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Scientific Conference
Engineering TODAY**

2026

BOOK OF ABSTRACTS

25 - 27 JUNE 2026, VRNJAČKA BANJA, SERBIA

**FACULTY OF MECHANICAL AND CIVIL ENGINEERING IN KRALJEVO
UNIVERSITY OF KRAGUJEVAC**

XII INTERNATIONAL TRIENNIAL SCIENTIFIC CONFERENCE

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PREFACE

Ladies and gentlemen, dear colleagues,

Welcome to Vrnjačka Banja, to the XII International Scientific Conference *Engineering TODAY*. Since 1993, the Faculty of Mechanical and Civil Engineering in Kraljevo has been organizing this triennial scientific conference. After eleven successful editions under the name Heavy Machinery (HM), the conference now continues under the name Engineering TODAY (ET) - a change that reflects the expansion of the faculty's study programmes and research into the areas well beyond its traditional scope, while retaining full continuity with the HM series: the same ordinal number, the same triennial cycle, and the same international character.

This year the conference takes place in Vrnjačka Banja from 25 to 27 June 2026, in the year when the Faculty celebrates 65 years of university teaching.

The goal of the Conference is to make research available and applicable within both domestic and international frames, and to give our scientists the opportunity to share results and learn from colleagues abroad. The Conference covers a wide spectrum of contemporary engineering disciplines through the following thematic areas:

- Earth-moving and transportation machinery,
- Railway engineering,
- Thermal technique,
- Environment protection,
- Automatic control and fluid technique,
- Applied mechanics,
- Computer-aided design,
- Computer-integrated processes,
- Design of machining processes,
- Entrepreneurial engineering and management,
- Civil engineering,
- Information technologies and software engineering,
- Artificial intelligence and machine learning.

The high scientific reputation of the participants and the number of papers are a guarantee that the Conference will be a success. The papers reflect the state of the art and address the topics of current interest across mechanical, civil and information engineering.

I would especially like to thank the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for its support, as well as the other sponsors of the Conference. My sincere thanks also go to the members of the scientific, organizing and technical committees, the reviewers, and all participants and invited speakers.

Thank you, and see you at the next conference in three years.

Kraljevo, Vrnjačka Banja, June 2026

Conference Chairman

Prof. Dr Goran Marković

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Trustworthy edge intelligence in Engineering Today: Applications in industrial control, robotics and transport engineering

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ABSTRACT: Artificial intelligence is rapidly transforming modern engineering systems, enabling unprecedented levels of autonomy, adaptability, and real-time decision-making in industrial automation, robotics, and intelligent transportation systems. However, the increasing deployment of complex machine-learning models in safety-critical applications introduces significant challenges related to transparency, interpretability, reliability, and trustworthiness. This invited plenary paper presents a synthesis of the authors' recent research results focused on trustworthy edge intelligence for engineering applications, with particular emphasis on explainable artificial intelligence (XAI), edge computing, and resource-constrained intelligent systems. The paper presents recent developments in explainable AI approaches for industrial automation and robotics, including hybrid deep-learning and ANFIS-based architectures for interpretable industrial decision support and machine-vision applications. Recent results in TinyML- and Industrial Internet of Things (IIoT)-based intelligent edge systems for low-cost industrial quality control are also discussed. In transport engineering, special attention is devoted to edge-AI implementations for intelligent transportation systems based on YOLO and Grad-CAM approaches deployed on embedded platforms such as NVIDIA Jetson devices and Raspberry Pi systems equipped with AI accelerators. Comparative analyses of performance, explainability, energy efficiency, and deployment suitability are presented. Finally, future directions toward human-centered, explainable, and trustworthy intelligent engineering systems are discussed in the broader context of engineering today and emerging Industry 5.0 paradigms.

KEYWORDS: Trustworthy artificial intelligence, Explainable artificial intelligence, Edge computing, Industrial automation, Robotics, Intelligent transportation systems.

From data scarcity to open-set generalization: A unified framework for robust rotating machinery fault diagnosis

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ABSTRACT: Unexpected failures in rotating machinery cause substantial economic losses and safety hazards in industrial systems, underscoring the practical need for reliable condition-based monitoring. Intelligent fault diagnosis must simultaneously address three real-world constraints in Industrial IoT deployments: severe data scarcity, dynamic distribution shifts, and the presence of previously unseen fault categories. This paper reviews a decade of methodological progress (2016–2026), tracing the development from unsupervised clustering and few-shot meta-learning to open-set single-source domain generalization. We propose a unified six-tier taxonomy classifying methods into data-level synthesis, metric/meta-learning, domain adaptation, domain generalization, open-set recognition, and an emerging category covering attention-based and self-supervised approaches. We examine the integration of wavelet-guided generative models with adversarial and prototype-aware alignment objectives, contextualize convergent findings on attention mechanisms and self-supervised pre-training that corroborate the role of structural frequency priors, and show that purely distributional alignment is insufficient under open-set conditions without latent-space structural constraints. Five open problems are identified: OS-SSDG, calibrated conformal thresholding, physics-informed class completion, zero-shot disentanglement, and foundation-model pre-training for IIoT. We conclude that Conformal Prediction combined with wavelet-structured representations offers a principled path toward bounded, interpretable fault diagnosis under realistic industrial constraints.

KEYWORDS: Intelligent fault diagnosis, Domain generalization, Open-set recognition, Wavelet packet transform, Generative models, Transfer learning.

Experimental study of energy efficiency of a hydrogen vehicle

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ABSTRACT: This study aims to determine the fuel economy of a hydrogen vehicle by analyzing its energy efficiency in real road conditions. The object of the study is a fuel cell vehicle. Hyundai NEXO, in which hydrogen is an energy carrier, from which electrical energy is obtained for the drive. The purpose of the development is to determine the hydrogen consumption and the corresponding energy intensity (kWh/km) in different driving modes, as well as to analyze the influence of speed, driving dynamics and road conditions on the efficiency of the vehicle. The experimental study is carried out in a real road environment on the territory of Sofia and the adjacent expressways. Two main road cycles are defined: urban and mixed, which reflect the typical modes of operation of cars. A GPS-based system for measuring dynamic parameters is used to collect data, and hydrogen consumption is determined by the vehicle's on-board instruments. The assessment of economy is carried out using indicators such as hydrogen consumption (kg/100 km) and energy consumption (kWh/km), which allows comparison between different driving modes. Particular attention is paid to the influence of different speeds on energy efficiency, as well as the differences between urban and extra-urban traffic. The results obtained contribute to a detailed study of the real-world operational efficiency of hydrogen vehicles and can be used to assess their role in sustainable transport. The study has practical significance in the context of the growing interest in hydrogen technologies and policies for the decarbonization of the transport sector.

KEYWORDS: Hydrogen car, Hydrogen fuel cell, Hydrogen consumption, Hydrogen, FCEV.

Comparative analysis of rack layouts according to the storage unit placement method

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ABSTRACT: The paper presents a comparative analysis of two selective pallet rack configurations based on the storage unit placement method, using the same rack orientation within the warehouse space. Selective pallet racks are simple, efficient, and widely used systems for storing palletized goods. They provide direct and unobstructed access to every individual pallet at any time. The storage unit was defined, and the sizing of the beams and upright frames was performed. Appropriate storage and retrieval equipment was selected. The rack layout in the warehouse was determined in accordance with warehouse system design principles. Adequate structural components were chosen, and the total capacity of the rack warehouse was calculated. Within the comparative analysis of selective racking solutions in the planned warehouse space, designs with both transverse and longitudinal storage unit placement were considered. The design focus was on increasing warehouse capacity and reducing rack construction costs.

KEYWORDS: Warehouse, Pallet rack, Forklift.

Mechatronic system for monitoring crane lifting operations

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ABSTRACT: Cranes are equipment that performs lifting and handling operations of loads with various masses and geometric configurations. Their safe use is regulated by the obligation to equip them with safety devices to limit the loads. The paper presents the development of a mechatronic system based on the integration of new technologies developed in the field of sensors and artificial intelligence in the field of lifting equipment. The implementation of the mechatronic system contributes to increasing the safety level of lifting machinery, by reducing the risk of accidents, ensuring the protection of operators and workers, as well as maintaining the integrity of the handled objects and those in the vicinity of the installation. The adoption of advanced technologies and intelligent systems to support the operation of equipment with the potential to cause accidents, accelerates the transition to automation of construction works.

KEYWORDS: Lifting machinery, Safety, Crane AI, Mechatronic cranes.

Comparative overview of determining service classes of industrial cranes according to relevant standards and guidelines

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ABSTRACT: The service class of a crane is one of the key parameters in crane design and can be determined according to various standards. In domestic practice, the classification according to the JUS M.D1.020 standard was prevalent for a long time, defining four crane service classes based on the number of working cycles and operating time. In the past, many renowned crane manufacturers based their classification on the DIN 15020 standard, which is predicated on FEM (Fédération Européenne de la Manutention) guidelines (which consider operating time and load spectrum as the dominant classification parameters). Older versions of ISO standards are also closely linked to FEM guidelines and provide service classes equivalent to these recommendations. With the introduction of the EN 13001 series of standards and ISO 4301-1:2016, the number of operating cycles has a more significant impact on crane classification. Unfortunately, in domestic engineering practice, the newly adopted standards for industrial cranes are still not widely applied due to various uncertainties. The aim of this paper is to resolve certain uncertainties regarding the definition of crane service classes and to present, in a concise form, a comparison and the relationship between parameters according to current standards and guidelines. A brief overview of the withdrawn JUS M.D1.020 standard is also included.

KEYWORDS: Service class, Crane design, Crane classification, Classification of parameters.

Remarks on the influence of the dynamic behavior of belt conveyors on the response of the spreader superstructure

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ABSTRACT: This review paper emphasizes the necessity of analyzing the dynamic behavior of spreaders, as high-capacity machines for continuous transport and stacking of bulk materials. Given that spreaders are self-propelled supporting structures for belt conveyors, a dominant portion of the dynamic loads originates from the conveyors themselves. A review of the existing literature shows that transverse and longitudinal oscillations of the belt represent a significant problem, typically treated from the standpoint of bearing maintenance and variable belt tensioning. Furthermore, modernization trends focused on energy efficiency increasingly employ variable frequency drives for continuous belt speed control, directly affecting the variability of dynamic loads caused by the eccentricity of rotating components. These issues are typically addressed from the standpoint of conveyor functionality, often neglecting the potential appearance of negative dynamic effects on the supporting structure, particularly in cases like spreaders, where the conveyor is not directly resting on the ground. Given the variable configuration of the spreader superstructure, with each configuration representing a unique dynamic system, a comprehensive analysis of the system dynamic behavior is fully justified. Evaluating the structural dynamic response to periodically variable excitation loads is essential for extending the service life of existing machines and optimizing the design of future units.

KEYWORDS: Belt conveyors, Spreaders, Dynamic behavior, Belt oscillations.

The determination of the deflection of the stepped column by the finite difference method

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ABSTRACT: Besides the strength criterion, steel structures must also meet the deformation criterion, which in some cases may be critical. Excessive deformation of the structure may lead to additional loads and improper operation of the installed equipment. The most common practice in steel structure design involves using the finite element method (FEM) to calculate the stress and deformation of the current model. However, this is usually limited to the case study for the particular structural model. The paper demonstrates the application of the finite difference method (FDM) to determine the deflection of a stepped column, enabling a broader parametric study and analysis of a variety of solutions that satisfy the deformation criterion. The application of FDM yields a scheme convenient for coding in MATLAB while showing the dependence between the column deflection and the design parameters. The results from the finite element analysis (FEA) are in excellent agreement with those from the FDM.

KEYWORDS: Stepped column, Deflection, Finite difference method, Finite element method.

Analysis and calculation of overhead conveyor for metal housings transportation

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ABSTRACT: Overhead conveyors are used to increase productivity in manufacturing processes and warehouse centers. These are continuous transport devices that operate above or over the head of both workers and other equipment. Their advantage is that they can transfer the load in any direction in space. Steel ropes and chains are used as pulling elements. The pulling element is connected to the trolley where the carriers are attached. The loads from the cargo are transferred via the wheels to the carrier conveyor track. The carrier track is most often connected to the construction of the hall. In this paper, the analysis and calculation of the overhead chain conveyor for the transportation of metal housings was performed.

KEYWORDS: Continuous transport systems, Overhead conveyors, Transport devices.

A fuzzy AHP approach for evaluating circular efficiency of hydraulic excavator swing drive systems

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ABSTRACT: Hydraulic excavators are among the most energy-intensive categories of heavy mobile machinery, characterized by intensive duty cycles, high energy demand, and significant environmental impact. Within the circular economy framework, the evaluation and design of key subsystems should not be limited to conventional performance indicators but should also include life-cycle-oriented criteria, such as durability, remanufacturing potential, resource efficiency, reliability, and user-related economic benefits. This paper proposes an integrated decision-making framework for assessing the circular efficiency of the hydraulic excavator swing drive system by combining engineering performance analysis with the fuzzy Analytic Hierarchy Process (fuzzy AHP). The application of triangular fuzzy numbers enables the modeling of uncertainty and subjectivity in expert judgments, thereby improving the robustness and reliability of criteria weighting. Based on a previously conducted energy-efficiency analysis of a 17-ton hydraulic excavator, two representative design alternatives were selected from a broader set of feasible configurations and evaluated according to hierarchically structured circular economy criteria. The results show that alternative L1 achieves higher overall circular efficiency than alternative L2, mainly due to better performance in energy efficiency, durability, and remanufacturing-related criteria. The proposed fuzzy AHP framework supports sustainable engineering design and component selection in heavy machinery systems.

KEYWORDS: Hydraulic excavator, Swing drive, Circular economy, Fuzzy AHP.

Physical analysis of forces, moments, and energy efficiency of multi-rotor unmanned aerial vehicles from the perspective of flight control

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ABSTRACT: Multirotor unmanned aerial vehicles (UAVs) form a specific class of aircraft in which lift is generated directly by rotor thrust rather than by fixed wings. This principle enables vertical take-off and landing, hovering and precise low-speed positioning, but it also increases energy demand and makes the flight dynamics strongly coupled. This paper analyses the physical principles that govern multirotor UAV behaviour, with emphasis on the distribution of forces, moments and energy consumption. Hovering, vertical motion, translational motion through aircraft tilt and yaw control by counter-rotating rotors are considered from the perspective of flight control. The energy model is interpreted through disk loading, induced velocity and ideal hover power. A reference numerical example for a 4 kg UAV is used to compare propeller diameters and quadrotor, hexarotor and octorotor configurations. The results show that larger total rotor-disk area reduces induced power and can extend hover endurance, while additional rotors improve redundancy at the cost of mass, structural complexity and control allocation requirements. The analysis provides a compact basis for engineering optimisation of multirotor UAV systems.

KEYWORDS: UAV, Multirotor, Flight physics, Thrust, Moments, Disk loading, Energy efficiency, Flight control.

Segment-based energy balance and propulsion feasibility analysis of a light passenger VTOL aircraft for a regional mission

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ABSTRACT: This paper presents an engineering calculation of the energy balance of a light passenger vertical take-off and landing (VTOL) aircraft for a reference regional route between Novi Sad and Novi Beograd. The mission profile is divided into vertical take-off, climb, transition, cruise, descent, vertical landing and operational reserve. For each segment, the required shaft power and energy are estimated using the adopted aircraft mass, rotor geometry, disk loading and propulsion efficiency. The analysis compares battery-electric, liquid-fuel piston and hybrid-electric propulsion concepts from the aspects of available energy, mass balance, peak power demand and practical feasibility. The numerical case study indicates that the reference mission requires approximately 189.93 kWh of shaft energy for a flight time of 53.25 min, while the vertical phases impose peak power requirements of about 265 kW. The results show that battery-electric propulsion is limited mainly by energy-storage mass, liquid-fuel propulsion offers a more favorable specific-energy basis, and hybrid-electric propulsion can represent a practical compromise if its additional system complexity is justified by mission range and power-distribution benefits.

KEYWORDS: VTOL aircraft, Energy balance, Propulsion feasibility, Disk loading, Hybrid-electric propulsion, Energy efficiency, Shaft power, Regional air mobility.

Strength-deformation analysis of wheel reducer for metro cars

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ABSTRACT: Railway transport requires high reliability and safety in operation, which places high demands on the elements of the gear boxes. A particularly important role is played by the wheel reducers, which ensure the transmission of torque from the traction electric motor to the wheelsets of the rolling stock, as well as the braking torque during electrodynamic braking applied to the same wheelsets. In this work, a strength-deformation analysis of a wheel reducer for metro cars used in the Sofia Metropolitan is carried out. The main objective of the study is to find weak points in the structure through qualitative and quantitative analysis of the acting loads to increase the reliability and operational stability of the transmission mechanism of the bogies in the rolling stock of the Sofia Metropolitan. A review of the transmission mechanisms used in the rolling stock of the metro trains is carried out, considering their design features and operational characteristics. The operational condition of the considered node was analyzed, in which characteristic failures in the elastic membrane coupling EZK-MEM 250-1, related to stress concentrations and installation inaccuracies, were identified and analyzed. The conclusion provides recommendations for improving the design, installation, maintenance, repair and operation of this important for traffic safety node.

KEYWORDS: Wheel reducer, Metro cars, Strength-strain analysis, Finite element method, Operational reliability, EZK-MEM coupling.

Influence of signal-to-noise ratio on the accuracy of experimental determination of wheel–rail interaction forces

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ABSTRACT: This paper analyzes the influence of the signal-to-noise ratio (SNR) on the accuracy of the experimental determination of wheel-rail interaction parameters – vertical force Q , lateral force Y , and contact point position y_{tk} . The research was conducted on an instrumented wheelset developed from a standard wheelset, with strain gauges optimally positioned and connected into Wheatstone bridges. Experimental tests were carried out on a specialized test stand within the Laboratory for Railway Engineering and Structural Testing at the Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac. The noise level in the electronic components of the measurement system and its influence on the final measurement error were analyzed based on the results of corresponding static and dynamic measurements. Using appropriate statistical analysis, it was determined that the noise level originating from the Wheatstone bridges and associated electronics causes significant dispersion of output signals, especially at lower force intensities. The results show that under lower loads (characteristic of empty vehicles) the SNR is less favorable, leading to an increase in the relative measurement errors of the aforementioned parameters. Conversely, under higher loads and critical values of the Y/Q ratio, which are of interest for assessing vehicle running stability according to relevant international standards, the SNR is significantly more favorable and measurement errors decrease. The obtained results confirm that the SNR is a key factor in the reliability of the measurement system for the experimental determination of wheel-rail interaction parameters. One of the directions for further improvement in measurement accuracy is the application of modern fiber-optic sensors, which have significantly higher resistance to electromagnetic interference and enable a more favorable SNR, thus opening a promising path toward a new generation of instrumented wheelsets with even higher measurement accuracy.

KEYWORDS: Signal-to-noise ratio, SNR, Wheel–rail interaction, Wheel–rail contact forces, Wheel–rail contact point, Instrumented wheelset, Derailment coefficient, Strain gauges.

Impact of deteriorated tram tracks on the current collectors of trams

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ABSTRACT: This article presents the results of a measurement campaign conducted during the summer of 2025 in Sofia. The study aims to determine the impact of deteriorated tram tracks on the current collectors of trams. Measurements were carried out on sections of the tram network where the tracks are in emergency or pre-emergency condition. The measured parameters include linear accelerations, angular velocities, and magnetic field values along the three axes. The sensors were positioned on the tram roof and on the collector strip holder. The analysis of the findings includes a comparison of the parameter values recorded at both locations, a general assessment of their impact on the current collector, and a comparison with results from a previous study conducted in 2019. Based on the obtained data, conclusions have been drawn regarding the influence of the tram's lateral sway on the current collector.

KEYWORDS: Trams, Electrical current collector, Railroad, Accelerometer, Gyroscope, Magnetometer, Kalman filter.

Systems for precision control of microclimate in world rail transport: Technological structure and intelligent management

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ABSTRACT: The issue of ensuring a suitable microclimate in railway carriages and analyses of the key parameters determining the quality of the environment in the carriages – temperature, relative humidity, air flow rate, carbon dioxide (CO₂) levels are considered in the publication. The detailed hierarchy of systems is described, including a real-time data sensor network, centralized logic control controllers and actuators (frequency-controlled compressors, heating modules and recirculation valves). Special attention is paid to the transition to intelligent management technologies. Mechanisms for automated optimization of energy consumption through adaptive control algorithms and remote monitoring have been considered. On the importance of preventive diagnostics and the implementation of environmentally friendly refrigerants as key trends for achieving sustainable and energy- efficient railway transport, and recommendations are made regarding the implementation of these systems in practice and their importance for safety and energy efficiency in transport conclusions has been formulated.

KEYWORDS: HVAC systems, Automated control, Energy efficiency, Microclimate, Railway safety, Railway transport, Sensor networks.

Comparative analysis of methods for the investigation of brake wear particles emission of railway vehicles

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ABSTRACT: The braking systems of railway vehicles are a key element for the safe and efficient operation of trains. Although according to official reports, the railway sector contributes less than 1% to total PM emissions in Europe, PM concentrations in enclosed spaces of underground railways are of great concern due to the confined nature of these spaces. Numerous studies have identified brake wear as the primary source of these emissions, as particles are generated during the braking process, under conditions of intense heating and wear in the contact zone between brake pads and discs. The aim of this paper is to critically analyze previous experimental studies to arrive at the most efficient and appropriate methodology that would provide knowledge about the mechanisms of particle generation caused by wear of brake pair elements in order to find ways to control the number and size distribution of particles in the air. In this regard, the advantages and disadvantages of various field tests with full-size brakes, laboratory tests on real brakes and reduced-scale brakes, as well as laboratory tests with a pin-on-disc machine were analyzed.

KEYWORDS: Railway vehicles, Brakes, Particle matter, Methodology.

Methods of increasing the wear resistance with repairs of BDZ freight wagon bogies

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ABSTRACT: The increase in the time between various repairs of freight wagons determines the urgency of the problem of improving the wear resistance and service life for the restoration of supporting nodes and parts of the bogie for freight wagons due to excessive wear of the friction working surfaces. Most of the freight wagon bogie parts can be restored by subsequent processing. According to the existing technology and methods, the quality of freight wagon bogie repair does not provide the bogie mileage of specified kilometers necessary between repairs or in inter-repair periods. In this regard, to study the impact of surface restoration quality parameters on the wear process of parts in operation and after the repair is a priority task. The problem of providing methodology for various repairs of freight wagon bogies aims at increasing the wear resistance of bogie parts, which is a complex task and includes the use of modern methods to predict wear and technological warranty of the resource of repair parts.

KEYWORDS: Bogies, Freight wagons, Wear resistance, Repair, Hardfacing, Heat treatment, Railway transport.

Impact of automated systems on reducing the human factor in rail transport

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ABSTRACT: In the last 5 years, the role of rail transport has grown a lot within the European Union. It is the most environmentally friendly and safest transport, transports a huge amount of cargo and passengers over short and long distances, and employs thousands of people. There is a shortage of trained personnel in all European countries. The human factor is still leading in all activities in railway transport. This leads to wrong ones that are the result of accumulated fatigue, distraction, delayed reactions, incorrect reading of signals, etc. Digitalization in rail transport aims to increase its safety and reliability. This article reviews the impact of automated systems to reduce human error. The advantages and disadvantages of modern technologies used for this purpose are analyzed. Different types of process automations are presented - semi-automatic and automatic. The challenges accompanying the implementation process are considered, such as high cost, infrastructure modernization and cybersecurity. Automated systems are not aimed at completely replacing people, but at supporting and controlling processes. The future of rail transport is impossible without the deployment of intelligent and automated systems.

KEYWORDS: Railway transport, Human factor, Automation, ERTMS, ETCS, ATO, Safety, Cybersecurity.

State of dispatcher systems in Bulgaria and their role in the liberalised passenger rail market

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ABSTRACT: Modern dispatcher systems are a key element of railway traffic management, directly shaping punctuality, operational reliability, and passenger comfort. In a liberalised passenger rail market, where operators compete through service quality, punctuality becomes a critical determinant of competitiveness. This paper examines the current state of dispatcher systems in Bulgaria, identifying technological disparities and their impact on operations. A conceptual framework is developed to show how automation, communication quality, and safety systems influence punctuality and, consequently, perceived comfort. A comparative analysis of the Sofia-Plovdiv and Sofia-Burgas corridors illustrates how different modernisation levels affect performance. The results show that completing dispatcher system upgrades significantly improves punctuality, reduces delay propagation, and enhances service predictability. These improvements directly increase passenger comfort and strengthen operator competitiveness in an open market. The findings demonstrate that dispatcher system modernisation is not only a technical requirement but a strategic prerequisite for equal access, higher service quality, and successful liberalisation of passenger rail transport in Bulgaria.

KEYWORDS: Dispatcher systems, Punctuality, Passenger comfort, Railway operations, Liberalised rail market.

An electronic business model for the regulation of railway traffic and transport based on artificial intelligence

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ABSTRACT: The accelerated development of railway systems is based on modernization of infrastructure, interoperability of signaling and telecommunication systems, and digital transformation of operational processes. Modern railway traffic management requires efficient coordination between infrastructure systems, dispatch centers, rolling stock, and information technologies. Due to the complexity of railway operations, human errors may occur during traffic regulation and transport management. This paper presents an electronic business model for railway traffic and transport regulation based on artificial intelligence and advanced information and communication technologies. The proposed model integrates internal databases, intelligent algorithms, and digital communication systems into a unified platform for sustainable and safe railway traffic management. Particular attention is focused on the application of AI systems in decision-making processes, predictive analytics, automation, and operational safety. The paper also analyzes the advantages and limitations of AI implementation in railway systems and discusses future development trends in digital railway transport. Research results indicate that AI-based electronic business models can significantly improve operational efficiency, interoperability, safety, and sustainability in railway traffic regulation.

KEYWORDS: Railway traffic and transport, Artificial intelligence, Interoperability, Electronic business, Safety, Sustainability.

Tests for the assessment of devices for securing semi-trailers during transport on a freight wagon

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ABSTRACT: WAG TSI defines requirements for the devices to secure semi-trailers on the freight wagons. The device shall hold semi-trailer in a safe position by withstanding the longitudinal, lateral and vertical downwards directed forces in accordance with the design operating state. After the accident on 2019, when a semi-trailer was detached during a severe storm and struck an oncoming passenger train, Denmark has introduced controls and restrictions that have now been accepted and included in the WAG TSI. Additionally, the device shall lock semi-trailers by withstanding the vertical upwards directed forces, caused by crosswind at the minimum crosswind stability or in absence of this data, the upward force shall be at least 85 kN. This paper presents real tests of one device for securing a semi-trailer on a freight wagon, and the assessment of conformity with EU regulations.

KEYWORDS: Semi-trailer, King-pin, Securing device, Vertical upward force, Freight wagon.

Measurement of distortion power and power factor in electric traction substations "Serbia Railway Infrastructure" when powering electric locomotives in traction and recuperative braking

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ABSTRACT: The aim of this paper is to point out the need to adapt the existing power measurement methods in electric traction substations of the "Railway Infrastructure of Serbia" in accordance with the provisions of the European standards EN 50470-1 and EN 50470-3:2022. The widespread use of power converters on electric locomotives, as typical non-linear consumers, has called into question the validity of existing methods of recording railway consumption. The waveform of the traction and regenerative braking current of electric locomotives deviates from the sinusoidal waveform, due to which part of the delivered energy remains invisible, which, among other things, leads to significant losses. To solve this problem, it is necessary to detect and quantify the power factor that takes into account the power distortion due to the power supply of electric locomotives as nonlinear consumers. This manuscript proposes and describes indirect methods of measuring electricity with single-phase intelligent electricity meters that enable not only an efficient tariff policy, but also the need for compensation of higher harmonics at the point of connection of electric traction substations to the three-phase electrical network.

KEYWORDS: Voltage and current harmonics, Traction mode, Regenerative braking.

Strength analysis of an electric locomotive transmission mechanism

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ABSTRACT: The transmission of traction electric motor torque to the electric locomotive wheelset is carried out through a wheelset reducer with cylindrical gears with straight or inclined teeth. The wheelset reducer is one of the most important units of a modern electric locomotive. It bears significant alternating loads when the locomotive starts, accelerates and stops. It is of paramount importance to choose the right drive option, which the locomotive movement and dynamics of its running depend on. At high running speed, the system must be reliable in terms of the oscillations of locomotive unstrung masses. The thirty-year operation of electric locomotives in Bulgaria has shown a number of shortcomings of wheel reducers that cause difficulties with operation and repair activities in locomotive depots. The paper presents a strength analysis of a transmission mechanism, that has shown low operational reliability leading to locomotive derailment. The results of analysis have indicated the areas, which need monitoring in operation to prevent the occurrence of incidents and accidents due to the transmission mechanism operation.

KEYWORDS: Railway, Electric locomotive, Transmission mechanism, Strength analysis.

Study on the wear of cylindrical gears of transmission mechanisms

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ABSTRACT: Gears are the main elements of transmission mechanisms such as reducers for general industrial applications, gearboxes of land transport vehicles and railway reduction gearboxes. They all are subjected to substantial dynamic loading and wear during operation. This paper analyses the materials used to produce various types of reducers. The main wear processes are examined in compliance to DIN 50320. The presented heat treatment technologies are aimed to achieve the best indicators determining the workability, contact strength and bending strength of materials. Measurements of gear profiles made of different materials and intended for a railway vehicle (electric locomotive) have been done. A formula for predicting the wear of gear profiles has been worked out in a probabilistic aspect. Optimised approaches to extend the service life of gears are suggested. It is also proposed what type of materials and technologies to choose for heat treatment of the selected reducer gears.

KEYWORDS: Reducer, Gears, Materials for gears, Gear profile, Gear wear, Electric locomotive.

Reverse-engineered open-tip and closed-loop water propellers: CFD validation route, prototype verification and sustainability screening

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ABSTRACT: This paper presents a transparent preliminary benchmark for comparing a reverse-engineered open-tip water propeller with a closed-loop candidate geometry. The contribution is deliberately framed as a work-in-progress conference paper: local activities already completed include structured-light scanning of commercial propellers, CAD reconstruction, development of a closed-loop model and fabrication of FDM prototypes, whereas CFD and hydrodynamic tests remain pending. The paper integrates three evidence layers: completed local prototype work, literature-calibrated hydrodynamic benchmarks and bounded sustainability scenarios. The open-tip reference is the Wageningen B3-45-070 geometry, while the closed-loop benchmark indicates a relative efficiency increase of 9.9% at $J = 0.6$. Preliminary scan-to-CAD verification gives a mean deviation of 0.27 mm, equivalent to 0.11% of a 240 mm propeller diameter. For a 40 hp craft operated 200 h/year, a conservative 10% fuel-saving scenario corresponds to approximately 557 kg CO₂/year less direct emissions. The main contribution is a reproducible decision pathway linking geometry capture, CFD validation, prototype quality control and sustainability screening without overstating uncompleted local results.

KEYWORDS: Water propeller, Closed-loop propeller, Reverse engineering, CFD validation, FDM prototyping, Sustainability screening, Material circularity, Cost screening.

Prediction of mechanical properties of FDM 3D-printed polymer and composite materials

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ABSTRACT: The prediction of mechanical properties of additively manufactured polymer and composite materials remains a critical challenge due to the complex interaction of process parameters, material characteristics, and structural anisotropy inherent to fused deposition modeling (FDM). This study presents the development and experimental validation of mathematical models for predicting the mechanical behavior of FDM 3D-printed materials. The research focuses on the influence of key process parameters, including printing temperature, layer orientation, and printing speed, on the tensile properties of polymer and carbon fiber-reinforced composite materials. Experimental data were obtained through standardized mechanical testing, while statistical and regression-based modeling approaches were applied to establish predictive relationships between input parameters and resulting mechanical performance. The developed models were validated against experimental results, demonstrating a high level of accuracy in predicting tensile strength and stiffness. The integration of numerical modeling and experimental validation enables a deeper understanding of process–structure–property relationships in FDM manufacturing. Furthermore, the study highlights the potential of predictive modeling for optimizing process parameters, reducing material waste, and improving production efficiency in industrial applications. The proposed approach contributes to bridging the gap between theoretical modeling and practical implementation, supporting the development of reliable and efficient additive manufacturing processes. The findings provide a foundation for future integration of advanced modeling techniques, including artificial intelligence and machine learning, in the prediction and optimization of mechanical properties of additively manufactured materials.

KEYWORDS: FDM, Mechanical properties, Predictive models, Polymers, Composites, Tensile behavior, Process parameters.

Comparative finite element analysis of stochastic and pseudo-stochastic 2D Voronoi lattices under compression

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ABSTRACT: Cellular materials and lattice structures are increasingly utilized in lightweight mechanical design due to their exceptional strength-to-weight ratios and energy absorption capabilities. This study investigates the compressive behavior of 2D Voronoi lattice structures using a custom parametric modeling generator developed in Rhinoceros and Grasshopper. Two distinct geometrical classes are systematically modeled for standard 60x60x5 mm test specimens: purely stochastic networks and pseudo-stochastic configurations. The pseudo-stochastic structures are generated by utilizing Centroidal Voronoi Tessellation, which is optimized iteratively via Lloyd's algorithm to achieve a mathematically relaxed and more uniform cell distribution. To evaluate their comparative mechanical response, rigorous Finite Element Analysis (FEA) simulating uniaxial compression is conducted on both model sets. The primary objective is to quantify and compare the strain distribution, ultimate yield strength, and overall structural stiffness between the highly randomized stochastic designs and their optimized pseudo-stochastic counterparts. By mapping the resulting stress-strain behavior and identifying localized failure mechanisms such as buckling and stress concentrations, the findings provide critical insights into how cell regularity governs overall structural integrity. Ultimately, this research establishes a robust computational framework for predicting and tailoring the mechanical properties of biomimetic cellular materials for advanced engineering applications.

KEYWORDS: Cellular materials, Parametric design, Lloyd's algorithm, Structural optimization, Biomimetics.

Modular design concepts in mechanical engineering with applications in mining machinery

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ABSTRACT: This paper presents an overview of the principles and development of modular design concepts in modern mechanical engineering, with a particular focus on their application in mining machinery. Special attention is given to the theoretical foundations of modular construction, structural adaptability, maintenance efficiency, and the standardization of functional assemblies in bucket-wheel excavators. Through selected examples, the paper highlights the advantages and engineering challenges of implementing modular design approaches in complex machinery and equipment.

KEYWORDS: Bucket wheel excavators, CAD, Modular design approach.

From Industry 4.0 to Industry 5.0: The transition from digitalization and cybernation to cognitization and human-machine synergy

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ABSTRACT: The transition from Industry 4.0 to Industry 5.0 represents a fundamental shift in the evolution of manufacturing systems, moving beyond digital connectivity and automation toward cognitive, human-centric production environments. This paper examines the conceptual and structural progression from digitalization and cybernation to cognitization, highlighting how these phases redefine the interaction between technological systems and human actors. Digitalization establishes the informational foundation of modern manufacturing through data acquisition, connectivity, and transparency. Cybernation builds upon this foundation by integrating physical and digital systems into cyber-physical production systems (CPPS), enabling adaptive, autonomous, and data-driven control. The emerging phase of cognitization extends these capabilities by incorporating learning, semantic interpretation, and context-aware reasoning into production systems, giving rise to cognitive cyber-physical production systems (C-CPPS). Particular attention is devoted to the role of human-machine synergy, where human cognition, ethical reasoning, and contextual understanding complement machine intelligence. This integration leads to the development of Human-Cyber-Physical Systems (HCPS), in which decision-making is distributed across human and artificial agents. The paper provides a structured interpretation of this three-phase evolution and discusses its implications for the design of resilient, sustainable, and human-centric manufacturing systems. The findings suggest that the future of industrial development will depend not only on technological advancement, but on the ability to harmonize autonomy, cognition, and human values within integrated industrial ecosystems, as envisioned in the Industry 5.0 paradigm.

KEYWORDS: Industry 4.0, Industry 5.0, Digitalization, Cybernation, Cognitization, Artificial intelligence, Cognitive systems, Human-machine integration, Smart manufacturing, Sustainability.

Spreadsheet-based approach to the calculation of load combinations in racking structures

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ABSTRACT: Cold-formed thin-walled steel profiles occupy a primary place in the production of racking storage systems, primarily due to the efficiency of material processing. However, their structural behavior is very complex due to their high slenderness and significant sensitivity to different actions. Ensuring a stable spatial racking structure requires a rigorous approach that must take into account very precisely all permanent, variable and accidental actions. This research focuses on the analysis of different load combinations, taking into account the racking structure behavior in both down-aisle and cross-aisle directions. A critical aspect of pallet racks' behavior based on the evaluation of applied bracing systems, as well as the influence of stiffness for both beam-to-column and baseplate connections, is also considered. All these conditions are integrated into an analytical framework, as specified by relevant regulations and standards for detailed analysis of various load combinations. To manage these complexities, advancements in computational techniques were used in order to establish a system in which parameter changes are synchronized with rapid, automated, but precise calculations. This approach serves as an attempt at a time-efficient and cost-effective methodology for load combinations for further verification of the structural response of racking systems.

KEYWORDS: Thin-walled cold-formed profiles, Racking structures, Actions, Load combinations, Spreadsheet calculation.

Robot-assisted lathe machine servicing

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ABSTRACT: This paper describes a simulation of an industrial robot-assisted lathe servicing process using ABB RobotStudio software. The objective of the simulation is to demonstrate how integrating a robot for material handling can improve productivity and ensure safer operation within a manufacturing environment. The first part of the paper outlines the procedure for importing 3D models of the robot and the lathe into the simulation environment. Special focus is placed on defining the lathe's movable elements, such as its door, as well as a conveyor belt for moving finished parts outside the safety zone. Key operational parameters were established, including target positions for the robot (pick-up from the raw material storage, insertion into the chuck, and deposition onto the conveyor) and the robot's movement trajectory. Based on these, an optimized RAPID program was developed to control the robot and other moving components during the simulation. The final stage includes testing and visual evaluation of the entire process, confirming both the system's functionality and the robustness of the proposed automation solution.

KEYWORDS: CNC lathe machine, Industrial robot, Simulation, Workpiece handling.

Sudden and gradual refuses in pipeline systems for the transportation of natural gas and petroleum products – Occurrence and models

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ABSTRACT: The article assesses the impact of refuses in pipelines for the transmission of natural gas and/or petroleum products, considering them as a mechanical system. This allows for a more accurate model of the impact of these refuses on the safe and trouble-free operation of the pipelines. Based on a thorough study of the recurrence of sudden and gradual refuses that occurred in various pipeline systems for the transmission and distribution of natural gas, a model of their occurrence has been developed. As a result, the possibilities of making theoretical predictions about the probability of one of the two types of refuses occurring without the need for long-term practical observation and analyzing of the behavior of a specific pipeline for the transmission of natural gas and/or petroleum products are described.

KEYWORDS: Gradual refuse model, Refuses in pipelines for the transmission of natural gas and/or petroleum products, Reliability of natural gas and petroleum pipelines, Sudden refuse model.

Environmental impact analysis of laser cutting: A case study of thin stainless steel and aluminum alloy sheets

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ABSTRACT: The analysis of environmental impacts of manufacturing processes is essential for promoting cleaner and more sustainable production. The present study examined the total environmental impact in laser cutting of thin stainless steel and aluminum alloy sheets. To this aim, an integrated approach, which combines design of experiments methodology for parameter effect assessment, analytical-empirical models and life cycle assessment methods for resource consumption estimation and environmental impact evaluation, was proposed. In addition to the analysis of main laser cutting parameter effects on total environmental impact, development of regression models for predicting environmental impact, and analysis of contributions to the environmental impact, i.e., energy consumption of the laser cutting machine, assist gas consumption, and generated waste material, were also addressed. The presented approach is useful and receptive in order to quantify and predict the environmental impact of the selected laser cutting conditions directly during the process planning step.

KEYWORDS: Laser fusion cutting, Sustainability, Cleaner production, Life cycle assessment.

Three-objective Pareto optimization of GMAW process parameters using a modified force balance model

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ABSTRACT: In this paper, a three-objective optimization model was developed for the preliminary selection of welding current and electrode wire extension length in the gas metal arc welding (GMAW) process, to achieve a droplet size characteristic for the projected spray metal transfer mode. The model is based on a modified force balance model, i.e., the MFBM approach, in which the droplet detachment condition is determined from the balance between the total detaching force and the surface tension force. A correction of the effective electrode wire neck radius, based on the balance between the pressure due to surface tension and the electromagnetic pinch pressure, was introduced to account for the tapering/necking effect at higher current values. The optimization variables are the welding current and electrode wire extension length, while the objective functions are defined to maximize the melting rate, minimize the deviation of the normalized droplet diameter from the target value, and minimize the normalized Joule/stick-out index. The obtained Pareto front indicates a clear compromise between productivity, droplet size control, and thermal loading of the electrode wire extension. A dynamic diagnostic layer was also introduced to verify the regularity of the droplet growth and detachment cycle for selected Pareto solutions.

KEYWORDS: GMAW, MFBM, Pareto optimization, Electrode wire neck radius, Metal transfer, Projected spray transfer.

Investigation of the influence of cutting parameters on noise emission during face turning of beech wood

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ABSTRACT: The paper presents the results of an experimental study of the influence of workpiece overhang length, feed rate and depth of cut on the equivalent sound pressure level during face turning of beech wood. Data analysis and mathematical model development were carried out using the Response Surface Methodology in the Design-Expert software package. The results of statistical analysis showed that the greatest influence on the equivalent sound pressure level is exerted by the depth of cut, followed by workpiece overhang, while the influence of feed rate is less pronounced. Based on the obtained data, a quadratic mathematical model was developed to predict the value of the equivalent sound pressure level. Additional experimental tests confirmed good agreement between the measured and model-predicted values. The obtained results can serve as a basis for selecting optimal process parameters in order to increase process quality and productivity during face turning of beech wood.

KEYWORDS: Face turning, Equivalent sound pressure level, Cutting parameters, Response Surface Methodology .

Investigation of cutting parameters influence on vibration during milling of HDPE

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ABSTRACT: The paper analyzes the influence of spindle speed, feed rate and axial depth of cut on vibration acceleration in feed direction during peripheral milling of high-density polyethylene. Experimental research was planned and implemented using the response surface methodology in the Design-Expert software package. Based on the experimental results, a statistical analysis was performed and a mathematical model was developed to predict vibration acceleration. The research results showed that feed rate and axial depth of cut have a dominant influence on vibration acceleration, while the influence of spindle speed is less pronounced. A reduced quadratic mathematical model was developed to describe the dependence between process parameters and vibration acceleration in feed direction. Model diagnostics and validation results confirmed its adequacy and good predictive ability. The obtained results can serve as a basis for selecting process parameters in order to reduce vibrations and improve the stability of the peripheral milling of high-density polyethylene.

KEYWORDS: Peripheral milling, Vibration acceleration, Cutting parameters, Response Surface Methodology.

Energy efficiency and carbon footprint of welded, adhesive and hybrid joining processes in the context of circular economy

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ABSTRACT: This paper presents a systematic comparative analysis of energy efficiency and carbon footprint of welded, adhesive, and hybrid (weld-bonding) joining processes for metallic components, within the framework of the circular economy and Extended Producer Responsibility (EPR). With global welding energy consumption estimated at over 400 TWh annually, the identification of lower-energy joining alternatives is a critical step toward industrial decarbonization aligned with Paris Agreement targets and EU climate neutrality goals for 2050. The study integrates quantitative energy balances, Life Cycle Assessment (LCA) data, and experimental results on surface preparation effects on adhesive joint performance. Results demonstrate that adhesive bonding requires up to 6000×less direct process energy than MIG/MAG welding for equivalent joints, and generates 3–50×lower CO₂ emissions per meter of joint. Hybrid joining reduces energy consumption by approximately 30% compared to pure spot welding while improving fatigue strength by 60–70%. The circular economy implications of each technology - including repairability, disassembly, and end-of-life recyclability - are examined, and a conceptual decision framework for joining technology selection is proposed, based on lifecycle performance indicators and EPR compliance.

KEYWORDS: Energy efficiency, Carbon footprint, Welding, Adhesive bonding, Hybrid joints, Circular economy.

Sound absorption properties of recycled granular materials and their mixtures

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ABSTRACT: Noise represents a significant environmental and public health issue in modern society, creating a growing need for sustainable sound-absorbing materials. This study investigates the acoustic properties of granular materials based on recycled rubber, recycled plastics, and sand, as well as their mixtures. The experimental design was defined using the simplex centroid mixture design method. The sound absorption coefficient was measured in an impedance tube in accordance with SRPS EN ISO 10534-2, while airflow resistivity was determined according to ISO 9053. Based on the experimental data, statistical models were developed using ANOVA in Design-Expert software. The results indicate that appropriate combinations of granular materials can significantly improve sound absorption performance and enable frequency-dependent optimization. The main contribution of this work lies in the integration of mixture design and statistical modeling for the prediction and optimization of the acoustic properties of recycled granular materials.

KEYWORDS: Sound absorption, Granular materials, Recycled materials, Mixture design, ANOVA, Optimization.

A fuzzy AHP-based approach for optimal transport mode selection

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ABSTRACT: The selection of an optimal transport mode in modern logistics systems represents a complex multi-criteria decision-making problem requiring the simultaneous consideration of economic, operational, and environmental factors. This study applies the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) method to determine the weighting coefficients of evaluation criteria and rank alternative freight transport solutions. The analysis focuses on containerized freight flows, considering road, rail, and inland waterway transport as the main alternatives, evaluated according to transportation cost, delivery time, CO₂ emissions, and reliability. A key contribution of the study is reflected in the comparative analysis of three shipment scenarios with different cargo volumes (10, 100, and 500 TEU), enabling a systematic assessment of the influence of shipment size on transport mode selection. The obtained results indicate that increasing cargo volume improves the competitiveness of rail and inland waterway transport due to economies of scale, particularly in terms of cost efficiency and environmental performance, while road transport maintains an advantage primarily in delivery time. The findings confirm the applicability of MCDM approaches in sustainable transport planning and logistics decision-making.

KEYWORDS: Fuzzy AHP, Transport mode selection, MCDM, Container freight, Sustainable logistics.

Selection and analysis of key occupational safety and health indicators: A case study in the foundry industry

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ABSTRACT: Selection of key performance indicators (KPI) in the field of occupational safety and health requires precise definition of measurable parameters which allow efficient monitoring of the level of employee protection and evaluation of the success of implemented preventive measures. In the foundry industry, which is characterized by high temperatures, use of heavy equipment, complex technological processes and the presence of hazardous and harmful materials, continuous monitoring of situation in the field of employee health protection is a significant basis for improving working conditions, reducing professional risks and increasing the level of employee safety and health. This paper presents the identification and analysis of key indicators of occupational safety and health through a case study conducted in a foundry in Serbia. Special attention was paid to the LTIFR (Lost Time Injury Frequency Rate), SR (Severity Rate) and AFR (Accident Frequency Rate) indicators, with the analysis of their values in the period 2018–2024, which allowed the quantitative assessment of workplace injury frequency and severity. The results indicate an increased level of professional risk in the observed foundry from the case study. The analysis established that the highest risk workplaces are connected with machine molding, grinding and final treatment of castings, while arms and eyes are the most frequently injured body parts. The obtained results emphasize the importance of preventive measures, education of employees, improvement of risk assessment, more consistent use of personal protective equipment and modernization of technological processes for the purpose of improving occupational safety and health.

KEYWORDS: Occupational safety and health, Foundry industry, Workplace injuries, KPIs, LTIFR, AFR, Severity rate, Risk assessment, Industrial safety, Occupational risk.

A hybrid SWARA–MULTIMOORA approach for production job prioritization

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ABSTRACT: Efficient prioritization of production jobs is a critical task in manufacturing systems, especially in environments with limited resources, multiple customer orders, and conflicting operational objectives. Production managers must determine which jobs should be processed first while considering several criteria such as due date urgency, profit margin, processing time, customer importance, and setup time. This decision-making problem can be effectively addressed using multi-criteria decision-making (MCDM) methods. In this paper, a hybrid SWARA–MULTIMOORA model is proposed for prioritizing production jobs. The SWARA (Step-wise Weight Assessment Ratio Analysis) method is applied to determine the relative importance of evaluation criteria based on expert judgment, while the MULTIMOORA (Multi-Objective Optimization by Ratio Analysis plus the Full Multiplicative Form) method is used to rank production jobs. The proposed approach is illustrated through a case study involving five production orders in a manufacturing environment. The results demonstrate that the model provides a systematic, transparent, and practical decision-support tool for production managers, enabling more effective scheduling decisions and improved utilization of manufacturing resources. The proposed methodology can be easily integrated into existing production planning and scheduling systems.

KEYWORDS: Job prioritization, Production planning, MCDM, Decision support systems.

Balancing between public service obligations and market efficiency: Modern challenges in passenger rail transport

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ABSTRACT: Public service contracts (PSCs) in passenger rail are a cornerstone of sustainable mobility policy, ensuring the provision of socially necessary but commercially unviable services. However, evolving regulatory frameworks, rising operating costs, decarbonisation targets and rising service quality expectations are putting pressure on traditional contracting models. This report examines the contemporary challenges faced by PSCs in passenger rail, with a focus on the tension between public service obligations and market-driven efficiency. The study focuses on the consequences of market liberalisation and the introduction of competitive tendering under the EU's Fourth Railway Package. Key risks are identified, including information asymmetry between contracting authorities and operators. Through policy analysis, the report proposes a bargaining model that balances flexibility, accountability, and long-term investment incentives. The findings contribute to the ongoing debate on how to structure effective and sustainable public service contracts (PSCs) that can adapt to changing economic, technological and environmental conditions, while maintaining accessibility and affordability for passengers. Practical recommendations are proposed for policymakers, transport authorities and rail operators seeking to optimize public services in a rapidly changing mobility landscape.

KEYWORDS: Rail transport, Public service obligation, Sustainable mobility, Liberalization.

Hybrid simulation of an inverted pendulum

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ABSTRACT: Hybrid simulation (Hardware-in-the-Loop) of an inverted pendulum is an approach that combines numerical simulation and physical experimentation, with the aim of faithfully replicating real operating conditions in the control of dynamic systems. In this paper, an experimental setup is implemented in which the system dynamics - the cart motion and the pendulum angle - are calculated on a personal computer using the Python environment and the SciPy library, while the control algorithm is executed on the Arduino microcontroller platform. This division enables the simulation and control to run on independent processors, which brings the operating conditions closer to real systems. The mathematical model of the system is based on nonlinear differential equations that describe the cart position and the pendulum deflection angle, while the microcontroller receives the state values in real time and calculates the control signal using the LQR algorithm. In this way, interaction is achieved between the software and hardware parts - Python represents the physics model, while Arduino represents the real controller. The advantage of this approach is the possibility of analyzing delay and time response under conditions close to real ones, which is often neglected in classical simulations. Different microcontroller platforms (ATmega328P, ATmega32u4, ESP32 with FPU) make it possible to experimentally evaluate stability, latency and control-computation speed. The influence of the sampling frequency and communication channels (serial transmission) on system performance is also analyzed. Hybrid simulation represents a bridge between theoretical modeling and practical implementation, enabling safe testing of control algorithms and comparison of hardware platforms in real time.

KEYWORDS: Inverted pendulum, Hybrid simulation, LQR control, System delay, Multi-threaded modeling, Real-time systems, Hardware-in-the-loop (HIL), Arduino Leonardo, ESP32, System dynamics, Python simulation, Controller optimization, Latency, Digital control, Experimental verification.

Intelligent control of a UAV using a sensor glove

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ABSTRACT: This paper presents the development and simulation of an intelligent system for controlling a drone through hand gestures, evaluated and tested in the MATLAB/Simulink environment. First, a detailed mathematical model of the drone dynamics is built, including aerodynamic forces, motor dynamics and battery model. For precise estimation of the system states the model also incorporates the sensor noise, processed with an Unscented Kalman filter. Flight stabilization is achieved through a PID control system. The central contribution of the paper is an implementation of an intelligent control of a drone using a smart glove, equipped with flex sensors and an inertial measurement unit. The smart glove raw analog signals are processed and classified by a neural network with an 8–10–4 architecture, trained using the Levenberg -Marquardt algorithm. The network classifies the fused sensor signals into four discrete control commands, which are fed directly into the drone's flight control system, as structured reference inputs. The integrated system is verified through a simulation, where the drone successfully executes a three-dimensional trajectory, commanded exclusively by the hand gestures. The results show stable tracking of the reference signals, without oscillatory instability, confirming the practical applicability of the proposed approach.

KEYWORDS: Drone, Gesture control, Smart glove, Neural network, Kalman filter, PID controller, MATLAB/Simulink.

Event-triggered ADP for asymptotic output regulation of unknown linear systems

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ABSTRACT: The deployment of learning-based controllers in modern networked cyber-physical systems is constrained by bandwidth limitations, partial state observability, and parametric uncertainties. Traditional adaptive dynamic programming (ADP) relies on full-state feedback and periodic sampling, inducing network congestion and steady-state tracking errors. This paper develops a fully data-driven dynamic event-triggered output regulation scheme operating on measurable input-output streams. By integrating a projection-safeguarded value iteration algorithm with an internally evolving dynamic threshold variable, we guarantee asymptotic convergence of the sampling error without requiring an admissible initial stabilizing policy or explicit system identification. Simulations on a third-order uncertain plant demonstrate a 54.0% reduction in control transmissions and an 8.2% suboptimality bound relative to the model-based LQR baseline, with reconstruction error consistently decaying below 10^{-3} . The framework provides a computationally efficient, theoretically rigorous architecture for resource-constrained cyber-physical networks.

KEYWORDS: Adaptive dynamic programming, Dynamic event-triggered control, Data-driven output feedback, Value iteration, Optimal output regulation, Networked control systems.

Decentralized event-triggered output-feedback ADP for hydraulically-driven parallel robot platforms

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ABSTRACT: Hydraulically-driven parallel robots are extensively deployed in heavy machinery for their superior force-to-weight ratios, yet precise trajectory tracking remains constrained by unmeasurable internal states, strong inter-actuator couplings, and time-varying operational uncertainties. Conventional optimal controllers predominantly rely on full-state feedback and periodic sampling, which impose excessive computational loads and degrade under unknown system dynamics. This paper proposes a decentralized event-triggered output-feedback adaptive dynamic programming framework that learns optimal tracking policies exclusively from historical input–output measurements. A per-actuator triggering mechanism dynamically evaluates a Lyapunov-consistent sampling error threshold, updating control signals only when state estimation deviations exceed an adaptive bound. Simulation studies on a six-degree-of-freedom Stewart–Gough platform demonstrate steady-state position tracking errors below 1.2 mm while maintaining integral of time-weighted absolute error values within 2.5% of the periodic baseline. The aperiodic update scheme reduces total control transmissions by 80.8%, and comprehensive robustness analysis confirms uniform ultimate boundedness under $\pm 20\%$ parametric perturbations. The proposed framework separates communication load from tracking precision without requiring explicit model knowledge, constituting a practical data-driven architecture for multi-actuator systems in industrial applications where sensor and network resources are constrained.

KEYWORDS: Adaptive dynamic programming, Event-triggered control, Output feedback, Hydraulic servo actuator, Decentralized control, Parallel robot.

Event-triggered output-feedback ADP for single-joint robotic manipulators with unknown dynamics

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ABSTRACT: Robotic systems frequently operate under parametric uncertainties and constrained communication bandwidths, motivating data-driven control architectures that ensure optimal performance without explicit model identification. Conventional adaptive dynamic programming (ADP) methods for output-feedback control typically rely on periodic sampling, which increases network load, or lack formal stability guarantees under event-triggered updates with unmeasurable states. This paper develops an event-triggered output-feedback ADP scheme for single-joint (1-DOF) robotic manipulators with completely unknown dynamics. The framework combines Hankel-based state reconstruction from input-output history, an adaptive event-triggering mechanism with hysteresis, and a data-driven policy iteration algorithm that solves the algebraic Riccati equation online. Numerical validation confirms a 67% reduction in control updates relative to periodic ADP, while maintaining tracking error below 0.02 rad and ensuring policy iteration convergence within 4–5 iterations. Closed-loop uniform ultimate boundedness is proven with an explicit error bound, and Zeno execution is excluded via discrete-time Lipschitz analysis. The design enables resource-efficient optimal control for networked robotic applications.

KEYWORDS: Data-driven control, Event-triggered adaptive dynamic programming, Output feedback, Robotic manipulators, Unknown dynamics, Resource-constrained systems.

Minimum positioning-time for mechatronic systems

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ABSTRACT: The paper considers a method for transferring the state of a dynamic system to a specified state for minimum positioning time (positioning servo systems, manipulators, walking robots). The system under consideration is described by a sampled-data model based on a first-order hold element. It is a first-designed feed-forward controller using a special case of an optimal linear system based on a quadratic performance index. When the final state is fixed (final-state control), the result is open-loop control. Owing to the fact that all mechanical systems have resonant modes at high frequencies, the output of a given feed-forward controller must be converted to a smooth reference signal. For that, we use a lowpass filter implemented as an integrator. In the real system, various disturbance sources (disturbances, parameter uncertainty) exist. For such systems, a two-degree-of-freedom control strategy is proposed. In that case, in the paper, a feedback controller is designed using the superstability concept, and the solution is based on linear programming. The main contributions of the paper are: (i) design of a feedforward controller for sampled-data systems with a first-order hold element, based on optimal control theory; (ii) design of a low-pass filter for the above system; (iii) design of two-degree-of-freedom control systems where the feedback controller is based on the superstability theory of systems.

KEYWORDS: Sampled-data systems, First-order hold, Final-state control, Mechanical resonance, Two-degree-of-freedom control, Superstability.

Legal issues of ethical hacking: A systematic review of authorization, compliance, and liability frameworks

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ABSTRACT: The practice of ethical hacking, aimed at identifying and addressing vulnerabilities in information systems, applications, or networks, presents several legal considerations. This abstract explores the key legal issues associated with ethical hacking, emphasizing the importance of authorization, compliance with laws and regulations, data handling and privacy, documentation and reporting, professionalism and integrity, liability waivers and indemnification. By navigating these legal challenges, ethical hackers can effectively contribute to improving cybersecurity while mitigating legal risks. Ethical hacking plays a pivotal role in fortifying cybersecurity defenses, but its efficacy hinges on navigating complex legal considerations. By obtaining proper authorization, ensuring compliance with laws and regulations, handling data responsibly, documenting activities rigorously, maintaining professionalism and integrity, and utilizing liability waivers where appropriate, ethical hackers can effectively contribute to enhancing security while minimizing legal risks and liabilities.

KEYWORDS: Ethical hacking, Data, Cybersecurity, Information systems.

Real-time object recognition and audio feedback system for visually impaired individuals

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ABSTRACT: This study presents a real-time object recognition system specifically designed to support visually impaired individuals by improving their independence and environmental awareness. Unlike general-purpose object detection systems, the proposed approach is designed with accessibility as a primary focus. It emphasizes intuitive interaction and clear auditory feedback to better support the needs of visually impaired users. The system combines computer vision, natural language generation, and speech synthesis within a mobile application. The system then provides immediate audio descriptions of nearby objects and their positions in a clear and understandable way. The architecture consists of a React Native-based mobile frontend and a Python-based backend deployed on cloud infrastructure. A pretrained YOLOv8 object detection model is utilized to identify objects in real time. Spatial analysis is performed to determine the relative position of objects within the scene. Experimental results demonstrate that the application achieves reliable object detection with low latency. Furthermore, the user-centered design, including bilingual support and touch-based interaction, enhances usability and accessibility. Overall, the proposed solution contributes to the field of assistive technologies by offering an efficient, cost-effective, and portable tool. It improves environmental awareness and supports independent mobility for visually impaired individuals.

KEYWORDS: YOLOv8, Computer vision, Assistive technology, Visual impairment.

Model of application of artificial intelligence in higher education based on interaction between user and computer system

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ABSTRACT: Modern higher education is increasingly dependent on digital technologies, large scientific databases, and intelligent information systems. Researchers and academic staff face the challenge of processing large volumes of information in a short period of time. Traditional approaches to searching scientific literature and analyzing research data often require significant time and effort. The rapid development of Artificial Intelligence (AI), especially generative AI systems such as ChatGPT and Gemini, has enabled a new approach to research and education. This paper presents a model of AI application in higher education based on the interaction between users and computer systems. The proposed model includes the transformation of traditional educational and research processes into digital processes supported by intelligent algorithms. The paper analyzes the role of AI systems in scientific research, digital learning, and academic communication. Particular attention is given to the advantages, limitations, and future perspectives of AI implementation in higher education institutions. The results indicate that AI platforms can significantly improve research efficiency, access to information, and the quality of education, while also requiring adequate digital competencies and ethical standards.

KEYWORDS: Artificial intelligence, Higher education, Digital transformation, Research, ChatGPT, Interaction.

ML algorithm for COVID-19 outcome prediction based on demographic features in North Macedonia

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ABSTRACT: This study presents a machine learning approach for modeling and predicting COVID-19 patient outcomes in the Republic North Macedonia based on demographic characteristics. A decision tree-based classification model has been developed using algorithms implemented in WEKA environment. The model constructs the decision tree by selecting random subsets of features at each node and determines the optimal split points based on information gain. The results indicate that age is the most significant predictor of patient outcome, serving as the root node and primary splitting attributes in the decision tree. Individuals below 60 years of age are classified as recovered, while higher age groups exhibit an increased probability of death. The gender attribute appears as a secondary factor, contributing to more refined predictions within specific age intervals. In addition to its predictive capability, the model offers a high level of interpretability, enabling clear visualization of decision rules and facilitating understanding of the relationship between demographic factors and disease outcomes. These findings highlight the importance of age-based risk stratification and demonstrate the potential of machine learning models as decision support tools in public health management.

KEYWORDS: Machine learning, COVID-19, Decision tree.

Drug clustering upon toxicity effects on liver spheroids – A deep learning approach

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ABSTRACT: Starting point in this research was work performed by Dubinsky et al.¹, who established a DL model to predict ATP values (non-invasive estimation of cell viability), assess damage to the liver spheroids and predict hepatotoxicity based on spheroids images. They created a public database² containing 20,000 brightfield microscopy images of human liver spheroids exposed over a period of up to 7 days to 108 drug compounds for assessing cell viability. We clustered applied compounds by intensity of damage caused to liver spheroids (level of predicted ATP values), forming compounds in groups that have similar effects on liver cells and potentially similar mechanisms of toxicity. Then we explored whether selected drugs belong to the same class of pharmacotherapeutic classification – analgetic, antipyretics, antibiotics, etc. The model can detect if some drugs behave differently than expected, leading to detecting errors and revealing potential new phenomenological causes. Further, we analysed temporal dependence of drugs to cell viability (toxicity), providing the insights in dynamic of effects and toxicity progress over time. Future work will investigate drug effects in combination, since co-exposure of drugs can lead to different outcomes of hepatotoxicity, in comparison to individual exposure.

KEYWORDS: Clustering of drugs by toxicity effects, Deep learning, Hepatotoxicity, Liver spheroid, Toxicity dynamics.

Comparing QLoRA fine-tuning of a general-purpose and a mathematically specialized LLM on Serbian mathematics competition tasks

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ABSTRACT: This paper examines the effect of QLoRA fine-tuning of locally executable large language models on mathematics competition tasks for high school students in Serbia. The main focus is on comparing the general-purpose model Mistral-7B-Instruct and the mathematically specialized model Mathstral-7B, in order to determine whether prior specialization for mathematical reasoning affects the success of fine-tuning on a small, domain-specific corpus of tasks in Serbian. For the purposes of the study, an automatic evaluation framework was applied, in which generated solutions were assessed according to several criteria, including final answer accuracy, logical coherence of the solution, and explanation quality. The results indicate different effects of fine-tuning for the observed models: the general-purpose model showed a slight performance decline, while the mathematically specialized model showed an improvement. This outcome suggests that models previously adapted to mathematical reasoning may benefit more from domain-specific fine-tuning, while also confirming that Serbian mathematics competition tasks remain a highly demanding test for locally executable large language models.

KEYWORDS: Mistral-7B-Instruct, Mathstral-7B, QLoRA fine-tuning, Automatic evaluation, Large language models, Mathematical reasoning, Mathematics competitions.

Domain-adapted open-weight language model for KiCad printed-circuit-board design automation

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ABSTRACT: The printed-circuit-board (PCB) design workflow in the open source electronic design automation (EDA) suite KiCad is still mostly manual, involving interactions with the schematic editor and PCB editor. Other commercial generative copilots like Cadence Allegro X AI, from Cadence and Altium AI from Altium, are still closed and tightly integrated into their respective EDA stacks. We introduce Electrode 1.0, a 33,055 real KiCad projects domain-adapted 3-billion-parameter open-weight language model with two reference electronics textbooks, and the official KiCad Library Convention (KLC) skill set. The training of the model is done in 2 phases called Domain-adaptive pretraining (DAPT) and finetuning by supervised learning (SFT) using raw KiCAD S-expression and plugin-tool-call traces respectively. This results in a checkpoint deployed in an in-editor ReAct agent which performs real schematic and board operations using 60+ tool calls. Electrode 1.0 gets 0.5388 on a self-built 100-task KiCad test that uses the substring-match scoring method, which is 8.4 % ahead of baseline Qwen-Coder model, and 4 % absolute ahead of the last in-house iteration v8. We report the corpus pipeline, training schedule, evaluation method, a ceiling we discover on a subset of the substring metric, and a four-stage plan for Electrode 2.0, a successor with vision-enabled capabilities trained on rendered board images using Group-Relative Policy Optimisation.

KEYWORDS: Large language models, KiCad, Printed-circuit-board design, Electronic design automation, Domain-adaptive pre-training, QLoRA, Agentic tool use, Open-source EDA.

Change of the heat transfer coefficient in the tube-to-tube exchanger in the ground coffee cooling plant

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ABSTRACT: In coffee production facilities, one of the important elements for quality is the cooling of the coffee after leaving the mills. Most often, heat exchangers of the tube-in-tube type, with water as the cooling medium, are used. The mixture of ground coffee and air is considered as a heterogeneous system, with very low movement speeds. The paper analyzed the change in the heat transfer coefficient for the tube-to-tube type exchanger, for four characteristic cases. The first case is the movement of ground coffee without additional elements only by pneumatic transport, the second case is the movement of ground coffee using a chain, the third case is the movement of ground coffee using a chain with buckets and the fourth case is the movement of ground coffee in the exchanger using a chain with circular cross-section boards. The obtained results show that the heat transfer coefficient is the highest in the fourth case, slightly lower in the second case, while the first case is the most unfavorable. The ratio in the heat transfer coefficient of the mentioned exchanger between the most unfavorable and the most favorable case is approximately 3.6 times.

KEYWORDS: Heat transfer coefficient, Tube-to-tube exchanger, Ground coffee.

Integrated risk assessment and digital twin-based safety management in photovoltaic systems

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ABSTRACT: The rapid expansion of photovoltaic (PV) systems has increased the importance of effective occupational health and safety management throughout the system life cycle. While photovoltaic technology is generally considered a safe and sustainable energy solution, numerous technical, environmental, organizational, and occupational hazards remain present during manufacturing, installation, operation, maintenance, and decommissioning phases. This paper presents a comprehensive literature review of risks associated with photovoltaic systems and proposes a Digital Twin-Assisted Failure Mode and Effects Analysis (DT-FMEA) framework for integrated risk assessment. The proposed approach combines traditional risk assessment principles with digital twin technology, enabling continuous monitoring, predictive diagnostics, and dynamic risk evaluation. The framework integrates technical, health-related, environmental, and social risk factors into a unified model capable of supporting predictive maintenance and proactive safety management. The results indicate that digital twins can significantly improve hazard detection capabilities, reduce risk priority levels, and enhance the overall sustainability and safety performance of photovoltaic installations. The study contributes to the development of next-generation safety management systems for renewable energy infrastructures.

KEYWORDS: Photovoltaic systems, Digital twins, Risk assessment, FMEA, Occupational safety, Predictive maintenance.

Operational diagnostics of natural gas preheating: A case study

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ABSTRACT: This paper analyzes a conventional gas preheating setup at a typical city gate station. To assess the condition and thermal efficiency of the gas preheating system, operational parameters were measured during its performance. Operational data, including gas pressure, temperature, and volumetric flow, were recorded via calibrated instrumentation integrated into the facility. The thermal efficiency of the gas preheating system was evaluated using only the measured flow parameters on the gas side. At the observed station, the applied method confirmed suspicions of energy losses and/or a fouled gas heater in the natural gas preheating process. This simple method can be implemented very quickly for the operational diagnostics of the natural gas preheating process. While the proposed method enables the evaluation of the overall thermal efficiency of a gas preheating system, it does not allow for the assessment of the efficiency of individual system components.

KEYWORDS: Natural gas, City gate station, Gas preheating, Heat exchanger, Energy efficiency.

Analysis of the influence of the rotation speed of the DFIG wind turbine generator on the temperature of the generator

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ABSTRACT: The paper analyzes the influence of the rotation speed of a DFIG (Doubly-Fed Induction Generator) wind turbine generator on the temperature in the operating mode and in the idle state, based on one-year data from the SCADA (Supervisory Control and Data Acquisition) system. The aim is to quantitatively determine the intensity and statistical significance of this relationship. The methodology includes data filtering, linear regression and correlation analysis, with the calculation of the Pearson coefficient (r) and the coefficient of determination (R^2). The accuracy of the model was assessed by RMSE and MAE, while statistical validation was carried out by ANOVA analysis and residual analysis. The results show a moderately strong positive correlation between rotation speed and temperature ($r = 0.7034$), with $R^2 = 0.4949$ indicating that speed changes explain about 49.5% of the variability. In idle state, the temperature depends mainly on external factors (ambient temperature, wind, solar radiation, humidity and surrounding objects). The proposed model enables reliable temperature prediction in the operating mode and can be used for operation optimization, monitoring and predictive maintenance of wind turbines.

KEYWORDS: Generator rotation speed, Wind turbine generator, Generator temperature, Linear regression, Residuals.

Influence of overheating exposure time on the microstructural stability and mechanical properties of HP40-0.63Nb alloy

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ABSTRACT: HP40-Nb heat-resistant cast steels are widely used for reformer furnace tubes operating at elevated temperatures, where accidental overheating may induce microstructural degradation and alter mechanical properties. This study investigates the influence of overheating time on the microstructure and mechanical properties of centrifugally cast HP40-0.63Nb alloy. Samples were overheated at 950 and 1150 °C for 30, 120 and 480 min. Microstructural characterization was performed using light microscopy (LM), scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS), while tensile testing and hardness measurements were used to evaluate mechanical performance. The as-cast microstructure consisted of an austenitic dendritic matrix and eutectic chromium-rich and niobium-rich carbides. Overheating promoted the precipitation of secondary chromium-rich carbides, causing significant changes in carbide morphology and distribution. The highest yield strength (346 MPa) was achieved after overheating at 950 °C for 120 min due to intensive precipitation hardening. Prolonged overheating led to carbide coarsening and partial dissolution, reducing the strengthening effect. The highest tensile strength (582 MPa) and favorable ductility (8.76 %) were obtained after overheating at 1150 °C for 30 min. The results demonstrate that overheating time strongly influences carbide evolution and mechanical behavior of HP40-0.63Nb alloy, with 950 °C/120 min providing maximum strengthening and 1150 °C/30 min the best strength–ductility balance.

KEYWORDS: HP40-Nb alloy, Overheating time, Secondary carbides, Mechanical properties.

Active and passive condensation in biomass heating systems

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ABSTRACT: There is a global consensus to use energy more efficiently and in an environmentally friendly manner. Utilizing the higher heating value (HHV) of fuels aligns with this goal. Two approaches exist: passive systems, which typically rely solely on flue gas condensers, and active systems, which are required when the temperature of the heated medium, in the examined case, water, exceeds the flue gas dew point. Active systems always employ heat pumps (HPs)—compressor HPs for a wide range of applications and absorption HPs especially for large district heating systems. Alternative HP types, such as open absorption HPs, remain in the research phase. Apart from the active condensation, the vapor pump boiler is a promising technology that raises the flue gas dew point and utilizes the HHV. This paper presents experimental investigations of an HHV utilization system integrated with a 20-kW pellet boiler. The system, comprising a flue gas condenser and a wet scrubber, recovers an additional 3.4 kW of thermal power. Furthermore, the system is used for flue gas conditioning, i.e., adjusting the exit temperature and relative humidity.

KEYWORDS: Active condensation, Biomass combustion, Flue gas, Flue gas condenser, Higher heating value.

Assessment of the microclimate and subjective perception of the thermal environment in school

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ABSTRACT: The report presents results of a study of thermal comfort as a criterion for ensuring a favorable learning environment in school buildings. By combining objective measurements of the physical factors of the environment, PMV/PPD indices and subjective surveys, the influence of the microclimate on students in high school are analyzed. The study includes objective measurement and assessment of the microclimate by the classical method and indices for thermal comfort and assessment of the subjective thermal sensation of students during the measurement. It is performed during the "cold" period of the year, which is characterized by an average twenty-four-hour temperature below 10°C and covers 300 male students (14–16 years old) in schools in Sofia. Specialized equipment is used to measure microclimate parameters: temperature, relative humidity, air velocity, radiation temperature and PMV/PPD indices. Tools for visualizing comfort data of the PMV and PPD indices were used as well. To assess the subjective thermal sensation of the environment an anonymous survey among students of the mentioned age group was conducted with a non-representative sample. Conclusions have been drawn concerning the connection between the data from the two types of research, which provides information about the relationship between the values of the studied parameters of the microclimate in the classrooms and the ability of students to concentrate at the temperatures causing discomfort. Over 70% of respondents indicate that thermal conditions affect in moderate to very strong degree affects their attention and concentration. The existing limit values for microclimate could be used as a starting point for development a new legislation for schools environment, but other approach is needed for assessment and control thermal environment.

KEYWORDS: Microclimate, Thermal comfort, School hygiene, High school students, PMV and PPD indices.

Green building and new materials

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ABSTRACT: The intensive development of all segments of modern society also causes a large consumption of energy, which primarily comes from non-renewable sources, whose reserves are decreasing more and more. Renewable energy sources represent an alternative to the use of energy originating from non-renewable sources. In addition to the fact that renewable energy sources are continuously replenished, a significant advantage is reflected in smaller negative impacts on the environment, which arise as a result of their use. The importance of applying the concept of green construction is best seen on the basis of the fact that the construction sector, on a global level, participates with about 30% in the total energy consumption and with 27% in the total emissions of harmful gases. The use of new, green building materials has become imperative in modern construction. The use of green materials for construction is attracting more and more attention in order to solve environmental problems and promote sustainable development. New materials play a key role in the construction of buildings in which the emphasis is placed on minimizing negative impacts on the environment during their lifetime.

KEYWORDS: Green construction, New materials, Renewable energy sources.

Urban acupuncture and visual activism as foundations for environmentally responsible riverside transformation: The case of the Vrbas River in Banja Luka

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ABSTRACT: Environmental protection of urban riparian spaces increasingly demands approaches that go beyond technical and regulatory frameworks — yet the role of cumulative small-scale interventions in establishing standards for future large-scale transformation remains poorly understood. This paper asks: can student-led small-scale physical interventions and visual activism progressively build the spatial, pedagogical, and civic foundations necessary for environmentally responsible riverside transformation? A qualitative analysis of three interrelated student initiatives along the Vrbas River in Banja Luka was conducted, spanning nearly a decade: the Banjalučki mol (2017), a wooden riverside platform realised through an international student workshop; the Sewage Pipes Festival (2021), combining spatial mapping and an urban installation to expose river pollution caused by absent wastewater treatment infrastructure; and the "Vrbas is Neither a Construction Site — Nor a Trash Can" campaign (2025), producing seven visual interventions with civil society organisations in response to illegal riverbed construction. Each case was examined through process documentation, material outcomes, institutional responses, and patterns of community engagement. The Banjalučki mol revitalised a marginalised riverside location and demonstrated the public value of riparian space. The Sewage Pipes Festival initiated public debate on systemic ecological infrastructure. The 2025 campaign triggered inspection procedures and established civic monitoring as environmental advocacy. Small-scale experimental projects, developed through student pedagogy over time, function not only as independent acts of environmental protection but as preparation for — and implicit criteria governing — future large-scale riverside transformation.

KEYWORDS: Environmental protection, Urban acupuncture, Visual activism, Vrbas River, Small-scale interventions, Riparian transformation, Student pedagogy.

Design solution of a cyclone for the separation of PM10 and PM2.5 particulate matter

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ABSTRACT: Despite all efforts toward energy transition and the replacement of fossil fuels with renewable energy sources, the use of fossil fuels (coal, oil, and natural gas) continues to be the foundation of modern energy infrastructure, while simultaneously serving as the primary cause of environmental degradation. The combustion of fossil fuels releases energy, but also byproducts that directly alter the chemical and physical composition of the air. Anthropogenic activities lead to atmospheric pollution and climate change, primarily due to the increased concentration of greenhouse gases and particulate matter (PM), which mostly originates from fossil fuel combustion processes. Air pollution caused by particulate matter is one of the greatest environmental challenges of our time. These particles are not gases, but microscopic solids suspended in the air. To reduce the concentration of PM particles in the air to permissible limit values, various systems and devices are used for their separation. Cyclone separators represent one of the oldest and most economical technologies for cleaning gases from suspended particles. Although they are mainly used for and have a high separation efficiency for particles larger than PM10, the goal of this paper is to propose a design for a cyclone that enables the separation of all particles, including PM10 and PM2.5. Also, the goal is to keep the overall dimensions unchanged while achieving the highest possible efficiency for the separation of suspended particles.

KEYWORDS: Cyclone, Design, Flow analysis, Particulate matter.

Application of robotic systems in intensive livestock farming from the aspect of environmental protection

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ABSTRACT: Modern livestock production is characterized by the increasing application of automated and robotic systems aimed at improving production processes and more efficient resource utilization. Robotic systems in livestock farming are most commonly applied in milking processes, feed distribution, manure removal, and control of microclimatic conditions on farms. Their application can contribute to more rational water and energy consumption, more efficient animal waste management, and reduction of harmful gas emissions. In addition to technological and production advantages, modern robotic systems play an important role in improving the sustainability of livestock production and environmental protection.

KEYWORDS: Robotic systems, Livestock farming, Environmental protection, Sustainability, Gas emissions, Automation.

Chemical pollutants in the soil of Novi Pazar and ecological risk assessment

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ABSTRACT: Soil pollution by chemical pollutants poses a critical threat to environmental quality and human health. This study investigates the concentration, composition and spatial distribution of selected chemical pollutants - including heavy metals (Pb, Cd, Ni, Hg, Zn) and organic matter in urban soil of the city of Novi Pazar. Its analysis is based on data collected by the Environmental Protection Agency of the Republic of Serbia (SEPA), during year of 2023. Sampling was carried out at 7 representative locations (city park, recreation center, kindergartens, water supply source, industrial zone) at a depth of 50 cm. The results obtained were compared with the normative limit values for Serbia, and it was determined that the concentrations of heavy metals in some locations exceeded the limit values. This especially applies to Pb and Ni. The research confirms that the soil in Novi Pazar is under moderate anthropogenic pressure. Risk assessment based on international soil quality guidelines indicates potential ecological and health hazards. These findings highlight the need for continuous soil monitoring and stricter regulatory controls to mitigate pollutant accumulation and safeguard soil ecosystem.

KEYWORDS: Heavy metals, Organic contaminants, Anthropogenic sources, Soil pollution, Environmental risk.

Monitoring of heavy metals and their movement through the environment of the city of Kragujevac

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ABSTRACT: This paper analyzes the presence, distribution and trends in concentrations of heavy metals (lead, cadmium, nickel, zinc, arsenic and chromium) in different environmental media - air, surface water and soil - in the territory of the city of Kragujevac over a three-year period (2022, 2023 and 2024). Special focus is placed on identifying the main sources of pollution, such as industrial activities, traffic and individual combustion plants. Data were collected through regular annual and monthly monitoring reports conducted by city departments and the Serbian Environmental Protection Agency (SEPA). Metal concentrations in suspended particulate matter (PM₁₀) and sediments were analyzed at key measurement sites (Mala Vaga, Medical School). Although most parameters are within the legally permitted limits, continuous monitoring is necessary, especially in urban areas with high traffic volumes. The results for 2024 indicate the need for further integration of local environmental action plans to reduce emissions of carcinogenic metals and protect public health.

KEYWORDS: Heavy metals, Air pollution, Soil, Monitoring, Environment.

Numerical analysis of the mechanical properties of a star-shaped auxetic structure under compressive loading

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ABSTRACT: Auxetic structures are mechanical metamaterials characterized by a negative value of Poisson's ratio when subjected to external loading. Owing to this unusual property, these materials exhibit enhanced energy absorption capacity, improved shear resistance, and superior indentation resistance compared to conventional materials. As a result, auxetic structures have attracted significant attention and have found increasing applications in various engineering fields, including aerospace, automotive engineering, civil engineering, military protection systems, biomedicine, and the textile industry. In this study, the mechanical behavior of a star-shaped auxetic structure subjected to compressive loading is investigated using the finite element method. The numerical analysis was performed using the LS-DYNA solver implemented within the ANSYS software environment. The material used in the simulations is 316L stainless steel. A lattice configuration consisting of 6×6 unit cells was considered in order to capture the global mechanical response of the structure. Additionally, the study examines the maximum compression velocity that ensures quasi-static loading conditions during the numerical simulation. The primary objective of the analysis is to obtain the force–displacement response of the structure, which provides a clear insight into its mechanical performance under large deformation conditions. Based on the obtained numerical results, the energy absorption capability of the structure is also evaluated. Finally, the numerical results are visually verified through comparison with experimental observations reported in a previous study. **Keywords:** Negative Poisson's ratio; Auxetic; Metamaterials; Finite element method; Energy absorption

KEYWORDS: Negative Poisson's ratio, Auxetic, Metamaterials, Finite element method, Energy absorption.

Volume optimization of the worm gear using SSO algorithm

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ABSTRACT: Machine design is a field of research where the process of designing a mechanical element is optimized, having certain goals and limitations in mind. In this paper, the Sperm Swarm Optimization algorithm (SSO for short) was used to optimize volume of worm gear with constant number of variables. By applying the SSO algorithm, we obtained optimal or near-optimal results. By further development of this algorithm, this method can be modified and improved in order to obtain better results.

KEYWORDS: Optimization, Worm gear, Sperm swarm optimization.

Mathematical modeling of surface roughness on the involute gear tooth flank

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ABSTRACT: The load-carrying capacity of gear tooth flanks with an involute profile, as the most commonly used geometry in mechanical power transmission systems, is crucial for their safe and reliable operation. Due to the fatigue-driven nature of flank failure, surface roughness represents one of the key influencing factors. In addition to the natural running-in process, during which surface roughness decreases in the initial stage of operation, there are also undesirable phenomena caused by fluid–structure interaction (FSI). One such phenomenon is cavitation, whose erosive action leads to an increase in surface roughness within cavitation zones. This paper presents a mathematical model for approximating the surface roughness of involute gear tooth flanks and analyzes the variation of model parameters as a function of changes in surface roughness.

KEYWORDS: Cavitation erosion, Involute gear tooth profile, Load carrying capacity, Surface roughness.

Application of the SARO algorithm in the dimensional synthesis of a hybrid four-bar mechanism

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ABSTRACT: Hybrid mechanisms are a combination of mechanisms with rigid and flexible links. Despite good performance, their application is significantly smaller compared to traditional ones with rigid links. The reason for this lies in the complexity of the design process of these mechanisms. Therefore, the focus of this paper is to solve the problem of dimensional synthesis of a hybrid four-bar mechanism for open path generation. All links of the mechanism are rigid, except for the input one, which is elastic and represented as a fixed continuum rod of constant curvature. The dimensional synthesis problem is solved using optimization techniques. Two numerical examples in which open path generation was performed were solved using the SARO algorithm. An appropriate comparative analysis was performed - a comparison of the achieved results with the results obtained by applying other optimization algorithms.

KEYWORDS: SARO algorithm, Dimensional synthesis, Hybrid mechanisms, Optimization.

Kinematic and dynamic modeling of a six-axis industrial robot toward virtual twin development

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ABSTRACT: Industrial robots are complex mechatronic systems whose effective modeling plays a significant role in the development of virtual twins and advanced control systems. This paper presents the development of the kinematic and dynamic model of the Mitsubishi RV-2FRL industrial robot in the MATLAB programmable environment for the implementation of its virtual twin. The robot's kinematic model was developed based on the Denavit–Hartenberg method, through the definition of geometric parameters and transformation matrices required for determining the position and orientation of the end effector. Both forward and inverse kinematic models were implemented, enabling motion analysis and the generation of desired joint configurations. The dynamic model was derived using the Euler–Lagrange formalism, incorporating inertial, Coriolis, centrifugal, and gravitational effects acting on the robot. The developed mathematical models were implemented and validated in the MATLAB environment through appropriate simulations. The obtained results demonstrate that the models accurately describe the kinematic and dynamic behavior of the robot and provide a reliable foundation for the development of its virtual twin. Such an approach enables system performance analysis, simulation of various operating scenarios, and the development of control algorithms prior to their implementation on the physical robotic system.

KEYWORDS: Robotics, Kinematics, Dynamics, Mitsubishi RV-2FRL, Virtual twin.

Numerical investigation of a star-shaped auxetic structure under different impact velocities

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ABSTRACT: Auxetic structures are a class of mechanical metamaterials characterized by a negative Poisson's ratio and enhanced energy absorption capabilities under impact loading. In this study, the influence of impact velocity on the mechanical response of a star-shaped auxetic (SSA) structure is investigated using the finite element method implemented in ANSYS Workbench LS-DYNA. A cellular structure composed of a 6×6 arrangement of SSA unit cells was subjected to compressive impact loading at velocities of 1 m/s, 10 m/s, and 100 m/s. The deformation mechanisms, force–displacement response, kinetic and internal energy histories, and energy absorption characteristics were analyzed. The results show that the deformation patterns obtained at 1 m/s and 10 m/s are nearly identical, exhibiting the characteristic elastic, plateau, and densification stages of cellular structures. Furthermore, the quasi-static condition was satisfied for these loading velocities, as the kinetic energy remained significantly lower than the internal energy throughout the simulations. In contrast, the response at 100 m/s was dominated by dynamic effects, resulting in non-uniform deformation, increased impact forces, and significantly higher energy absorption. The findings provide insight into the influence of impact velocity on the mechanical behavior of star-shaped auxetic structures and may contribute to their application in energy-absorbing systems.

KEYWORDS: Auxetic, Energy absorption, Finite element method, Quasi-static, Star-shaped structure.

Road surface wear – Analysis of tests and possibilities for application of new materials

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ABSTRACT: Wear and tear is a process, which is related with the operation of roads, and regardless of the measures taken to reduce it, this process cannot be completely avoided. The surface layer of the road surface is in continual contact with the vehicle tires of moving vehicles and the impact of aggressive environments of various origins. The efficiency and the safety of road transport depends on several indicators, one of which is the degree of road surface wear. Now only to traffic safety, wear and tear significantly impacts to human health and the environment. In this paper has been conducted an extensive literature review of studies, which are related to road surface wear. New methods and materials to reduce this process are considered. Their results have been analyzed and systematized. Possibilities for using innovative construction materials have been examined, taking into account their specific properties and advantages that would allow their use as part of the road surface, in various facilities, and as road elements.

KEYWORDS: Road surface, Wear, Self-compacting concrete.

Comparative study of bleeding process in ordinary and self-compacting concrete – Influence on the reliability of reinforced concrete elements

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ABSTRACT: Worldwide there is an intensive development of the construction sector, which is invariably associated with the building of various reinforced concrete elements and facilities. Increasingly attractive projects, significant support distances imply the use of large cross-sections of reinforced concrete, which are made with a high percentage of reinforcement. Their precise technological implementation and correct composition contribute to high durability and minimizing maintenance costs. This article examines the features of the bleeding process, which invariably accompanies all concrete works. Its influence on finished reinforced concrete elements is analyzed. A comparison of the bleeding process in ordinary concrete and self-compacting concrete is made, taking into account its influence on the bond strength between the two types of concrete and reinforcing steel. Conclusions are drawn and recommendations are given for the applicability of the two types of concrete, especially in elements with great thickness and/or height.

KEYWORDS: Self-compacting concrete, Bleeding effect, Bond strength concrete-reinforcement, Durability.

Biocomposite based on corn cobs as an innovative thermal insulation material

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ABSTRACT: Under contemporary conditions of increasingly intensive climate change and growing energy demands, the role of renewable energy sources has become increasingly important. However, their availability and efficiency largely depend on variable meteorological conditions, which directly affect the stability and reliability of energy systems based on renewable energy sources. At the same time, climate change is altering energy consumption patterns, particularly through the growing need for adequate thermal insulation of buildings in order to maintain energy efficiency. Based on these facts, this research investigates the possibility of using ground corn cobs as an aggregate in the production of thermal insulation materials. The aim is to develop a composite material with satisfactory thermal insulation properties that could be applied in construction practice. This study contributes to the development of innovative materials that support the improvement of building energy efficiency.

KEYWORDS: Biocomposite, Thermal conductivity, Thermal insulator, Energy efficiency.

Recycled steel in contemporary architecture: Sustainable potentials and applications through case studies

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ABSTRACT: Rapid urbanization and growing environmental challenges demand the use of sustainable materials, which has become a key aspect of contemporary architectural and engineering design. Recycled steel stands out due to its ability to retain mechanical properties through multiple recycling cycles while significantly reducing energy consumption and carbon emissions compared to primary production. This paper examines the potential of recycled steel in architecture and construction, focusing on its role in structural systems and spatial design. Selected case studies, including Hearst Tower, Olympic Stadium, and Empire State Building, illustrate diverse approaches to its application, from advanced structural concepts to adaptive reuse strategies. The research is based on a comparative analysis of structural systems, levels of recycled material use, and their impact on energy efficiency and overall sustainability. Particular attention is given to the relationship between structural logic, economic considerations, and architectural expression. The findings suggest that recycled steel not only reduces environmental impact but also enables the development of flexible, adaptable, and resource-efficient structures, positioning it as a key material in sustainable and circular architecture.

KEYWORDS: Recycled steel, Structural engineering, Structural systems, Material performance, Energy efficiency, Low-carbon construction, Case studies.

Pushover analysis with various material nonlinearity models

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ABSTRACT: In this paper, the nonlinear behavior of a reinforced concrete five-story building exposed to seismic action designed according to EN 1992-1-1 and EN 1998-1 is analyzed. In addition to the required load capacity, the local ductility conditions are also met in the critical sections of the structure. Nonlinear static (pushover) analysis of the structure subjected to different lateral force distributions (uniform and modal) was performed using four material nonlinearity models (infrmFB, infrmFBPH, infrmDB, and infrmDBPH) for two orthogonal directions. The analysis was carried out using the SeismoStruct software package for seismic analysis of structures. The seismic performance assessment of the structure was based on the pushover analysis results for each applied nonlinear material model.

KEYWORDS: Pushover analysis, Material nonlinearity, Seismic performance.

Evolution of nonlinear analysis of RC sections: From iterative computations to rapid moment–curvature prediction using ANN models

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ABSTRACT: Nonlinear moment–curvature (M – ϕ) analysis is essential for evaluating the strength and ductility of reinforced concrete (RC) structures. Traditional numerical methods, such as iterative fiber analysis, provide high accuracy but are computationally intensive. This paper presents the evolution of approaches – from empirical and classical numerical methods to modern artificial intelligence (AI)-based models. Examples of applying artificial neural networks (ANN) and hybrid ANFIS models for predicting the nonlinear response of beams, columns, and beam–column joints are analyzed. Special attention is given to model architecture, input–output parameters, and prediction accuracy. The paper discusses differences between pointwise and parametric models, as well as recent approaches enhancing ANN interpretability. The study provides a critical review of ANN applications in defining moment–curvature relationships and identifies directions for future research in structural engineering.

KEYWORDS: Moment-curvature relationship, Reinforced concrete, Artificial neural networks, ANFIS, Pointwise models, Parametric models.

Methodology for measuring pressure at the contact surface between a column footing model and a soil layer limited by a rigid base using earth pressure cells

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ABSTRACT: The design of all building structures largely depends on the foundation support system, i.e., the relevant actions for structural design depend on soil–structure interaction. This paper describes a methodology for measuring pressures at the contact surface between a column footing model and a soil layer limited by a rigid base using earth pressure cells. The purpose of the research is to assess the reliability of the obtained results representing contact stress distributions between the interacting components under laboratory conditions. The concept of a reduced-scale footing model is presented, along with the procedure for preparing and installing earth pressure cells in the soil, with special emphasis on their position, calibration, and data acquisition method. The main factors affecting measurement accuracy are also discussed, including soil characteristics, geometric and material properties of the tested footing model. The aim of this paper is to define an experimental procedure for a footing model and a soil layer limited by a rigid base that can serve as a basis for further experimental research and validation of numerical models. The reliability control of the measured contact stresses using earth pressure cells is based on comparison with analytical results.

KEYWORDS: Column footing, Contact stresses, Earth pressure cells, Experimental methodology, Foundation, Geomechanics, Reduced-scale footing model, Soil layer limited by a rigid base.

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