal and sandstone detected using this method closely matched the actual line determined by the geologist, confirming the validity of the proposed method.

Keywords: acoustic coal–rock interface detection, short-time Fourier transform, k-nearest neighbours, support vector machine (SVM), shearer operation optimization, hard coal mining technology.

Testbed for technical diagnostics in industry 4.0: a framework for algorithm validation and data repository development

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Abstract: The development of advanced diagnostic algorithms for industrial systems increasingly relies on artificial intelligence and data-driven approaches, which require access to reliable datasets and controlled testing environments. In practice, a significant limitation of modern technical diagnostics is the lack of representative data and the difficulty of validating AI-based models under realistic operating conditions. This challenge is particularly relevant in Industry 4.0 systems, where machine learning and intelligent analytics play a central role.

The aim of this paper is to present the concept and functionality of a Technology Testing Center for Industry 4.0, designed by APA Group company as an experimental environment for validating diagnostic algorithms and generating structured datasets. The proposed testbed enables controlled experiments on industrial processes, allowing for the acquisition of high-quality data under varying operational conditions, including different load levels, disturbances, and fault scenarios.

The framework provides dedicated support for the development, training, and evaluation of artificial intelligence algorithms, including machine learning, deep learning, and hybrid approaches combining data-driven and physics-based models. Particular attention is given to the generation and management of multivariate datasets, which form the basis for building a reusable data repository for diagnostic applications.

The experimental environment allows for controlled fault injection and scenario-based testing, enabling systematic evaluation of AI algorithms in terms of detection accuracy, robustness, generalization capability, and adaptability to changing conditions. The integration of sensing, data acquisition, and processing modules supports the implementation of end-to-end diagnostic pipelines.

The paper also discusses the role of such environments in bridging the gap between laboratory research and industrial deployment of AI-based diagnostic systems. By providing both a validation platform and a structured data source, the proposed approach supports the development of reliable, scalable, and context-aware diagnostic solutions in Industry 4.0 environments.

The presented approach contributes to the development of advanced diagnostic systems capable of operating effectively in complex and dynamic industrial environments, forming a foundation for context-aware, intelligent maintenance solutions in Industry 4.0.

Keywords: technical diagnostics, testbed, artificial intelligence, data repository, industry 4.0.

Application of spatial-time-frequency analysis to estimate the direction of movement and position of an object

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Abstract: This paper presents a vision-based localization system that utilizes a proprietary spatial-time-frequency method to determine the position of an object in space.
The system utilizes visual light markers that emit pulsed light at a precisely defined frequency and have fixed coordinates in a predefined reference frame. The object being localized is equipped with a camera that records a sequence of images. The vision system uses the spatial-time-frequency method to search for light markers in the captured images and then determine the object's position in space. Significant emphasis is placed on the method of optimizing the vision system's performance, which assumes the ability to estimate the direction of movement of an object based on previous measurements. In subsequent steps, the system can analyse only those areas of the recorded images that are related to the detected direction of movement.
This paper discusses the theoretical foundations of the spatial-time-frequency method, which is the basis of the vision-based localization system. A workflow for the system is presented, including the marker detection stages and the prediction stage for determining the direction of movement. A detailed discussion is given of the concept of detecting the direction of marker changes in images, which can then be translated into estimating the direction of movement of an object with a camera. The concept was validated through simulation studies and implemented for the analysis of measurements from real-world tests. A summary of the research and further development options for the vision system are included in the paper.

Keywords: spectrum analysis, direction estimation, visual marker, localization, image processing.

Brake pad wear estimator with application of two kinds of neural networks

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Abstract: The paper describes the passenger car brake pad estimator. The estimator explores the driving cycles, occuring in the vehicle exploitation process. First step is the analysis of the driving cycles with the use of non-supervised learned neural network. The cycles have the same mileage. This network groups the driving cycles according to similarities between the braking processes, occuring in these cycles.
The next step is to order the driving cycle groups created by the unsupervised neural network. This ordering is from the group in which driving cycles ensure brake pad wear after the shortest mileage to the group in which driving cycles ensure brake pad wear after the longest mileage. Each group is assigned a mileage that can still be driven until the critical brake pad wear occurs, operating the vehicle according to the driving cycles specified in the given group.
This action creates data used to formulate the supervised neural network. The network estimates the mileage until the critical brake pad wear based on the driving cycles completed by the vehicle. The assigned mileage for each driving cycle group used to formulate this neural network is initially selected based on the author's experience in vehicle operation. Then it is adjusted to the exploitation of a Fiat Tipo in driving cycles with a predominance of city driving.

Keywords: wear estimation, brake pad, neural network, unsupervised learning, supervised learning.

Operational problems and rotor dynamic response of a 300 kW ORC turbogenerator supported on tilting pad bearings lubricated with a low-boiling working fluid

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Abstract: This paper presents an experimental study of the rotor dynamic behaviour of a 300 kW ORC turbogenerator supported on tilting pad journal bearings lubricated with the low-boiling working fluid of the cycle. In this configuration, the process fluid acts simultaneously as the expansion medium and as the lubricant and cooling medium, which creates strong coupling between thermal conditions, bearing performance and rotor stability. The study combines several measurement campaigns carried out during laboratory commissioning and subsequent field operation in an industrial ORC plant.

The investigation covered different machine configurations, including operation without preload, operation after preload correction, and operation under inverter-assisted start-up and off-design supply conditions. The measurements included shaft relative vibrations, journal trajectories, order tracking, FFT spectra, axial displacement and bearing temperatures. The results showed that the machine response was highly sensitive to bearing settings and operating conditions. In the initial configuration, increasing speed led to the growth of non-synchronous motion, irregular journal orbits and the appearance of a 0.5X subsynchronous component at high speed, indicating deterioration of fluid-film stability. A strong 4X component was also repeatedly observed and attributed to pad-related motion. Thermal effects were found to be important, as insufficient fluid cooling in the bearing nodes and elevated temperatures reduced dynamic margins. After preload correction, the rotor response became more repeatable and stable, and the run-up/run-down characteristics became more symmetric. In contrast, inverter-assisted operation and unfavourable plant conditions promoted additional dynamic excitation and increased vibration amplitudes.

The reported case demonstrates that the performance of high-speed ORC turbomachinery with process-lubricated tilting pad bearings depends not only on the rotor and bearing design itself, but also on preload, thermal state, and the actual supply mode of the machine. The results provide practical guidance for commissioning, diagnostics and design improvement of similar ORC units.

Keywords: ORC turbogenerator, rotor dynamics, tilting pad bearings, subsynchronous vibrations, preload, experimental investigation.

Condition assessment of power line conductors based on acoustic emission and thermal imaging

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Abstract: Power line infrastructure is a critical component of modern electrical grids that requires reliable diagnostics. They are subjected to multiple interacting stresses, including electrical, mechanical, thermal, and environmental, which contribute to their degradation and eventual failure. In overhead transmission lines, damage is frequently also observed in the vicinity of high-voltage insulators, where mounting clamps introduce additional mechanical stress concentrations.

Partial discharges, in the form of corona, are often associated with locally degraded conductors, where fractured strands form sharp protrusions that intensify the electric field. These defects are typically accompanied by a reduction in the effective cross-sectional area of the conductor, leading to increased local electrical resistance and consequent heating. As a result, both thermal and discharge-related phenomena may coexist and interact, accelerating the degradation of both the conductor and adjacent insulation systems.

In this work, a bimodal approach is proposed for the detection and characterization of such damage mechanisms, combining acoustic and thermal imaging. Both sensors are integrated on a quadruped mobile robotic platform, enabling automated positioning and reducing the risk to human operators during inspection tasks. The mobility of the platform allows repeatable measurements and flexible sensor placement with respect to the inspected infrastructure.

Experiments were conducted in a high-voltage laboratory under controlled conditions, with voltages up to 10.2 kV. Partial discharge activity reached apparent charge levels of up to −30 pC, accompanied by acoustic emissions of up to 20 dB SPL in the 45–50 kHz frequency band.

The acoustic camera enables spatial localization of partial discharge sources. Accurate temperature quantification remains challenging due to systematic errors arising from spatially varying surface emissivity and reflectivity, particularly for metallic conductors exposed to environmental conditions.

A clear temporal consistency was observed between the acoustic emission amplitude and the evolution of the apparent charge associated with partial discharges. The signals exhibit highly similar dynamic behavior, suggesting a strong underlying relationship. This indicates that acoustic measurements may serve as a proxy for monitoring discharge activity trends over time. The proposed multimodal approach demonstrates the potential for improved reliability of condition assessment through complementary sensing modalities.

Keywords: acoustic emission, thermography, mobile robot, partial discharges, high voltage diagnostics.

Proposal to modify the Eusama test stand to enable phase angle determination

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Abstract: EUSAMA vehicle suspension condition diagnostics by the European Shock Absorber Manufacturers' Association is based on the kinematic vibration excitation method. It involves determining the percentage of the wheel-to-ground resonance value applied to the static wheel pressure. Technical condition is classified using the so-called EUSAMA coefficient, which is a percentage of the ratio of the unsprung mass resonance to the tangential pressure of the vehicle on which they are mounted. This test stand is typically equipped with a power sensor built into the measurement system. Additional measurement capabilities include a displacement sensor and an inverter for the operating drive motor. Simultaneous measurement of the load on the main plate and its displacement allows for determining the phase angle between the plate displacement and the dynamic wheel load on the main plate. Changing the phase angle function, particularly in unsprung mass resonance testing, can provide additional information about the technical condition of the vehicle's suspension system. Diagnostic parameters allow for checking the vehicle's suspension condition. The use of an inverter in systems located in the field allows for the elimination of analysis at the runway level in favor of the precise design of the excitation scheme (vibration damping linearly over a specified time or using a step-wise procedure with excitation maintained at selected frequencies, etc.). These system components are subjected to periodic inspection by checking their technical condition at additional amplitudes. Control is only a minor expense, using displacement sensors (e.g., potentiometric) and an in-system inverter.

Keywords: Eusama test stand, schock absorber, phase angel.

Fluid bearing supply conditions in the context of rotor dynamic stability of a 300 kW ORC turbogenerator supported on tilting pad bearings

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Abstract: This paper presents an experimental study of the rotor dynamic behaviour of a 300 kW ORC turbogenerator supported on tilting pad journal bearings lubricated with the low-boiling working fluid of the cycle. In this configuration, the process fluid acts simultaneously as the expansion medium and as the lubricant and cooling medium, which creates strong coupling between thermal conditions, bearing performance and rotor stability. The study focused on the axial bearing and the effect of fluid flow control on rotor dynamics.
During the design process of the bearing system, nominal fluid flows through the fluid bearings were assumed based on calculations. Experimental testing of the test facility verified various scenarios to observe their impact on rotor dynamics. As rotational speed increased, lubricant film instability was observed, resulting in the appearance of subharmonic frequencies in the 0.38X-0.48X range in the spectrum. The possibility of regulating the flow of the medium through the bearings, in particular through the axial bearing which was the main object of interest of these studies, allowed for a partial reduction of subharmonics and a reduction of the instability of the lubricant film.
The case discussed in the research shows the influence of both the selection of the appropriate flow and the cooling of the medium supplying the bearings on the rotor dynamics. The results provide practical guidance for commissioning, diagnostics and design improvement of similar ORC units.

Keywords: ORC turbogenerator, rotor dynamics, tilting pad bearings, subsynchronous vibrations, film instability.

Application of digital twin technology for production scheduling optimization under limited availability of generating units

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Abstract: Modern production systems increasingly operate under conditions of reduced equipment availability, resulting from progressive wear, degradation of operating parameters, or deviations from nominal conditions. A particular challenge arises in decision-making under borderline operating conditions, where continued machine operation carries a risk of failure, while immediate shutdown leads to significant financial losses.

This paper presents the concept of using Digital Twin technology as a tool to support maintenance planning and dynamic optimization of production schedules under such conditions. The Digital Twin, fed with real-time measurement data, enables forecasting of further degradation of the technical condition of equipment and estimation of the remaining safe operating time until the scheduled maintenance outage.

A case study of a steam turbine within a combined heat and power (CHP) plant consisting of multiple generation units is presented. A decision-making model is developed that integrates production constraints, heat demand forecasts, and market conditions. The model enables the determination of an optimal load profile for the machines, minimizing the rate of degradation while maintaining the required heat production and maximizing operational profit. As a result, continuous operation of the equipment until the planned maintenance outage becomes feasible.

A comparative analysis demonstrates that the application of the Digital Twin approach reduces the number of unplanned outages and associated emergency repair costs, which include not only service expenses but also lost revenues and penalties for failure to deliver contracted energy. In the analyzed scenario, significant economic savings were achieved compared to the emergency shutdown case, along with improved predictability of system operation.

The results indicate that the integration of diagnostic, predictive, and optimization models within a Digital Twin framework constitutes an effective tool for supporting operation and maintenance management in modern energy systems.

Keywords: digital twin, limited availability, production scheduling optimization, combined heat and power, operational profit optimization.

Detection, classification and tracking system for underwater vehicles using hydrophones transferred by unmanned air vehicles

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Abstract: The main goal of the project with codename ZOP-BSP was to develop a swarm of Unmanned Aerial Vehicles (UAVs) capable of detecting, classifying, and tracking submarines (SUVs). Currently, anti-submarine warfare (ASW) is carried out through cooperation between surface and air units, primarily anti-submarine helicopters. Mi-14 helicopters (land-based) and Kaman SH-2G helicopters (ship-based) are being retired due to their service life, and are being replaced by AW-101 Merlin helicopters. Considering the Polish Navy's area of responsibility, the number of available helicopters, and the tactics of conducting Anti-Submarine Warfare (ASW) operations, the project proposes research into a UAV Swarm, which could provide future support for ASW operations. The project was carried out by the consortium consisting of Polish Naval Academy – leader, Air Force Institute of Technology, Military University of Technology and Jastrzębska Spółka Węglowa S.A. At the VI Technology Readiness Level (TRL), UAVs have been equipped with hydrophones to detect the hydroacoustic field of a potential threat swimming underwater. In subsequent stages of development, UAVs could be equipped with other sensors, such as magnetic field detection. The paper presents main assumptions and architecture of the detection, classification and tracking system and the results of its operation against Unmanned Underwater Vehicle (UUV) in the real conditions.

Keywords: detection, classification, tracking, underwater vehicles, hydrophones array.

Bench tests of vibration damping effectiveness by various child car seat models

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Abstract: This paper presents the results of bench tests measuring vibration propagation between the source and the child manikinanikin of a child seated in a child car seat. The tests were carried out on a vibration shaker for six different child car seat models. In the first stage of the experiment, two types of excitations were used: white noise in the frequency range 1–80 Hz and with an amplitude of ~10 m/s^2, and impulse excitation with amplitudes of 10, 20 and 50 m/s^2. The next stage of the research involved simulating excitation derived from a road profile compliant with ISO 8608. Simulations were carried out for road classes A to H travelled at three different speeds: 50, 90 and 130 km/h. In the final stage of the experiment, the simulated excitation was derived from recorded journeys in a passenger car through urban areas and on an expressway. The tests were designed to assess the level of protection against vibrations provided by individual child seat models. Under normal conditions of use, the design of the child car seat is intended to ensure the passive safety of the child sitting in it. However, an equally important aspect is the comfort of travel provided to the young passenger, as a lack of comfort caused by excessive vibration transmission through the seat's structure may lead to, for example, travel sickness or other symptoms of discomfort. However, the issue of vibration damping is, in most cases, completely overlooked in the available information on the properties of child car seats from various manufacturers. There is a lack of reliable information on vibration reduction by the child car seat. The bench tests carried out aim to provide a preliminary assessment of the degree of vibration transmission by different child car seat models. Vibration measurements were taken on a manikin simulating a child weighing 11 kg and 75 cm tall, at measurement points located under the seat, on the manikin torso and head, and on the seat's mounting and backrest (at head height). The results presented in the paper show how different car seat models behave when subjected to vibrations of varying nature and intensity, and thus how vibrations are transmitted to the test object.

Keywords: child car seat, ISO 8608 standard, vibration, shaker simulation, child travel comfort.

Multi-criteria analysis of an open-profile elevator frame with a screw drive

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Abstract: This paper presents an assessment of the stability of a screw-driven passenger lift with a lifting height of 3 m, for which the declared load capacity is 630 kg. The lift shaft structure was constructed using a modular design, i.e. it consists of repeatable segments made from cold-formed open steel sections, joined by bolted connections. The advantage of this solution is that it can be used both inside buildings and, in the case of existing structures, for external installation.
The aim of the study was to experimentally verify the use of cold-formed open steel sections in the construction of a passenger lift. The static verification of the structure was carried out based on FEM numerical analyses. The calculations considered self-weight and external loads, i.e. snow and wind, as well as operational loads: emergency braking, overload, load distribution, and modal analysis to determine the structure's resonance frequencies.
The results of the numerical analyses were verified by tests on a 1:1 scale model of the actual structure. Vibration acceleration measurements were taken at characteristic points of the shaft structure to determine the deformation of the structure under both no load and load conditions (the structure, comprising a prefabricated base slab, the shaft and the platform), to determine the natural frequencies of the prototype demonstrator structure of the modular vertical platform, and to analyse the structural performance in terms of the transmission of vibrations from the screw drive system to the frame of the shaft structure and the platform.
Tests on the actual structure confirmed the results of the numerical analyses. Limitations were identified in the applicability of the proposed solution, involving the use of open sections for structural elements of passenger lift shafts.

Keywords: passenger lifts, mechanical vibrations, resonance frequencies, deformations, open profiles, screw drive.

The use of synchronous analysis in the diagnostics of multi-stage gearboxes

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Abstract: The diagnosis of technical systems is based on the examination of physical phenomena occurring in mechanical systems during their operation. The most common method is the analysis of vibroacoustic signals directly related to the operation of individual components. Observing these signals makes it possible to identify changes occurring during the machine's operation.
In the diagnostics of multi-stage gearboxes, synchronous analysis is frequently used, employing shaft angular position markers. This is applied, amongst other things, as Time Synchronous Averaging (TSA). It is one of the most effective methods used to assess the technical condition of drive systems with complex designs (e.g. multi-stage).
Synchronizing the analysis with the shaft position makes it possible to isolate vibrations coming from specific gear pairs (individual stages), which is important in multi-stage gearboxes, where signals from different stages create a complex composite signal spectrum.
Synchronous averaging ensures that vibration components unrelated to the rotation of the shaft under test (random disturbances, vibrations from other gear stages, external interference) are minimised. As a result, we obtain a signal spectrum dominated by vibrations generated by a specific gear pair (gear stage).
Despite the clear advantages of this method, the effectiveness of Time Synchronous Averaging decreases in systems where rotational speed fluctuations occur during a single revolution. This may be caused by the operating characteristics of the drive motor, variable load, or the control system's response to variable load. By utilising the shaft position marker signal, the signal can be resampled to a constant change in angle over time. This will improve the effectiveness of Time Synchronous Averaging but will also enable the use of other analysis methods, e.g. zoom FFT, or the creation of time-sequential shaft rotation characteristics.
A modification of the zoom FFT function, involving the superposition of successive signal segments associated with the contact of a selected gear tooth, may allow the type of damage to be determined.
Analysis of the timing of successive gear teeth engaging the support allows, among other things, the determination of which gear (of the two gears in the gear stage) has a damaged tooth.
The use of extended synchronous analysis, aided by resampling of the signal corresponding to the constant angular velocity of the shaft, can significantly improve the diagnosis of multi-stage gearboxes and enhance the ability to determine the location and type of damage to the gears.

Keywords: technical diagnostics, multi-stage gears, synchronous signal analysis, signal resampling.

Acoustic deep learning for automated detection of structural defects in aluminium wheel rims

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Abstract: Reliable detection of structural defects in aluminium wheel rims remains challenging in routine workshop diagnostics, where assessment is largely based on visual inspection and operator experience. This study presents RimNet, a deep-learning-based diagnostic framework for automated evaluation of rim condition using acoustic responses generated by impulse excitation. The proposed method employs short-time Fourier transform (STFT) representations of acoustic signals and a convolutional neural network for classification of material defects.

The experimental dataset comprises 930 labelled aluminium rims collected under real workshop conditions, representing a wide range of operational states, including compliant rims, material defects, and geometric deviations. The RimNet pipeline incorporates domain filtering to exclude non-diagnostic variability and hard-negative mining to improve class separability and robustness. A two-stage classification approach is used, combining file-level predictions with probabilistic aggregation at the wheel level.

The system achieves high diagnostic performance, reaching up to 96.9% accuracy in inference mode and perfect classification at the aggregated wheel level. Analysis of multiple uncertainty measures, including entropy, prediction margins, and Brier score, demonstrates a strong relationship between prediction confidence and defect type. Misclassifications are primarily associated with geometrically distorted rims exhibiting weak acoustic signatures.

A practical implementation, RimNet Predictor, enables real-time diagnostics and provides interpretable uncertainty indicators supporting decision-making in workshop environments. The proposed approach requires only microphone-based acquisition and no modifications to existing equipment, facilitating easy integration into service practice.

The results confirm that deep-learning-based acoustic analysis constitutes an effective, non-invasive, and scalable solution for structural health monitoring of aluminium wheel rims and other lightweight structural components in practical engineering applications.

Keywords: deep learning, acoustic diagnostics, aluminium wheel rims, convolutional neural network, structural health monitoring, defect detection.

Explainable graph-based deep learning in fault diagnosis of complex mechatronic systems

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Abstract: The paper presents a fault diagnosis methodology based on a synergistic combination of Graph Neural Networks (GNN) and the Explainable Artificial Intelligence (XAI) paradigm. Modern mechatronic systems, due to their high complexity and dense network of interconnections between components, require tools capable of analyzing multidimensional dependencies while maintaining full transparency of decision-making processes. Traditional approaches based on rigid alarm thresholds exhibit low sensitivity to early failure symptoms, whereas classical neural networks, operating as so-called "black boxes," do not provide engineers with information regarding the physical basis of the detected anomaly, which hinders their acceptance in critical industrial applications.

The proposed PINN-GNN (Physics-Informed Graph Neural Network) approach treats the technical structure as a graph, where nodes correspond to individual sensors and joints, and edges map their topological, kinematic, and dynamic relationships. By incorporating physical laws directly into the network optimization process, the model ensures high diagnostic precision and physical consistency of predictions, even in conditions with limited fault data. A key contribution of this work is the integration of the model with post-hoc explainability techniques, enabling the automatic extraction of subgraphs and input features of greatest significance to the established diagnosis. This solution enables the operator to understand which parameters and inter-component relationships influenced the detection of the emergency state, which is crucial for auditability and building trust in autonomous systems in accordance with the requirements of modern legal regulations.

The study performs a detailed comparative analysis of the proposed method against classical threshold-based diagnostics and standard graph models lacking an interpretable layer. It was demonstrated that combining physical knowledge with relational modeling significantly reduces the number of false alarms and more accurately identifies the source of the fault. The effectiveness of the developed method is illustrated through the example of UR3e cobot diagnostics, conducting comprehensive simulation studies and test-bench examinations on a real technical object for this purpose.

Keywords: technical diagnostics, graph neural networks (GNN), explainable artificial intelligence (XAI), PINN-GNN, UR3e cobot, fault localization.

Reconstruction of local transient regions in transport signals using neural operators

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Abstract: Reconstructing local transient regions in one-dimensional transport signals is a critical challenge for modern intelligent transportation systems, traffic management, and vehicle operating state diagnostics. Traditional signal reconstruction techniques based on linear or spline interpolations exhibit severe limitations when recovering sharp spatial transitions, such as traffic-density shockwaves or abrupt speed variations, often producing excessive smoothing or spatial front displacements. This paper presents a novel transient-centred evaluation protocol designed to isolate and quantify model performance at the most operationally significant signal features. In the proposed protocol, the unobserved missing region is deliberately placed around the strongest local spatial gradient of the profile, exposing critical localisation and smoothing errors that remain hidden under standard global evaluation metrics. The framework is systematically evaluated on a controlled macroscopic traffic-flow benchmark comprising 756 spatial density profiles derived from 42 Godunov-type Lighthill-Whitham-Richards (LWR) scenarios, and further validated through external checks on real vehicle speed-over-distance telemetry from Toyota Yaris Hybrid and Tesla electric vehicle field trials. Fourier Neural Operator (FNO) and Laplace Neural Operator (LNO) architectures are evaluated against linear interpolation and shape-preserving PCHIP baselines across hidden window widths of 20%, 30%, and 40%. The quantitative results demonstrate that neural operators achieve substantial error reductions in the hidden transient region, decreasing transient Mean Absolute Error (MAE) by up to 51.3% in the primary LWR benchmark and by up to 30.0% in real electric vehicle telemetry. Furthermore, the comparative analysis reveals clear domain applicability boundaries: LNO excels under narrow and moderate hidden windows (20–30%) due to its natural representation of exponentially decaying wave fronts, whereas FNO demonstrates superior stability and lower front-position localisation error when wide signal segments (40%) are unobserved. Overall, the primary scientific contribution of this work is diagnostic and methodological, providing a rigorous front-centred evaluation paradigm.

Keywords: transport signals, transient reconstruction, neural operators, Fourier neural operator (FNO), Laplace neural operator (LNO), LWR model.

Preliminary study on geometry-driven mechanical tailoring of MultiJet printed photopolymer components

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Abstract: Material jetting offers high geometric fidelity, yet the relation between internal architecture and the mechanical response of functional photopolymer parts remains insufficiently described for design-oriented applications. This contribution presents a preliminary framework for tailoring the behaviour of MultiJet printed components made of VisiJet M3-X through controlled modification of their internal geometry. A set of tensile specimens with identical outer dimensions and different internal topologies was prepared and screened numerically before fabrication. Finite element analyses were used to compare stiffness trends and identify stress concentration zones, while static tensile tests provided an experimental basis for verification in the linear-elastic range. The study is intentionally limited to a narrow proof-of-concept scope: it focuses on the role of geometry under unified manufacturing conditions and does not discuss the full application-oriented stage. The comparison highlights that, for a constant base material, internal architecture can be used to tune stiffness and load transfer pathways. The proposed workflow may serve as a starting point for subsequent studies on dynamic behaviour and implementation in machine elements.

Keywords: material jetting, MultiJet printing, VisiJet M3-X, internal architecture, mechanical response, finite element analysis.

Health index design based on 2D vibration signal representation using machine learning

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Abstract: This study addresses the challenge of extracting the Health Index (HI) for rolling-element bearings from measured vibration data. The HI is a scalar value that describes changes in the machine's condition. It can be obtained through various methods, such as statistical analyses, decompositions, or AI-based approaches; however, this research focuses on machine learning techniques. The analyzed procedures focus on transforming the bi-frequency representation, i.e., the cyclic spectral coherence map (CSC), into the HI. The massive volume of data generated by CSC maps (especially for long-term measurements), combined with their high dimensionality and specialized expertise required for their interpretation, makes manual inspection and traditional feature extraction impractical. The methodology considers several dimensionality reduction and factorization techniques such as principal component analysis (PCA), lasso, non-negative matrix and tensor factorization (NMF and NTF), and higher-order singular value decomposition (HOSVD). To ensure the efficiency of the proposed methods, a standardized set of benchmark data, specifically designed to illustrate run-to-failure scenarios, was used for testing and validation results.

Keywords: health index, cyclostationary map, machine learning.

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SelGram: A hybrid informative frequency band detection procedure

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Abstract: Local damage detection in machines with rotating elements often benefits from a prefiltering. One of the most popular techniques for that is an approach mostly popularized by Kurtogram, which, in general, can be described as a Banded Feature Map (BFM). In these methods, the informative frequency band (IFB) detection is based on selecting the most meaningful one from filter bank decomposition, evaluated by calculating the kurtosis of signals processed with each elementary filter. Unfortunately, despite its many advantages, the BFM selects only the band with the highest value of the working statistic. For cases with multiple resonant bands, it is clear that it will select the strongest one without performing any fusion. Consequently, the strongest band will be selected as the only one, even if the neighboring band is almost as good, and the result would benefit from connecting those bands. In such a scenario, a wider band on the higher level of decomposition would provide a lower value of the statistic than the selected, narrower band on the deeper level. Typically, the deeper levels of decomposition provide better results in terms of the statistical value, because there is a strong chance that narrower filtration will provide a better signal-to-noise ratio, but the information contained in other parts of the spectrum is disregarded. Another issue is the fact that, regardless of the quality of the selected band, the filter has a flat response in the passband, which ignores local differences between the elementary frequency bins. In this work, the authors propose merging the ideas of the BFM-based approach (selecting the best band while completely rejecting the others) with a selector (a custom filter that responds much more granularly). In such a configuration, a BFM would still be selecting a specific band while disregarding others, but selector-based enhancement would allow to effectively customize the response of the bandpass filter responsible for processing a given band. It has two major consequences. Firstly, the filtration of a single band can be performed even better than for a standard bandpass filter. Secondly, non-uniform, or even multimodal spectral signatures of an informative component that would ideally be captured by a wider band, can be captured as a whole when selector processing allows broader bands to have a better kurtosis score than a deeper, narrower band, because the selector will better extract the information of interest.

Keywords: selector, banded feature map, informative frequency band detection, spectral analysis, local damage detection.

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Methods of changing thermal conductivity in phase change materials (PCM) used in heat storage

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Abstract: Phase change materials (PCMs) are increasingly used in latent heat thermal energy storage. Their greatest advantage is a narrow operating range while maintaining a high thermal capacity per unit volume. They can be used to store energy or as elements that dampen temperature fluctuations in liquid or gas systems by using carefully selected values of phase change temperature and latent heat. One of the challenges facing heat storage system designers is the limited thermal conductivity of PCMs, both the liquid and solid phases. Currently, methods exist for increasing thermal conductivity by doping with nanoparticles of highly conductive materials (e.g., aluminum, copper, carbon nanotubes, graphene, and similar), which can increase this parameter two or even threefold. The disadvantage of doping is a slight reduction in the thermal capacity of the material, as a small percentage is occupied by nanoparticles, and the problem of their sedimentation, i.e., settling at the bottom of the storage container. As a result, nanoparticles settling reduces the thermal conductivity in the rest of the heat accumulator, extending its charge and discharge times. To prevent this, two low-energy solutions have been proposed, used for very short periods. These solutions remix the PCM with nanoparticles, restoring high thermal conductivity in the liquid phase and, indirectly, in the solid phase. An additional aspect of mixing is the ability to influence the charging and discharging time of the heat accumulator, which is desirable in some applications. The first method is based on bubbling, which uses air from above the PCM liquid surface, injected at the bottom of the container by a dedicated pump, causing mixing of the PCM with the nanoparticles. The second method utilizes ultrasonic technology, which, through appropriate adjustment of vibration frequency parameters and a dedicated assembly design, induces vibration and mixing of the PCM and nanoparticles. This paper presents the effect of selected nanoparticles on the thermal conductivity of the PCM, a method of measuring thermal conductivity and a comparison of the thermal conductivity of the material in which the nanoparticles have sedimented and then have been remixed.

Keywords: PCM (phase change material), thermal energy storage, cold energy storage, thermal conductivity, nanoparticles sedimentation.

Analysis of changes in wheel alignment and chassis geometry of electric and hybrid vehicles during operation

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Abstract: Nowadays, we can observe significant development in electromobility. Unfortunately, the process of wear and tear of all components of electric vehicles during operation is still not fully understood. This study assessed the effects of vehicle mileage on the floor panel geometry and the upper mounting of the McPherson struts, as well as on the wheel alignment parameters. Geometry changes were determined in cars with similar design parameters, but differing in engine type and drivetrain configuration. The vehicles under study were panel vans equipped with spark-ignition internal combustion engines and electric vehicles. The aim of the study presented in the paper was to analyse and identify the magnitude of shifts of the floor panel basis point changes in wheel geometry in vehicles with different design parameters. The vehicles differed significantly in terms of their axle load distribution. There were ten cars in each group. The examination was carried out after approximately 100,000 km of mileage. A detailed analysis covered not only the main causes of changes in body geometry, namely the influence of the vehicles' mileage and design parameters, but also the effect of identifying the values of changes in the suspension and steering system geometry parameters. The study determined the relationships between changes in body geometry and wheel alignment. Changes in body geometry were determined by the type of basis point and the type of vehicle under analysis. The measurements of floor panel geometry and the upper mounting of the McPherson struts were performed using an Autorobot EzCalipre. Measurements of the suspension and steering geometry were carried out using a Hofmann Geoliner 678, which enabled the identification of over a dozen wheel alignment parameters for both the front and rear axles. The study identified areas in which the greatest changes in floor panel geometry, as well as areas of lesser change intensity, occurred, depending on the type of internal engine and the associated varying distribution of weight on the vehicle axles. The differences in changes to body geometry and wheel alignment between electric and internal combustion engine vehicles were significant. Much greater changes in geometry were observed in electric cars. There is a relationship between the body geometry and the wheel alignment. In electric vehicles, there have been significant changes to the toe-in, camber angles, kingpin inclination angles, and kingpin offset angles.

Keywords: diagnostics, operation, electric vehicle, hybrid vehicle, wheel alignment, body geometry.

Dual-stream CNN with cross-modal attention for bearing fault diagnosis using spectrogram and cyclic spectral correlation maps

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Abstract: This paper proposes a novel dual-stream convolutional neural network (CNN) architecture that fuses time-frequency and cyclostationary representations for intelligent bearing fault diagnosis. The proposed methodology transforms raw vibration signals into two complementary representations: spectrograms capturing transient time-frequency patterns, and Cyclic Spectral Correlation (CSC) maps revealing periodic fault signatures. A custom dual-stream CNN architecture processes these representations in parallel, where the spectrogram stream employs standard convolutional blocks while the CSC stream utilises asymmetric kernels designed to capture vertical fault frequency patterns. A novel cross-modal attention mechanism is introduced to enable adaptive feature fusion, allowing each stream to guide the other by highlighting discriminative regions. The attention-weighted features are combined and fed to a fully connected classifier for fault categorisation. The proposed method is validated on the Case Western Reserve University (CWRU) bearing dataset with four fault conditions: normal, inner race fault, outer race fault, and ball fault. Experimental results demonstrate that the dual-stream approach with cross-modal attention achieves superior classification accuracy compared to single-representation methods. The physics-guided CSC map generation using load-specific bearing defect frequencies further enhances the model's interpretability and robustness across varying operating conditions.

Keywords: bearing fault diagnosis, dual-stream CNN, spectrogram, cyclic spectral correlation, cross-modal attention, deep learning.

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A methodology for assessing wear of a fleet of semi-trailer axles using sensory data

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Abstract: A unified framework for evaluating the remaining life of curtain-side semi-trailers was proposed by leveraging data from telematics, inertial measurement units (IMU), strain gauges, pressure sensors, GPS, and MEMS-based IMU devices. There are presented a prognostic methodology that translates real-world sensory streams into robust wear indices for critical structural elements, enabling long-term life cycle supervision, informed design decisions, and optimized maintenance planning while reducing life-cycle costs and preserving operational continuity. A scalar damage measure was introduced that aggregates multi-axial stress states into a single, interpretable metric. The subject of research is a curtain-side, tractor-trailer combination produced by Wielton S.A., equipped with a bespoke measurement system comprising tensometers, accelerometers, and pressure sensors mounted at strategic nodes on the chassis and suspension. The methodology integrates sensor data with geolocation and vehicle dynamics information to derive a profiled road input and a corresponding stress history, which are used to calibrate a prototype predictive model of structural wear. The planned work encompasses a comprehensive review of fatigue hypotheses and their applicability to elastic-plastic materials, followed by the design of an experimental program executed on a multi-post test rig (MTS) to emulate real-world loading over an expanded duty cycle. The testing protocol is described to include sensor installation, road profiling for reference trajectories, the execution of durability tests on loaded and unloaded configurations, and a rigorous data processing pipeline that filters, normalizes, and fuses measurements from diverse channels. A central objective is to develop a computational model capable of estimating wear progression and forecasting imminent damage, with validation against both controlled laboratory tests and field data. The project anticipates delivering a prototype wear-assessment algorithm and a validation plan outlining metrics, data sources, sensor deployment, and performance criteria. The outcomes include a wear-estimation tool for predictive maintenance, evidence of cost savings through extended service intervals and optimized spare-part strategies, and actionable guidance for product design improvements and service-level optimization. Some results obtained to date will be presented.

Keywords: predictive maintenance, wear assessment, sensor data fusion, fatigue life and damage modelling, truck trailer diagnostics, prognostic health management.

Hybrid and electric vehicles in vehicle technical inspections

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Abstract: This study analyses current methods of conducting technical inspections of hybrid and electric vehicles. Rapid advancements in electrified powertrain technologies have led to a gap between current diagnostic practices and the actual requirements of modern vehicles especially BEV and HEV. In response, this study outlines proposed enhancements to inspection protocols, focusing on detailed evaluation of high-voltage systems, condition monitoring of traction batteries, and assessment of electrical safety and power electronic components. The conducted analyses and experimental tests, performed using diagnostic tools available at Periodical Technical Inspection, demonstrate the potential to improve fault detection accuracy and overall operational safety of the energy storage. The research was carried out on selected passenger vehicles equipped with hybrid and fully electric drivetrains.

Keywords: hybrid vehicles, electric vehicles, vehicle diagnostics, PTI, energy storage safety.

Vibration energy harvesting with a nonlinear piezomagnetic beam assisted by another elastic beam working as an amplifier

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Abstract: In order to amplify the broadband performance of a bistable energy harvester under weak vibration conditions, this paper proposes a piezoelectric, non-linear energy harvester equipped with dual coupling beams (Fig. 1). The proposed device consists of a bistable, non-linear energy harvester, elastically coupled to another linear oscillator. The additional degree of freedom in the device would help to overcome the potential barrier and therefore harvest energy from sources of smaller amplitudes. We estimate power output for various spring couplings between the beams. Additionally we study the synchronization of the beams.

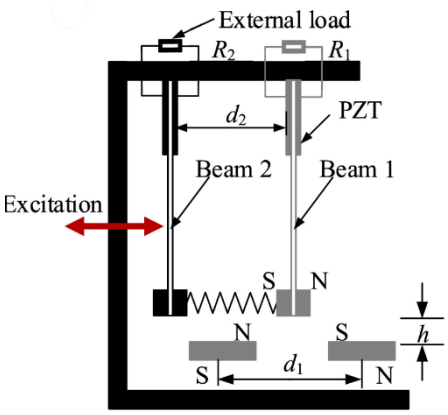


Fig. 1 The schematics of the structure [1]. Optionally, Beam 2 could be coupled as in [1] or without coupling to another piezoelectric.

[1] K Chen et al. J. Sound Vib. High performance piezoelectric energy harvester with dual-coupling beams and bistable configurations 561 (2023) 117822

Keywords: energy harvesting, broadband effect, nonlinear dynamics.

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Hybrid active–passive inspection framework for intelligent structural health monitoring of wind turbine blades

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Abstract: The continuous expansion of wind energy systems, together with the increasing size and structural complexity of modern wind turbine blades, has intensified the challenges associated with blade inspection and condition assessment. As large composite structures operating under highly variable mechanical and environmental loads, wind turbine blades are prone to progressive damage mechanisms such as delamination, adhesive degradation, fatigue cracking, and moisture ingress. Conventional inspection strategies rely either on passive structural health monitoring or on active non-destructive testing techniques, each of which exhibits fundamental limitations when applied independently.

This research proposes a hybrid active–passive inspection framework for intelligent structural health monitoring of wind turbine blades. The proposed approach integrates continuous passive monitoring methods with selectively triggered active inspection techniques within a unified, decision-driven architecture. Passive methods, including acoustic emission monitoring, vibration-based analysis, strain sensing, and optical inspection, are used for early anomaly detection during normal operation. Active non-destructive testing methods are subsequently applied in a targeted manner when justified by monitoring evidence and risk assessment.

A central element of the research is the development of formal triggering logic that translates passive monitoring indicators into actionable inspection decisions, considering defect criticality, uncertainty, inspection cost, and operational constraints. The proposed framework aims to enable earlier and more reliable characterization of subsurface blade damage while reducing unnecessary inspections and operational downtime. The research outcomes are expected to support condition-based maintenance, improve asset reliability, and facilitate integration with predictive maintenance and digital twin frameworks for wind energy systems.

Keywords: wind turbine blades, structural health monitoring, non-destructive testing, hybrid active–passive inspection, triggering logic.

Diagnostics of a shipboard electric power system

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Abstract: Diagnostics of a shipboard electric power system is a critical component in ensuring operational safety and continuity of power supply to essential onboard devices. This article presents a concept of a multi-layered approach to monitoring and condition assessment of the electric power system, encompassing energy sources (synchronous generators, power electronic converters), distribution networks, and loads.

The proposed approach integrates classical diagnostic methods, based on the analysis of electrical parameters (voltage, current, frequency, power factor), with modern signal processing techniques. Particular attention is given to the identification of transient states, detection of insulation faults, load asymmetry, and harmonic disturbances, which significantly affect system reliability.

The application of spectral and time–frequency analysis methods for extracting diagnostic features under variable load conditions and islanded operation of the system was also discussed. Preliminary simulation and laboratory experiment results are presented, confirming the effectiveness of the proposed approach in detecting selected classes of faults.

Directions for future research were indicated, particularly in the implementation of real-time diagnostic solutions and their integration with onboard energy management systems (EMS).

Keywords: diagnostics, shipboard electric power system, measurement, signal processing.

Assessment of the technical condition of steel bars based on the observation of the entropy of the external magnetic field

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Abstract: The state of materials magnetization is strongly dependent on externally supplied energy. Under stable energy conditions, a state of uniform magnetization is maintained. Areas of uniform magnetization are magnetic domains, which change the direction of magnetization under the influence of an external magnetic field.
Every ferromagnetic material is characterized by an arrangement of magnetic domains, the size of which is most often related to the grain size of the crystal lattice. In a metallic material that crystallizes freely, its natural behavior is the formation of a spatially distributed network of magnetic domains. The local magnetic fields of the domains cancel each other out, resulting in a material with an approximately zero external magnetic field. This arrangement of magnetic domains minimizes the energy of the internal magnetic field.
The effect of changes in the magnetic induction of the external field on the movement of the magnetic domain walls is particularly interesting for small changes in its intensity. In this range, the magnetic domain walls are observed to move while maintaining the original directionality of the domain magnetization. A weak external magnetic field alone may not be sufficient to cause the movement of the magnetic domain boundaries. Another form of energy, such as mechanical energy, may be an additional factor.
From the perspective of ongoing studies of the spontaneous magnetization of steel rods under cyclic mechanical loading, the interactions of the ferromagnetic material of the rods with a low-intensity external magnetic field are more important. The interaction between a ferromagnetic material and an external weak magnetic field occurred during the tests on single thin-walled steel rods. In the tested rods, subjected to cyclic mechanical loading with an energy source that changed the position of the magnetic domain walls, variable mechanical stresses were used. Given that the material of the tested rods was loaded within the elastic deformation range, the observable effect of magnetization changes is related to the movement of defects in the crystallographic lattice. That is, cyclic deformation-induced shifts in atomic defects in the crystalline material caused shifts in magnetic domain boundaries, resulting in the observable local magnetization of the tested material. Measurements of magnetic induction near the tested rod revealed the relationship between the number of mechanical loading cycles and the changing directionality of the magnetic field vectors. This allowed changes in the entropy of the magnetic field to be used to determine measures of the material's structural degradation.

Keywords: cyclic mechanical loading, spontaneous magnetization, structural degradation, entropy of the magnetic field.

Diagnostics of production plant operation through the use of an economic model

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Abstract: In today's era of global crisis, instability in fuel markets, and continuously rising CO_2 emission allowance prices, industrial plants are facing the need to identify the most significant cost-driving factors in order to optimize operating costs.
One response to these challenges may be the implementation of economic models based on the technology, operational capabilities, and production capacities of energy generation assets. A prerequisite for the successful implementation of such a model is the availability of generation units utilizing different fuels, due to their varying CO_2 emission factors, as well as the presence of condensing steam turbines.
The model operates as follows: based on the current prices of coal, natural gas, CO_2 emission allowances, and electricity purchased from the Day-Ahead Market (DAM), it calculates the costs of the current operating configuration and compares them with the costs of a simulated alternative configuration.
For example, if a coal-fired boiler has a higher minimum operating load than a gas-fired boiler, and the steam demand falls between the minimum loads of these two sources, the coal-fired boiler must direct part of the excess steam to condensation. In such a case, the model compares the total operating cost of the coal-fired boiler combined with a condensing turbine against the alternative configuration of a gas-fired boiler supplemented by electricity purchased from the Day-Ahead Market.
Proper implementation of the model can result in significant savings through avoided costs. One such model has already been implemented in a large industrial company and is currently delivering measurable benefits.

Keywords: diagnostic, production plant.

Explainable deep learning in multi-label electrocardiogram classification

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Abstract: Electrocardiographic (ECG) signals contain information that can be used for the identification of various cardiac abnormalities. Publicly available datasets and deep learning methods provide an opportunity to investigate automatic ECG classification and the interpretation of model decisions.
This work presents a deep learning approach for multi-label classification of 12-lead ECG recordings using the publicly available PTB-XL dataset. The proposed framework employs a convolutional neural network trained on all diagnostic labels available in the dataset. Classification performance is evaluated using the area under the receiver operating characteristic curve (AUC) together with additional performance metrics. To improve model interpretability, explainable artificial intelligence (XAI) techniques are applied to identify the signal regions that contribute most strongly to the predicted diagnostic classes.
The objective of this study is to evaluate a deep learning model for multi-label ECG classification and to compare selected explainable artificial intelligence techniques with respect to the interpretation of model predictions. The study compares the obtained classification results and discusses the information provided by the selected XAI techniques. The presented approach illustrates the application of deep learning and explainability methods to multichannel biomedical signal analysis and may provide useful observations for the development of data-driven diagnostic systems.

Keywords: electrocardiography, deep learning, multi-label classification, explainable artificial intelligence.

On the application of bionic principles to the development of a start-up and power control pattern for a small-power turbine

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Abstract: Steam turbine start-up and load-change phases are characterized by significant fluctuations in measured thermodynamic and flow parameters. Start-up states and load-change cycles differ markedly between large- and low-power turbines, reflecting the dynamic behavior of the technical system under these conditions.
Low-power steam turbines exhibit significantly lower thermal and mechanical inertia than large-power turbines. As a result, the profiles of measured parameters undergo substantial fluctuations, greater than those observed in large-power turbines, with values that depend on the turbine's operating phase.
This paper presents an analysis of time-dependent phenomena occurring during the start-up and load variation of a selected low-power steam turbine, leading to the development of an algorithm that calculates the reference state for correct turbine operation under changing operating conditions. A back-pressure turbine used for energy recovery in industrial installations was selected for the study. It illustrates a modified artificial intelligence (AI) method for constructing the aforementioned algorithm, drawing upon the principles of bionics, an interdisciplinary science that transfers biological solutions to fields such as engineering and technology. In this instance, the modification of the AI model is based on the functioning of the biological brain.
This paper focuses on establishing neural patterns of proper operation, which are essential for fault detection. Deep learning, a widely used method for preparing neural computation, is employed frequently; it allows for the modeling of extensive and complex relationships between observed external influences and the responses generated by artificial neural systems. However, a drawback is the significant amount of computer memory required, necessitating the use of computers with increasingly high processing power.
In some cases, this difficulty can be omitted. This applies to the neural modeling of certain technical systems where, basing on knowledge of physical layouts and the operation of biological neural systems, it is possible to link the interactions between the various functional areas of their components. Deep learning models can then be replaced by sets of simpler, fast-learning neural networks. This paper illustrates the analysis of such a complex system's operation using measurement data from the aforementioned low-power turbine.

Keywords: steam turbine, artificial neural networks, artificial intelligence, bionics, diagnostics.

Comparing time-series-to-image encodings for wind turbine fault detection: a magnitude-preserving raster embedding of SCADA signals

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Abstract: Recasting multivariate SCADA time series as images and classifying them with convolutional neural networks has recently emerged as a promising route to wind-turbine condition monitoring, and a variety of time-series-to-image encodings have been proposed for it. In this study we systematically compare established encodings – Gramian Angular Fields, Markov Transition fields, Recurrence Plots, Kernel-Density and Spectrogram heatmaps – for wind turbine fault detection under a common classifier and evaluation protocol, and we introduce a new one: a Magnitude-Preserving Raster embedding. Rather than rescaling each window independently, our encoding normalizes every signal channel with a single global, leak-free scale and reshapes the window directly into an image grid, so that the absolute signal level and variation-scale are preserved for the classifier. This matters because per-window normalization discards exactly the operating-point information that distinguishes healthy from faulty behaviour, mapping healthy and anomalous windows onto nearly identical images. We evaluate all encodings on open wind farm SCADA data with a fine-tuned convolutional backbone and a leakage-safe temporal split that holds out unseen operating periods. Across the compared encodings, preliminary results indicate that this embedding matches or outperforms the more elaborate transforms while remaining markedly cheaper to compute, and it is competitive with strong tabular baselines. We analyze why retaining absolute magnitude benefits image-based classification, examine the failure modes of the rescaled encodings, and discuss the implications for practical, interpretable, and transferable image-based turbine condition monitoring.

Keywords: SCADA data, wind turbine condition monitoring, time-series-to-image encoding, image embedding, convolutional neural networks, magnitude-preserving raster embedding.

Horizon-dependent performance of seasonal autoregressive integrated moving average with exogenous variables and gradient boosting in day-ahead district heating demand forecasting: evidence from multiple networks

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Abstract: Day-ahead heat demand forecasting in district heating networks, at horizons up to 40 hours, is critical for source dispatch and operational optimization. Yet the applied literature (Energy and Buildings, Energy) is dominated by decomposition-based hybrids benchmarked against weak baselines and evaluated under regimes that inflate apparent accuracy. In this work we compare two model families — dynamic harmonic regression SARIMAX (Fourier terms for daily and weekly seasonality, exogenous weather variables, Kalman-filter state re-anchoring) and gradient boosting (XGBoost) with a rich set of autoregressive, rolling, and calendar features — on hourly SCADA data from three independent district heating networks differing in scale and load structure. Evaluation is conducted under a single honest rolling-origin regime with a 40-hour forecast window applied identically to both families, avoiding the common conflation of one-step-ahead metrics with multi-hour forecasting. Our central finding is a reproducible crossover of error curves as a function of horizon: SARIMAX dominates at short horizons (1 to a few hours), where fresh lags and residual AR structure are available, whereas XGBoost takes over at the day-ahead horizon, once recent lags become inaccessible and nonlinear interactions among exogenous variables carry the predictive load. The crossover holds across all three networks, indicating a mechanistic rather than artifactual origin. We provide a mechanistic explanation grounded in the availability of autoregressive information as a function of horizon, together with a residual analysis (an AR(2) signature plus a residual diurnal hump at lags 20–24 in XGBoost). The results yield a practical, horizon-dependent model-selection rule and demonstrate that a methodologically clean, honestly validated pair of simple models outperforms the complex hybrids prevalent in the literature.

Keywords: district heating, heat demand forecasting, SARIMAX, gradient boosting, XGBoost, day-ahead forecasting, rolling-origin evaluation, time-series forecasting, forecast horizon, SCADA data.

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