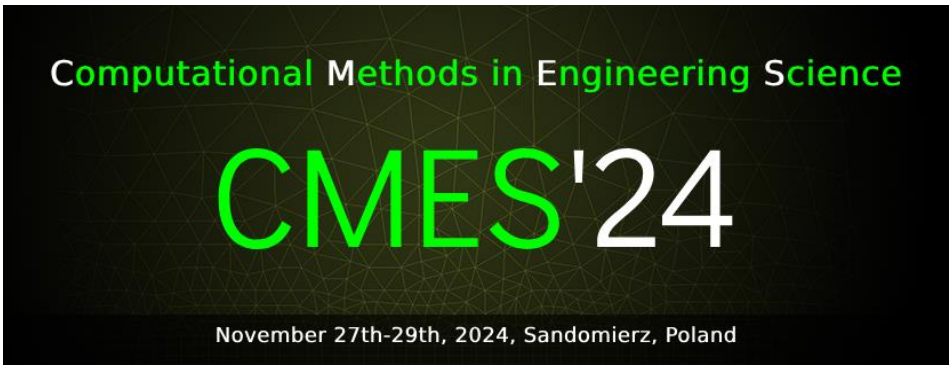

BOOK OF ABSTRACTS

Editors

Zbigniew Czyż, Mirosław Szala, Monika Kulisz,
Wojciech Cel, Katarzyna Falkowicz,
Justyna Kujawska, Marcin Badurowicz, Jakub Pizoń

Polish Air Force University
Dęblin 2024

IX International Conference of Computational Methods in Engineering Science - CMES 2024
November 27th-29th, 2024, Sandomierz, Poland

Book of Abstracts

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TABLE OF CONTENTS

ABOUT THE CONFERENCE

IX International Conference on Computational Methods in Engineering Science (CMES 2024) serves as a valuable platform for specialists to delve into the development and application of computational methods across various engineering disciplines. Scheduled for November 27-29, 2024, in Sandomierz, Poland, it is jointly organized by the Polish Society for the Promotion of Knowledge, Lublin University of Technology (Faculty of Mechanical Engineering, Faculty of Electrical Engineering and Computer Science, Faculty of Management, and Faculty of Environmental Engineering), and the Polish Air Force University (Faculty of Aviation).

Since its inception in 2016, when the first edition took place in Lublin on October 28-29, CMES has become an annual event of high scientific caliber. The second edition was also held in Lublin from November 23-25, 2017. The third and fourth editions moved to Kazimierz Dolny, where participants met at the Creative Work House of the Polish Journalists Association, continuing the tradition of November gatherings. The fifth edition in 2020 was conducted entirely online via the Zoom platform due to COVID-19 restrictions, highlighting the organizers' flexibility and determination to continue the conference's mission. The sixth and seventh editions returned to an in-person format in Zamość during November, while the eighth edition took place in Puławy from November 23-25, 2023. The current, ninth conference will be held in November in Sandomierz, solidifying November as a fixed date in the academic calendar. The choice of locations underscores the cultural and historical richness of the most beautiful areas of the Lublin Voivodeship and its surroundings.

CMES 2024 expects the participation of approximately 120 experts, including international speakers and industry representatives, fostering the exchange of knowledge and best practices between the scientific community and industry. The conference covers a broad range of topics, such as:

- analysis of engineering processes,
- application of computer programs in technology,
- artificial and computational intelligence,
- Computational Fluid Dynamics (CFD),
- computer simulations of processes and phenomena,
- Finite Element Method (FEM),
- research methods of material properties and structures,
- production engineering and quality control,
- technology management in energy acquisition processes.

Participants will have the opportunity to engage in plenary sessions and presentations by companies utilizing modern computational methods and tools to solve complex engineering problems. The interdisciplinary nature of the conference promotes collaboration among Polish and international research centers representing various fields of engineering and technical sciences.
The primary outcome of the conference is to highlight emerging trends in computational engineering methods and to enhance the visibility of ongoing research findings and scientific studies. A tangible result of the conference will include the dissemination of knowledge and the latest scientific advancements in the application of computational/numerical methods, presented through conference papers and

publications in reputable scientific journals. The CMES 2024 conference proceedings materials, after positive reviews, can be published in selected journals such as:

- Advances in Science and Technology Research Journal,
- Acta Mechanica et Automatica,
- Applied Computer Science,
- Journal of Ecological Engineering,
- Management Systems in Production Engineering,
- Advances in Materials Science.

Detailed information about CMES 2024 and previous editions is available on the official conference website: https://cmes.pl. The conference offers not only an opportunity to deepen knowledge in computational methods but also to network with peers and industry leaders in a historically rich environment.

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CMES 2024 Team – from the left: J. Pizoń, M. Szala, J. Kujawska, M. Kulisz, Z. Czyż, K. Falkowicz, M. Badurowicz, W. Cel.

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100 YEARS
OF THE POLISH AIR FORCE UNIVERSITY

CMES 2024 is part of the celebrations marking both the 100th anniversary of the Polish Air Force University in Dęblin and the 30th anniversary of the Faculty of Aviation.

SPONSORS

THE USE OF OPTICAL METHODS TO MEASURE THE MOST EFFORTED CROSS-SECTIONAL AREA IN THE TENSILE TEST

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ABSTRACT

Optical metrology has been developed for several dozen years. This development has accelerated with the advancement of computer technology. Optical measurement techniques such as: 3D scanning, CT (computed tomography) scanning, or the DIC (Digital Image Correlation) technique can be used both for metrology and help in measurements, e.g. strength.
The following article presents a comparison of metrological methods: precise 3D scanning and 3D scanning with the use of a tomograph and the use the possibility of determining the minimum cross-section of the sample for further measurements using the DIC technique in the static tensile test of samples made by 3D printing with various filling rate. In addition, a method for validating FEA analyses using Zeiss ARAMIS will be presented. The figure below presents successively the effect of a precise scan with the ATOS scanner, a CT scan with the Zeiss Metrotom 1 system and the deformation analysis in a tensile test carried out with the Zeiss ARAMIS SRX system.

Fig. 1. 3D scan of the sample

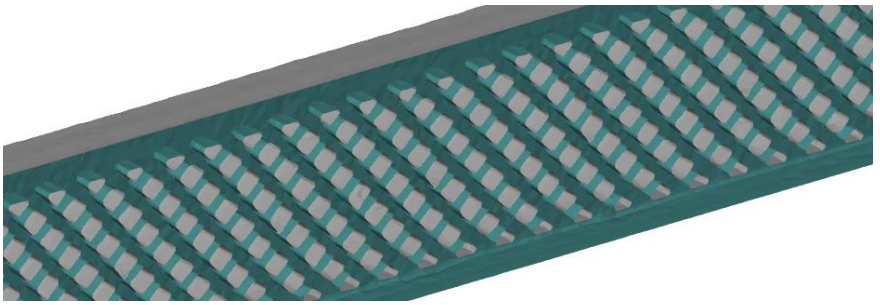

Fig. 2. CT scan (cross-section view)

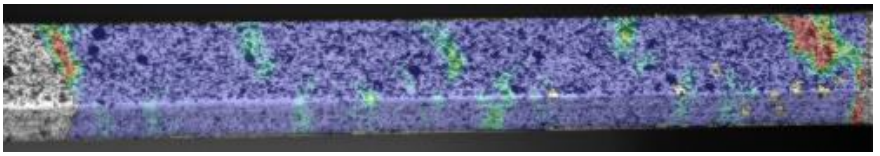

Fig. 3. The last stage before the sample breaking in the tensile test - photo + overlay

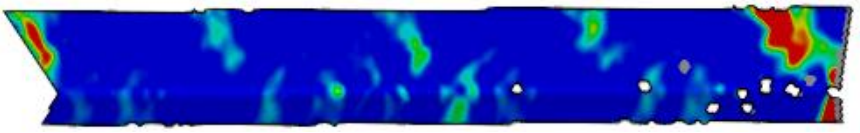

Fig. 4. Deformation map

During the conference, workshops will also be conducted by representatives of Carl Zeiss Sp. z o.o. The company successfully implements optical 3D measurement systems in quality control, development, and production departments. They oversee the entire process of installing and integrating 3D scanners into the Polish industry, universities, and research institutions. The company's qualified staff provide training in the operation of measurement machines and software, regardless of whether the solution is intended for quality analysis and control or reverse engineering. Both areas are well within their expertise. During the conference workshops, Carl Zeiss will showcase the capabilities of 2D measurements in fracture mechanics using the free Zeiss Inspect Correlate software and the Zeiss ARAMIS MC2D system, focusing on the "Identification and measurement of crack paths in tests such as DCB, MCB, SENB, or CT, as well as bending tests for concrete."

Representatives of the company will be available to provide any necessary information regarding their offerings and will be able to suggest potential solutions to research-related challenges. Additionally, it will be possible to conduct tests (tensile, compressive, and bending) on your own samples with forces up to 2.5 kN, using Digital Image Correlation (DIC) techniques.

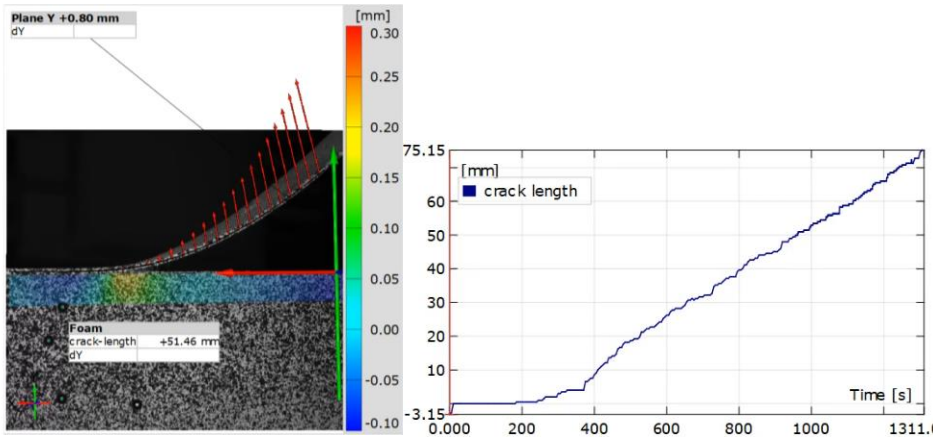

Fig. 5. An example of using the ARAMIS MC2D system for measuring crack length in an SENB test

SPEAKER BIOGRAPHY

Marcin Kneć has been involved with optical techniques for nearly 20 years. Since 1997, he has been employed at Lublin University of Technology (currently in the Faculty of Civil Engineering and Architecture – Construction Laboratory, previously in the Materials Strength Laboratory – Faculty of Mechanical Engineering). Since 2016, he has been affiliated with Lenso Sp. z o.o. (now Carl Zeiss Sp. z o.o.), where he manages various optical systems for measuring deformations. In 2016, he defended his PhD thesis at Rzeszów University of Technology, titled "Digital Image Correlation Technique in the Analysis of Deformation of Structural Component Joints Used in Aviation."

Paweł Szerszeń has been employed by Lenso Sp. z o.o. since 2020 in the Deformation Department and, following the company merger, now serves as an Application Engineer at Carl Zeiss Sp. z o.o. From the outset, he has worked with deformation measurement systems such as ARAMIS, ARGUS, and TRITOP. He is a graduate of the Faculty of Mechanical Engineering at Lublin University of Technology, specializing in Transport. He defended his master's thesis titled "Research on Selected Elements of Passive Safety in Means of Transport," with the experimental part conducted using integrated optical systems from the former GOM company.

BEYOND TRADITIONAL DEM: COUPLING ANSYS ROCKY AND ANSYS FLUENT

Maciej Szudarek, PhD
Symkom Sp. z o.o. / Warsaw University of Technology, Poland

ABSTRACT

Simulating the interaction between particles and fluid flow is essential in many industrial applications, from chemical processing to energy production. By combining the Discrete Element Method (DEM) with Computational Fluid Dynamics (CFD), engineers can capture the complex behaviors of particles in fluid environments more accurately than with either method alone. This integrated approach helps optimize designs, improve efficiency, and better predict system performance in areas such as mixing, transport, and separation.

Ansys Rocky, a recent addition to the Ansys simulation suite, offers advanced DEM capabilities. It allows for detailed particle modeling, including non-spherical and breakable particles, shells, and fibers, with support for large-scale simulations that can handle hundreds of millions of particles across multiple GPUs. These capabilities are crucial for industries such as agriculture, food processing, mining, pharmaceuticals, and energy, where particle-fluid interactions often govern the performance of equipment and processes. The coarse grain method in Rocky further enables efficient simulations of very large systems, while still maintaining accurate particle dynamics.

The software also seamlessly integrates with other tools in the Ansys ecosystem, particularly Ansys Fluent, a flagship CFD solver. When coupling Rocky with Fluent, users can simulate particle-fluid interactions. This is particularly useful for complex systems like fluidized beds, filtration processes, particle transport in pipelines, and mixing tanks.

In this presentation, an overview of how Ansys Rocky and Fluent work together to solve real-world engineering challenges will be provided. Examples will include applications from various industries, demonstrating the value of DEM-CFD coupling in improving the design and operation of systems involving particulate materials.

SPEAKER BIOGRAPHY

Maciej Szudarek, Ph.D., is the Technical Team Leader at Symkom, where he oversees the technical department and specializes in engineering simulations using Ansys software. With extensive hands-on experience, he has conducted numerous technical

training sessions and workshops, sharing his expertise in computational fluid dynamics (CFD) and simulation tools across various industries.

In addition to his work at Symkom, Maciej Szudarek is also an assistant professor at the Warsaw University of Technology, where his research focuses on flow metrology and the study of multiphase and unsteady flows. His academic role allows him to engage in scientific research, while also applying his knowledge to engineering projects for industry. These include developing a high-pressure natural gas meter calibration laboratory for CONAUT (Brazil), collaborating with PGNiG on liquefied natural gas flow measurement technologies, and consulting for PERN on long-distance fuel pipeline flow measurement systems. He also manages the Flow Laboratory at the Faculty of Mechatronics.

APPLICATION OF MACHINE LEARNING TO MONITORING INDUSTRIAL TANK REACTORS USING TOMOGRAPHY

Grzegorz Kłosowski, PhD
Department of Organisation of Enterprise, Management Faculty, Lublin University of Technology, Lublin, Poland

ABSTRACT

Monitoring industrial tank reactors is an essential element of process control. Various industries, including chemical, petrochemical, food, pharmaceutical, fertilizer, cosmetic, and energy, use industrial reactors in various types of processes. In order to ensure that the final product meets quality requirements while minimizing production costs, it is necessary to control the process in such a way that a number of parameters are within the specified ranges during the entire cycle of processing substrates into the final product. Industrial reactors play a special role in process production because the main chemical and physical changes take place inside them. Due to the reactor's closed nature, there is no possibility of direct insight into its interior, which is why determining the phase changes taking place (crystallization, gas bubbles) is also difficult. In practice, indirect methods monitor the changes occurring inside the reactor. Industrial tomography is the only method that allows imaging phase changes in specific planes of the reactor cross-section or in 3D. This presentation aims to present modern electrical and ultrasound tomography techniques that allow for insight into the interior of an industrial reactor. In order to increase image resolution, the use of various machine learning methods is proposed.

SPEAKER BIOGRAPHY

Dr. Eng Grzegorz Kłosowski is a graduate of the Faculty of Management at the Lublin University of Technology (1994). He also completed international doctoral studies in economics at the Institute of Organization and Management in Industry, "ORGMASZ," in Warsaw (2001). Since 2003, he has been an employee of the Lublin University of Technology's Faculty of Management in the Department of Enterprise Organization. In the years 2014-2020, he was the CEO of a special purpose vehicle of the Lublin University of Technology, whose task was the commercialization of scientific research. He is a specialist in research and innovation, as well as an IT specialist in the R&D domain. He is the author or co-author of over 130 scientific publications. Winner of the Best Paper Awards: Sensors 2020, Maintenance and Reliability in 2020 and 2021, International Interdisciplinary PhD Workshop 2023 of the IIPhDW’23 conference, May 3-5, 2023, Wismar, Germany. Since 2020, he has been continuously listed in the annual World's Top 2% Scientists, a prestigious list of the most influential scientists in the world created by Stanford University, Elsevier and SciTech Strategies.

FRACTIONAL-ORDER MODELING OF HEAT AND MOISTURE TRANSFER IN ANISOTROPIC MATERIALS

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ABSTRACT

The presentation presents a numerical solution of a new method of simulating two-dimensional heat-and-mass diffusion. The problem of atomic diffusion is described approximately by Fick's differential laws and the Arrhenius equation. The solution of the kinetic, second Fick's law for several boundary conditions is known, although simulating the course of diffusion in equilibrium systems where new phases are formed is problematic. Simulating mass-and-heat transport in anisotropic materials is similarly complicated. An example of such a material is wood, and the medium whose diffusion is important in it is water (moisture). Although experimental studies on real objects have been conducted for a long time, there are no satisfactory models of the course of phenomena. As in the case of diffusion in metals, it is easier to conduct simulations with a limited number of model dimensions. An example of a two-dimensional model using neural networks for simulation will be presented.

SPEAKER BIOGRAPHY

Dr K. Drozd graduated from the Lublin University of Technology in the field of Cars and Tractors. After several years of work in various companies, he returned to his alma mater and obtained a doctorate in the field of machine construction and operation. His doctoral thesis concerned the influence of structure on the high-cycle durability of materials. He continues to research and simulate the properties of materials and phenomena that affect their durability. For this purpose, he uses commercial software, available under the GNU license, and creates his own modules. The effect of recent cooperation with companies from the economic environment is a series of monographs on the research and simulation of the dynamics of suspended monorails with their own drive, operated in mines. For a dozen or so years, he has been an active popularizer of scientific achievements within the framework of national and international programs.

APPLICATION OF ELECTROMAGNETIC SIMULATIONS IN CALCULATING ELECTROMAGNETIC COMPATIBILITY (EMC) OF DEVICES AND ENVIRONMENTAL PROTECTION

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Dominik GAWLE, M.Eng.
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Specialist
Dassault Systemes sp z.o.o.

ABSTRACT

This paper discusses the possibilities of using numerical simulation in the analysis of electromagnetic compatibility (EMC) of electrical equipment and environmental protection for the general public using the electromagnetic simulation tools of the CST Studio Suite. The standards commonly used in engineering will be discussed, including ISO and CIPRS standards related to EMC, as well as the ICNIRP standard, which specifies permissible levels of exposure of the human body to low and high frequency electromagnetic radiation. The paper also presents an example of an EMC analysis, focusing on the conducted emission analysis of an inverter working with a BLDC motor and the effect of magnetic fields generated by high current wires on the human body in the automotive sector.

SPEAKER BIOGRAPHY

Prof. Rafal M. Wojciechowski received the MSc degree in Electrical Engineering from the Poznan University of Technology in 2005, PhD and D.Sc. degree in 2010 and 2017, respectively. His scientific interests are numerical modeling and analysis of electrical machines and devices using the multi-stage approach of the finite elements method (FEM). He has published over 70 papers on the electrical machines,

electrical and electronic devices, systems of wireless transmission power; and the computation of electromagnetic field and induced currents in multiply connected conductors. He is an co-author of 3 international patents and 9 patent application for invention on electrical devices designs. From 3 year he co-operetes with Technia Poland, as the Simulation expert in EM field.

Dominik Gawle has been associated with the CAD/SIM/CAM/PDM software market for engineers for over 18 years. He possesses extensive knowledge of Dassault Systèmes solutions, having previously worked for one of its partners in both technical and sales roles. He enjoys sharing his expertise with those interested. He is a graduate of the Cracow University of Technology in the field of Automation and Robotics, as well as a postgraduate in Project Management from AGH University of Science and Technology. Currently, he is responsible for the development of SIMULIA sales, both directly to selected clients and through Dassault Systèmes partners in Poland.

ABSTRACTS

ANALYSIS OF ENGINEERING PROCESSES

THE INFLUENCE OF SELECTED TECHNOLOGICAL PARAMETERS ON CHANGES IN THE FLANGING LOAD

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Abstract: The flanging process is widely used in stamping production: when collar drawing small holes for threads or to increase the stiffness of a draw piece. It can also replace the operation of deep drawing cylindrical draw pieces with a large flange followed by cutting the bottom. The paper discusses the influence of the shape of the punch and the grade of material on load changes at various collar drawing coefficients. Flat, spherical and conical punches and samples made of EN-AW 1050A aluminium, Cu-ETP copper, CuZn37 brass, S235JRG2 steel, H17 steel and 0H18N9 steel were used for testing. The relative thickness of test pieces was 0.015 (which corresponded to a thickness of 1 mm and a blank diameter of 66 mm). Various collar drawing factors ranging from 0.32 to 0.53 were adopted in the studies. An analysis of the obtained height of collars and wall thicknesses was carried out. The experimental tests were carried out using special tooling mounted on a testing machine with a 20kN load for 0.5 metrological class. Changes in the force as a function of the displacement of the punches were recorded using Test&Motion software that is commonly applied in research laboratories. Based on the obtained results at various technological parameters, possibility of flanging process was evaluated in industrial conditions.

Keywords: metal forming, flanging, collar drawing.

MULTI-CRITERIA DECISION SUPPORT IN THE EVALUATION OF HYDRODYNAMIC CAVITATION EFFECTS – A CASE STUDY

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Abstract: The work describes a method for searching for the best variant(s) of cavitation of coffee waste, taking into account the defined five criteria: sCOD/COD and DOC/TOC, which were maximised, and the others, i.e. caffeine concentration, phenols concentration and energy consumption, which were minimised. The method used in the first stage determines non-dominated variants, then a compromise variant, assuming that all criteria used are equally important. Further analysis allows us to determine further compromise options. The method of determining compromise solutions is based on the use of Chebyshev metric, which has been enriched with a mechanism for normalising individual criteria (which allows for their comparison) and the ability to define the importance of individual criteria. For normalisation, the so-called the ideal point, which is an internal property of the analysed variants, is determined each time for a given subset of non-dominated variants. After determining the first compromise solution, the process of generating new ideal points (their number is equal to the size of the criteria space) begins by associating the components of this solution with the components of the ideal point. Using new reference points, the method determines additional compromise solutions. The five-criteria evaluation of 20 variants obtained in the experiment showed that when adopting different values of the importance of individual criteria, some variants are never selected as a compromise. The subset of compromise variants ranged from 3 to 6. The variants that were repeatedly selected as compromise variants, with different values of the importance of individual criteria, were variants for which the cavitation process time was: 20 or 30 minutes and the cavitation inlet pressure was 5 bar. The multi-criteria assessment showed that these are the best compromise options and can be recommended for the coffee waste cavitation process.

Keywords: multi-criteria decision support, hydrodynamic cavitation, coffee waste, Chebyshev metric.

CONTROL SYSTEM FOR THE RECOVERY OF TECHNOLOGICAL WASTE HEAT IN THE STRETCH FILM PRODUCTION PROCESS

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Abstract: The paper discusses the development of a control system designed to optimize the recovery and reuse of waste heat in the stretch film production process. A critical aspect of maintaining high-quality stretch film involves controlling the temperature of the first roller, known as the calender. The system must consistently maintain the roller\'s surface temperature within a narrow range, achieved through a water flow system with an inlet temperature of 15°C and an outlet temperature of 16°C, ensuring a minimal temperature gradient. To address the significant amount of waste heat generated during the cooling of this roller, the authors designed a heat recovery system that includes two separate hydraulic circuits connected by a 400kW plate heat exchanger. The primary side of the heat exchanger is linked to heat pumps or fan coolers, which serve as the cooling source. The secondary side manages the transfer of waste heat from the calender. The article further elaborates on the industrial control system that governs this heat recovery line, detailing a layered control structure. Sensors, mainly those measuring temperature and flow, provide real-time data that influence the operation of output devices such as valves, pumps, and inverters. Moreover, the article introduces a process innovation by repurposing approximately 176 kW of low-temperature waste heat, which would typically dissipate into the atmosphere, to dry regranulate material, thereby enhancing the overall efficiency of the production process.

Keywords: control system, heat pump, heat waste recovery.

RESPONSE OF THE AIR FLOW ENERGY HARVESTER WITH TWO SIDE-BY-SIDE BLUFF BODIES OF VARIOUS SHAPES

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Abstract: We report the experimental results of flow energy harvesting where the bluff bodies with different cross-section shapes are placed at the ends of the cantilever beams. Namely, bluff bodies as cylinders and rectangles were considered under interaction the flowing air. The bluff bodies are coupled through the joint suspension frame where the other cantilever ends were clamped and also additionally by vortices created in the space between them. Finally, piezoelectric patches with corresponding electrical circuits were attached to the cantilever beams. They transduce the mechanical energy of the beam-bluff-body resonators into the electrical power. The resulting structure oscillated on the flowing air with several flow velocity ranges. Higher level of oscillations caused larger voltage response in the electric circuits. As the bluff bodies are responding differently we observed the moderate voltage output for fairly wide velocity range. For illustration of the energy transduction mechanism and validation of the experimental results CFD simulations were performed. We show the differences in the vortex formation and shedding causing vibration of mechanical structure in various conditions.

Keywords: energy harvesting, piezoelectric, bluff body, vortex, computational fluid dynamics.

WIND TUNNEL ANALYSIS OF THE AERODYNAMIC PROPERTIES OF A SELECTED TRAINER-COMBAT AIRCRAFT MODEL

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Abstract: The work describes the process of developing an FA-50 aircraft model and analyzing its aerodynamic properties based on wind tunnel testing. The experiments were conducted in a closed-circuit wind tunnel with a closed test chamber measuring 1275 x 1415 mm, allowing airflow at a maximum speed of 60 m/s. To accommodate the tunnel's specifications, the model was produced at a 1:14 scale using Fused Deposition Modeling (FDM) 3D printing technology on an Omni TECH printer by Omni3D. The model's design was based on the lightweight, multi-role FA-50 fighter aircraft, with detailed replication achieved in the CAD environment using SOLIDWORKS. The model creation process involved not only 3D printing but also a series of finishing steps, including filling, sanding, and painting, to ensure optimal surface quality and prepare the model for testing. The wind tunnel experiments yielded comprehensive data on the FA-50 model's aerodynamic characteristics, enabling a precise evaluation of its flight properties. These results provide valuable insights that can inform further research on design optimization and contribute to advancements in combat aircraft design technology. The findings presented may assist in future studies focused on aerodynamic modifications of similar units and serve as a foundation for broader analyses in the field of aircraft model aerodynamics.

Keywords: aerodynamic properties, wind tunnel testing, trainer-combat aircraft, 3D printed model, aerodynamic characteristics.

NUMERICAL AND EXPERIMENTAL STUDIES ON THE PERFORMANCE A VORTEX-INDUCED VIBRATION ENERGY HARVESTER

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Abstract: Cantilever-based piezoelectric vibration energy harvesters are quite promising considering the density of harvested power among other micro-scale energy harvesters. Such a piezoelectric device can harvest energy from the wind-induced excitations with the help of a bluff-body mounted at the tip-point of a cantilever. At low-to-moderate wind speeds, a cylindrical bluff-body creates transverse oscillations as the vortex shedding occurs. In this work at first, we present an approximate model for such a phenomenon of vortex-induced vibration of a piezoelectric harvester. Wind-induced excitation caused by vortex-shedding is modelled using the Van-der-Pol oscillator, for which the parameters are determined based on the experimental measurements. Numerical simulations are performed to identify the response and periodic lock-in region of the structure by sweeping the wind velocities over a range of low-to-moderate speeds. Such an aero-electro-mechanical model is qualitatively compared with the results obtained from the experimental test runs in the wind-tunnel. Cylindrical bluff-bodies made from Styrofoam and Polylactic Acid (PLA) filament with 3D printing are tested by mounting on the spring steel cantilever beams. We investigate the influence of stiffness by using two different sizes of beams to validate the numerical results. Influence of the tip mass on the periodic lock-in region is also studied with the bluff-bodies of various heights. The results of the numerical and experimental studies are useful for optimizing the sizes of the piezoelectric harvester and the bluff-body to maximize the energy harvesting potential of the device.

Keywords: vortex-induced vibrations, energy harvesting, piezoelectric, fluid-structure interaction.

APPLICATION OF COMPUTER PROGRAMS IN TECHNOLOGY

FEASIBILITY OF THE USAGE OF LOW-QUANT LOCAL LLMS FOR ENTERPRISE KNOWLEDGE BASE QUESTION ANSWERING

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Abstract: In this paper, the authors are presenting the results of the benchmark of the usage of locally-run Large Language Models (LLMs) in the context of question answering against the knowledge database using the RAG (Retrieval Augmented Generation) pipeline for 3 specific domains. The locally run LLMs are essential for the enterprise scenarios: the companies may use data which is not available online and may not be published or transferred to the online LLM providers because of personally identifiable information, medical data or trade secrets. Apart from testing 9 models, the authors analyze how the quantization process degrades the RAG quality, in the search of optimization between the model quality and its hardware requirements. The models are being evaluated using a multi-criteria score including the quality of the answer, as well as coherence. In the final scoring, the Gemma2-9B and Bielik-11B got the highest results.

Keywords: large language models, retrieval augmented generation, question answering, knowledge management.

GAP FILLING ALGORITHM FOR MOTION CAPTURE DATA TO CREATE REALISTIC VEHICLE ANIMATION

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Abstract: The dynamic development of the entertainment market entails the need to develop new methods enabling the application of current scientific achievements. Motion capture is one of the cutting-edge technologies that plays a key role in movement and trajectory computer mapping. The use of optical systems allows one to obtain highly precise motion data that is often applied in computer animations. This study aimed to define the research methodology proposed to analyze the movement of remotely controlled cars utilizing developed gap filling algorithm, a part of post-processing, for creating realistic vehicle animation. On a specially prepared model, six various types of movements were recorded, such as: driving straight line forward, driving straight line backwards, driving on a curve to the left, driving on a curve to the right and driving around a roundabout on both sides. These movements were recorded using a VICON passive motion capture system. As a result, three-dimensional models of vehicles were created that were further post-processed, mainly by filling in the gaps in the trajectories. The case study highlighted problems such as missing points at the beginning and end of the recordings. Therefore, algorithm have been developed to solve the above-mentioned problem and allowed for obtaining an accurate movement trajectory throughout the entire route. Realistic animations were created from the prepared data. The preliminary studies allowed one for the verification of the research method and implemented algorithm for obtaining animations reflecting accurate movements.

Keywords: methodology, motion capture, movement data, vehicles, animation.

MEASUREMENT OF THE ROTATION OF THE POLARISATION PLANE WITH TFBG AND DWT USAGE

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Abstract: Fibre optic sensors are used to measure a variety of physical quantities, including polarisation plane rotation. Existing solutions for measuring the rotation of the plane of polarisation in optical fibres are based on sensors using tilted fibre Bragg gratings (TFBGs). Articles describing the possibilities of measuring the rotation of the plane of polarisation are generally concepts that show the effect of the rotation of the plane of polarisation on quantities such as the change in optical power of the light transmitted through the TFBG, or the change in the position of the selected minimum of the light spectrum. The only method that allows the measurement of the rotation of the plane of polarisation is the one based on optical spectrum analysis. Unfortunately, this method requires manual calibration by an experienced operator for each sensor.

In the paper, the fully automatic method of sensor calibration and processing the signal from a TFBG to measure the rotation angle of the plane of polarisation is proposed. The method uses the discrete wavelet transform (DWT) to process the light spectrum. As many of DWT coefficients contain a significant level of interference, an automatic algorithm for coefficient interference assessment has been developed.

During a TFBG production process, some differences between TFBGs appear. Because of this, it is almost impossible to achieve a good level of sensor repeatability. There are always some differences in their characteristics. To automate the production process of the sensors, an automatic method for their calibration has been proposed and verified by the implementation of appropriate algorithms.

The calibration and measurement methods presented allow for the automation of calibration and measurement processes. The developed procedures allow measurement of the rotation of the plane of polarisation in the angle range 0°-180° with an average MSE=0.37°.

Keywords: TFBG, Polarisation, DWT, Rotation.

DETECTING INCIDENTS AND ANOMALIES IN SDN-BASED IMPLEMENTATIONS OF CRITICAL INFRASTRUCTURE RESULTING IN ADAPTIVE SYSTEM CHANGES

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Abstract: In paper an example of integrated Software-Defined Network (SDN) system with heterogeneous technological instances based on the Linux platform will be shown. The capabilities of these systems were examined in terms of responding to detected incidents and traffic anomalies. In particular, their appropriate responses to anomalies were tested, as well as the possibility of continuous monitoring of packet transfer between separate network components. For isolation and optimized resource management, some components, such as POX or the MQTT broker, were run in Docker containers. The test environment used both hardware cases and prepared software enabling comprehensive design and testing of networks based on the OpenFlow protocol used in SDN architecture, enabling the separation of control from traffic in computer networks. The results of this research make it possible to implement anomaly detection solutions in critical infrastructure systems that will adapt "on-the-go" to changing conditions arising, for example, in the event of an attack on such infrastructure or physical damage to it at a selected node.

Keywords: Software-Defined Network, anomaly detection, Open vSwitch, OpenFlow protocol, adaptive system changes.

ANALYSIS OF THE POSSIBILITY OF HIDING DECOMPOSED INFORMATION IN A VIRTUAL REALITY ENVIRONMENT

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Abstract: Information is a fundamental resource, generated by mankind, it is through it that one can reduce or eliminate the effects of a cataclysm, make or lose a fortune, or even shorten a war. The transmission of hidden information in the form of cryptographic techniques has been known to mankind since the dawn of time. Initially simple, basic encryption has evolved into sophisticated steganographic hiding of information gaining more and more resistance to breakage with the development of technology. It is very difficult to develop a new, effective encryption algorithm. Therefore, it becomes very important to skillfully use already existing cryptographic algorithms and develop a new general encryption algorithm. The idea of where to hide the data also becomes important.

The article proposes an author\'s novel system for decomposing the hidden information. Using steganography, a fragmented password is hidden in 3D objects in the Virtual Reality application world. The data is hidden directly in the VR world (a multiplayer simple game) with the caveat, however, that not everyone knows where to look for it. The time in which the information is sought is also important. Clues as to how , when and where to find the data are encoded in 3D objects. The possibility of hiding information in the metadata, in the texture, in the coordinates of the vertices of the objects and also in the UV map has been thoroughly investigated.

Keywords: Steganography, information decomposition, information hiding, punctual, selective access, Unity, Blender.

NONLINEAR MULTIDIMENSIONALITY REDUCTION METHODS FOR VISUALIZATION AND CLASSIFICATION OF GAS SENSOR ARRAY DATA

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Abstract: The presentation concerns the application and comparison of selected methods of nonlinear multidimensionality reduction. In environmental engineering, in the control of technological processes based on readouts from sensor arrays, the principal component analysis (PCA) constitutes a widely used method of multidimensionality reduction. It is most often used to test the classification potential of multidimensional data by visualizing it in a space reduced to two or three variables. The PCA method often provides a good representation of the global structure of the data, which consists of the location of clusters and outlier observations and the shape of the point cloud formed by the dataset. However, there are newer methods for nonlinear reduction of multidimensionality of sets that reproduce well the local structure of the data while preserving the neighborhood between points, the goal of which is to reproduce both the local and global structure as well as possible. A comparison was made between the performance of algorithms classically used in the visualization of data from gas sensor arrays and methods by which complex, nonlinear data structures can be identified. The data obtained in the reduction process using different algorithms was then used for a classification task and, using parameters for evaluating the quality of classification, the algorithms used were compared.

Keywords: dimension reduction, data visualization, data classification, water and wastewater quality, gas sensors array.

APPLICATION OF DEEP LEARNING METHODS IN AUTOMATIC IMAGE ANALYSIS OF MICROSCOPIC SAMPLES

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Abstract: The aim of this study is the automatic image analysis using the YOLO v8 deep learning neural network, focused on the detection of Cyclotella organisms. The quantity of these organisms can indicate the level of water pollution, making the automation of their detection a significant challenge in practical application of bioindication studies. Traditionally, detection and counting of objects in microscope images were performed manually. However, with the application of neural networks and machine learning, this process can be automated. YOLO (You Only Look Once) is an example of a network that, after appropriate training and validation, is capable of real-time image detection. In this study, the Roboflow tool was used for object annotation, creating a dataset divided into training, validation, and test sets. The network was trained, the model was validated, and its accuracy was assessed. The article presents the performance metrics of the YOLO v8 network on the test set, such as precision, recall, and accuracy. The method for determining the position of a given organism based on bounding boxes is also discussed. The presented results confirm the effectiveness of the applied method in the automatic analysis of microscopic images.

Keywords: deep learning neural network, automatic image analysis, YOLO, object annotation, microscopic samples, bioindication, water quality.

ANALYSIS OF VISUAL PERCEPTION IN CHILDREN USING AN EYE TRACKER

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Abstract: The main aim of this study was to conduct research on the analysis of the use of an eye tracker among children. The conducted research allowed for the examination and understanding of visual perception in children using the eye tracker. Additionally, an analysis of the obtained results regarding cognitive development, learning processes, and perceptual abilities in children was conducted.To properly achieve the goal of the study, it was crucial to select the appropriate research method and equipment for conducting the experiment. The choice of an eye tracker as a non-contact device enabled smooth research implementation.The study utilized a set of games called KINKA, designed to support communication in individuals with developmental challenges.An important aspect of the thesis was the proper preparation of the participants for the research procedure. The first step involved conducting the appropriate equipment calibration procedure, aiming to achieve the best possible performance of data extraction algorithms from the eye tracker. The data processing procedure consists of several steps: the first being the registration of eye activity using a non-invasive eye tracking system. The next step is the processing of the recorded data to eliminate unnecessary information and errors that occurred during the experiment. Finally, oculomotor features are extracted for classification. The last stage involves the analysis of visual perception in the examined children of different ages and the comparison of results among them. An analysis of the impact of specific visual stimuli on eye behavior was conducted. Special attention was given to eye tracking, which was applied in the research. Furthermore, the issue of eye activity used as part of the user interface during the study was discussed. The designed experiment involving an eye tracker was tested on a group of thirty children, where it fulfilled its purpose.

Keywords: saccades, fixations, eye movement analysis, visual perception analysis.

PERFORMANCE EVALUATION OF SELECTED CONTAINERIZATION METHODS IN WEB SERVICES APPLICATIONS

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Abstract: This paper evaluates the performance of selected containerization methods. As part of the research, infrastructure was created using Google Cloud public cloud, then load tests were conducted for each containerization method using Apache JMeter. The research has shown that choosing the right containerization method depends on the service to be implemented. It was shown that the highest performance was achieved by Podman together with Docker. An example implementation and performance of Kubernetes technology together with Docker and autoscaling using Google Cloud was demonstrated.

Keywords: Kubernetes, Docker, Podman, Google Cloud, Apache JMeter.

ANALYSIS OF THE TIME SLOT LENGTH IMPACT OF SELECTED DATA LINK LAYER PROTOCOLS (B-MAC, X-MAC, AND LMAC) ON ENERGY RESOURCE CONSUMPTION IN WSNs

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Abstract: The paper analyzes the effect of time slots on the correctness of packet delivery for selected Media Access Control protocols of WSN (Wireless Sensor Networks) like B-MAC, X-MAC, and LMAC. In the study, reliability, and power consumption were used as indicators of the quality of the protocol variant. The length of the time slot was shown to affect the consumption of energy resources of the nodes. For all network sizes considered, it was shown that the best results were achieved by the LMAC protocol, which also proved to be the most energy-efficient with a low ratio of energy resource consumption.

Keywords: sensors, energy-efficient, WSN, B-MAC, X-MAC, LMAC, OMNeT++.

RESEARCH ON ACTIVATED SLUDGE FOR THE SELECTION OF ORGANISMS FOR ASSESSING ITS CONDITION AND THE POSSIBILITY OF AUTOMATION IN THE PERSPECTIVE OF BUILDING AN ELECTRONIC EYE

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Abstract: Activated sludge is a process factor in the wastewater treatment process. It consists of organisms such as bacteria, ciliates, rotifers, amoebas, nematodes and others. Carbon, nitrogen and phosphorus compounds, which are pollutants from the human perspective, are treated as food and processed by the above-mentioned microorganisms. The environmental requirements for these organisms are not identical, but overlap to some extent, allowing all communities to grow. Changes in environmental conditions often cause a change in the number of individuals of specific species or their extinction, which may result in faulty operation of the bioreactor and the treatment process. Finding easily identifiable organisms among them, showing deterioration of environmental conditions or the proportion of individual organisms within the sludge itself, is of great importance in assessing its quality and ensures control over the stability as well as effectiveness of the treatment process. Selection of organisms should be based on the reaction of a given group to the parameters of the process being carried out, the visual properties (their geometry and form) and the possibility of extracting characteristic features that distinguish them from other similar ones. The possibility of identifying selected organisms is crucial from the point of view of process automation using an electronic eye, which includes a system for preparation and acquisition digital images and models of automatic image analysis, e.g. based on deep learning neural networks.

Keywords: activated sludge, bioreactors, bioindication, electronic eye, image analysis, computer vision, deep learning neural networks.

TENNIS PATTERNS RECOGNITION BASED ON A NOVEL TENNIS DATASET - 3DTENNISDS

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Abstract: Many scientific studies on tennis stroke recognition are based on datasets created for the purpose of research using video or motion capture techniques. The importance of such datasets has been increasing due to the athlete performance evaluation needs. The primary aim of this paper is to present a state-of-the-art 3DTennisDS storing four tennis strokes: forehand, backhand, volley forehand and volley backhand. The moves were registered using the Vicon optical motion capture and contain a 39-marker player and a 7-marker tennis racket models. The potential and quality of this unique dataset has been verified using Spatial-Temporal Graph Neural Networks, because this type of network topology matches to the human body structure. The presented 3DTennisDS has been compared with two well-known datasets: the THETIS and the Tennis-Mocap. They contain tennis movements in a form of motion capture data, registered using markerless and marker-based systems. The classification of tennis strokes has been performed to verify how various types of data acquisition (marker-based and marker-less ones) as well as the structure of the data affect the accuracy of human action recognition. In this study ONI files from THETIS, bvh from Tennis-Mocap and c3d data from 3DTennisDS were considered. Moreover, the impact of input data fuzzyfication was examined. The obtained results showed that the classification using 3DTennisDS achieved the highest results, both for fuzzy and non-fuzzy inputs. These outcomes indicate that the way of capturing data, its preparation and structure have great influence on classification accuracy. The developed 3DTennisDS has a great potential in further motion capture analysis.

Keywords: 3DTennisDS, tennis dataset, tennis strokes, motion capture, graph convolutional networks, fuzzy classification.

ADVANCEMENTS IN REFLECTIVE TOMOGRAPHY FOR INDOOR HUMAN DETECTION

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Abstract: The article details a project focusing on the application of radio tomography using electromagnetic waves at 5.8 GHz to detect indoor occupants. A comprehensive approach was taken to design the hardware and structure the data transfer network necessary for effective signal processing. The data captured by reflective methods are transmitted to a location engine, which converts these into actionable location information. The study extensively discusses methodologies for signal amplitude and frequency analysis, emphasizing their role in human detection. It explores the hardware specifics, including the MAX2828ETN+ transceiver, the nRF52832 microcontroller, and their functionalities in signal transmission and environmental sensing. The device integrates complex filtering circuits and uses a unique antenna design to enhance signal reception and processing. The system's efficacy is illustrated through real-time location updates, achieving a near RTLS speed, highlighting its potential for practical deployment in safety and monitoring applications. Results from the project show that by analyzing the reflected signals, it\'s possible to detect human presence accurately within a defined proximity, with visualizations depicted in the article demonstrating the application of this technology. The final device setup described promises a significant advance in the use of microwave tomography for real-time applications.

Keywords: microwave tomography, reflective methods, signal processing, real-time location systems, human detection, electromagnetic waves, radio tomography, indoor monitoring, device design, signal analysis.

ENHANCING ASSET MANAGEMENT WITH HIGH-FREQUENCY SIGNAL ANALYSIS IN DISTRIBUTED SYSTEMS

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Abstract: The article discusses the application of ultra-wideband (UWB) signal analysis in real-time localization systems (RTLS), specifically targeting distributed asset management. The focus is on the miniaturization and energy optimization of tag hardware, which are crucial for efficient and sustainable operations. The developed hardware involves two primary components: anchors and markers, where anchors have fixed positions and markers are mobile tags attached to assets. The system uses DWM microcontrollers supported by nRF52832 microcontrollers for non-localization data transmission. This setup allows for the integration of environmental sensors on each tag, enhancing the system\'s utility by providing additional environmental data. The article highlights the use of advanced algorithms for location estimation, comparing traditional trilateration methods with machine learning-assisted trilateration (MLET) and localization by optimization (LBO). These methods demonstrate improved accuracy in positioning, with MLET and LBO outperforming traditional trilateration by 25% in terms of error reduction. The analysis is complemented by a discussion on the application potential of this technology in warehouse management systems (WMS) and as an alternative to RSSI-based in-building navigation systems.

Keywords: ultra-wideband (UWB), real-time localization systems (RTLS), distributed asset management, high-frequency signal analysis, machine learning, trilateration, environmental sensing, miniaturization, energy optimization, indoor localization.

OPTIMIZING DEEP LEARNING MODELS FOR REAL-TIME APPLICATIONS THROUGH KNOWLEDGE DISTILLATION

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Abstract: The document discusses the application of knowledge distillation in deep learning, focusing on transferring complex model insights into more streamlined versions suitable for real-time applications. Knowledge distillation involves a two-stage process where a larger, complex "teacher" model transfers its knowledge to a smaller, more efficient \"student\" model. This method enables the student model to operate with reduced resource requirements while maintaining a performance level close to the teacher model. The initial stage involves training the teacher model on extensive data sets using powerful GPUs, while the inference stage sees the student model operating in real-time on CPUs without access to training data. The process employs soft labels and a Temperature SoftMax function to refine the student model\'s training, enhancing its ability to generalize from the teacher\'s output. Comparative tests reveal that while the teacher model generally performs better, the student model achieves commendable efficiency and speed, making it suitable for real-time applications. This approach is particularly beneficial in environments requiring rapid processing, such as embedded systems or mobile applications. The overall goal is to create smaller models that replicate the larger model's tasks with minimal performance loss, thus facilitating efficient real-time operations.

Keywords: knowledge distillation, deep learning, real-time systems, model optimization, soft labels, temperature softmax, embedded systems, mobile computing.

ENHANCING LUNG DISEASE DIAGNOSTICS USING ELECTRICAL IMPEDANCE TOMOGRAPHY

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Abstract: This article explores the innovative use of electrical impedance tomography (EIT) to diagnose various respiratory conditions effectively. The main focus of this research is to improve the diagnostic process for conditions like chronic obstructive pulmonary disease (COPD), acute respiratory distress syndrome (ARDS), pneumothorax (PTX), pneumonia (PNA), bronchospasm, and pulmonary hypertension (PHTN). The methodology employs a sophisticated medical diagnostic system that utilizes EIT to differentiate between diseased and healthy cases, thereby potentially reducing the number of diagnostic tests required. The research integrates numerical models representing both healthy and diseased lung conditions, enhancing the understanding of disease characteristics and progression. It involves simulations using the finite element method to gather data for analysis. The article discusses the development of two classification models: a Multi-layer Perceptron classifier and a Gradient Boosting Classifier, which were evaluated based on their accuracy in diagnosing specific lung diseases. Results indicated that these models, especially when trained on comprehensive datasets covering various disease stages, can significantly improve the speed and accuracy of respiratory disease diagnoses. This approach not only offers a rapid diagnostic tool but also opens avenues for personalized medicine, where treatments can be tailored based on precise diagnostics.

Keywords: electrical impedance tomography, lung diseases, COPD, ARDS, pneumothorax, pneumonia, pulmonary hypertension, bronchospasm, diagnostic systems, machine learning, respiratory disease diagnosis.

ADVANCED ULTRASONIC TOMOGRAPHY TECHNIQUES FOR ENHANCED INDUSTRIAL MONITORING

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Abstract: The document presents a detailed exploration of ultrasonic tomography utilized for non-invasive imaging in industrial applications. This technique leverages the scattering and absorption properties of ultrasonic waves within materials to reveal internal structural details. A significant focus is placed on enhancing the functionality and utility of ultrasonic tomographs, particularly in monitoring and optimizing various industrial processes. The article describes the development and operational nuances of a new ultrasonic tomograph model specifically designed for industrial research. Key hardware components include a measurement module capable of capturing precise single-frame measurements for detailed analysis. This module integrates seamlessly with sensor technology to ensure accurate data capture and storage. The practical application of acoustic impedance in understanding material characteristics is thoroughly discussed, explaining its relevance in determining the interaction between acoustic waves and different media. By calculating acoustic impedance, researchers can predict how waves will behave when encountering different materials, aiding in the design of more effective tomographic systems. The document also delves into the implications of these technologies in real-world industrial settings, suggesting significant improvements in process monitoring and material analysis. Overall, the study underscores the potential of ultrasonic tomography to revolutionize industrial diagnostics by providing deeper insights into material properties and process efficiencies.

Keywords: ultrasonic tomography, industrial research, non-invasive imaging, acoustic impedance, measurement modules, material characterization, process optimization, industrial monitoring, sensor technology, ultrasonic waves.

ADVANCEMENTS IN ULTRASONIC TOMOGRAPHY FOR INDUSTRIAL QUALITY CONTROL

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Abstract: This article explores the integration of ultrasonic tomography within industrial production lines, particularly focusing on defect detection in semi-finished products. Ultrasonic tomography utilizes high-frequency sound waves to inspect and identify discontinuities within materials non-invasively. This method is particularly valuable in sectors where internal integrity of products is crucial. The study discusses the design and implementation of a novel ultrasonic tomograph tailored for industrial applications, emphasizing its utility in enhancing product quality and process efficiency. Key to this system is the use of piezoelectric probes, which operate across a broad frequency spectrum to capture detailed images of internal structures. The technology is capable of distinguishing between healthy and defective parts by analyzing the reflection patterns and time-of-flight data of ultrasonic waves. The document elaborates on various ultrasonic tomography techniques such as reflection, transmission, and hybrid tomography, each offering unique benefits for specific applications. Additionally, the paper highlights the development of advanced algorithms for image reconstruction, which are critical for accurately interpreting the ultrasonic data. Practical applications demonstrated include testing on phantoms representing different material compositions, showcasing the system\'s ability to effectively detect and localize defects.

Keywords: ultrasonic tomography, industrial integration, defectoscopy, piezoelectric probes, non-invasive testing, image reconstruction, quality control, semi-finished products, process optimization, material testing.

ENHANCING PROCESS CONTROL WITH ADVANCED ELECTRICAL TOMOGRAPHY TECHNIQUES

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Abstract: This article presents a comprehensive study on the application of electrical tomography for improving technological processes. The focus is on the use of advanced electrical impedance tomography (EIT) to develop a prototype system for non-invasive monitoring and analysis of industrial processes. The system utilizes modern hardware and innovative signal processing methodologies coupled with machine learning algorithms to optimize operational efficiency. Through the implementation of LSTM and CNN neural networks, the research demonstrates significant enhancements in the quality and accuracy of tomographic image reconstructions. The document outlines the construction and functionality of a measurement module that enables accurate parameter readings essential for effective process control. By integrating FPGA microcontrollers, the system achieves high flexibility and dynamic reconfiguration capabilities, which are critical in adapting to varied research materials and process requirements. Furthermore, the research highlights the importance of efficient data communication interfaces that facilitate rapid data exchange and remote system management. The efficacy of the tomographic system is validated through practical applications, showing its potential in detecting subtle changes in materials and enhancing the quality of production processes.

Keywords: electrical tomography, technological processes, image reconstruction, machine learning, FPGA, process optimization, industrial monitoring, non-invasive monitoring, LSTM, CNN.

ADVANCING LONG-TERM UROLOGICAL MONITORING WITH INTEGRATED ULTRASOUND AND IMPEDANCE TOMOGRAPHY

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Abstract: This article details the development of a sophisticated portable ultrasound-impedance tomography device designed for long-term monitoring of the lower urinary tract. The integration of ultrasound and impedance tomography enhances the accuracy and reliability of urinary tract imaging, enabling detailed assessments of bladder functions. The device utilizes a phased array ultrasonic transducer for beamforming, which optimizes the detection capabilities. Key considerations in the electronic circuit design ensure compatibility with electromagnetic standards, essential for safe medical use. The article also highlights the testing procedures conducted at the Accredited Laboratory of Electromagnetic Compatibility at Wrocław University of Science and Technology to meet regulatory standards. Through practical examples, the paper illustrates how the device can operate effectively in both professional healthcare and home settings. Moreover, it discusses the technological innovations that allow for the real-time, non-invasive monitoring of patients, emphasizing improvements in patient comfort and device functionality. The device\'s compact, backpack-style design combines durability, hygiene, and comfort, making it suitable for continuous monitoring. Overall, the research underscores the potential of this technology to revolutionize the management and diagnosis of urinary tract conditions.

Keywords: ultrasound tomography, impedance tomography, lower urinary tract monitoring, electromagnetic compatibility, medical device innovation, non-invasive monitoring, long-term health monitoring, urology, patient comfort, healthcare technology.

INTEGRATING NEURAL NETWORKS WITH WEARABLE SENSORS FOR NON-INVASIVE URINARY TRACT MONITORING USING ELECTRICAL IMPEDANCE TOMOGRAPHY

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Abstract: This article explores the development of a system for non-invasive monitoring of urinary tract disorders using a combination of electrical impedance tomography (EIT) and potentially ultrasonic transmission tomography (UST). The focus is on integrating artificial neural networks with wearable sensors to enhance the diagnosis and monitoring capabilities for pediatric populations, who are significantly affected by urinary tract diseases. The paper details the challenges of current diagnostic methods, which often lack non-invasive options for a comprehensive functional analysis of the urinary system. By utilizing advanced imaging technologies, the research aims to reduce the misdiagnosis rate and unnecessary treatments in children. The proposed system features a modular design, incorporating both EIT and UST technologies to provide a detailed view of the urinary tract\'s functional state. Neural networks are employed to analyze the tomographic data, improving the resolution and accuracy of the reconstructed images. This integration promises to offer a significant advancement in pediatric urology, providing a reliable, non-invasive diagnostic tool that could potentially lead to better treatment outcomes. Key technical aspects include the development of neural network algorithms tailored to handle the specific challenges of EIT and UST data, focusing on overcoming issues like low resolution and the complex nature of the electrical properties of human tissues.

Keywords: electrical impedance tomography, ultrasonic transmission tomography, neural networks, non-invasive monitoring, pediatric urology, wearable sensors, urinary tract monitoring, medical imaging, diagnostic systems, machine learning.

ENHANCED MONITORING OF INDUSTRIAL REACTORS USING ADVANCED LSTM NETWORKS WITH SELF-ATTENTION LAYERS

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Abstract: The article discusses the development of an improved Long Short-Term Memory (LSTM) network enhanced with a self-attention layer, specifically designed for monitoring industrial reactors through electrical impedance tomography (EIT) and electrical capacitance tomography (ECT). This novel network architecture features dual channel inputs tailored to separately handle EIT and ECT measurement data, maintaining the distinct properties of each measurement type while allowing for comprehensive analysis. The LSTM network is detailed with an emphasis on its application in sequence-to-sequence mapping tasks, highlighting its utility in processing complex temporal data sequences from industrial monitoring systems. The network uses advanced machine learning techniques to enhance the accuracy and efficiency of tomographic imaging, improving the detection and characterization of anomalies within industrial reactors. A significant focus is placed on the integration of the self-attention mechanism, which augments the network's ability to discern relevant features in data sequences, thereby facilitating more precise reconstructions. The paper also outlines the experimental setup and the implementation details of the LSTM network, including the use of MATLAB and the Eidors toolbox for simulation and training. Additionally, it explores the challenges of synchronizing EIT and ECT data streams and discusses the implementation of LASSO regularization to standardize data input sizes. The effectiveness of the proposed network is validated through comparative analyses against standard neural network models, demonstrating superior performance in terms of accuracy, precision, and computational efficiency.

Keywords: LSTM network, self-attention layer, industrial reactors monitoring, electrical impedance tomography (EIT), electrical capacitance tomography (ECT), machine learning, neural networks, data synchronization, tomographic imaging, advanced signal processing.

ASSESSMENT OF THE POTENTIAL FOR USING MACHINE LEARNING METHODS TO FORECAST SOIL MOISTURE

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Abstract: In the face of global climate changes and increasing demand for water resources, agriculture faces the challenge of optimizing water management. Soil moisture is a key parameter influencing irrigation management and crop productivity. Accurate forecasting of soil moisture can significantly contribute to improving water use efficiency in agriculture, which motivates the search for new methods of analysis and prediction. The aim of this article is to assess the effectiveness of various machine learning algorithms in forecasting soil moisture and to identify the most efficient techniques for different environmental conditions. The hypothesis was that models based on deep learning, due to their ability to model complex nonlinearities in data, would provide the most accurate soil moisture forecasts. The study utilized data from soil moisture sensors installed in various types of soils. Models such as linear regression, random forests, and deep neural networks were analyzed. Model evaluation was based on criteria such as R-squared, mean squared error, and mean absolute error. The results confirmed the superiority of deep neural networks over other tested models, which was consistent with the hypothesis. Integrating advanced machine learning techniques with soil sensor systems can significantly increase the accuracy of soil moisture forecasts, which has direct implications for optimizing water use in agriculture

Keywords: soil moisture, neural network, linear regeression.

DEEP CONVOLUTIONAL GENERATIVE ADVERSARIAL NETWORKS IN RETINITIS PIGMENTOSA DISEASE IMAGES AUGMENTATION AND DETECTION

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Abstract: Large medical datasets are crucial for advancing contemporary medical practices that incorporate computer vision and machine learning techniques. They serve as indispensable resources for identifying patterns that assist healthcare professionals in diagnosing rare diseases and enhancing patient outcomes. Moreover, these datasets drive research into the causes and progression of such diseases, potentially leading to innovative therapeutic strategies. However, the acquisition of such data poses significant challenges due to privacy and ethical concerns, as well as the rarity of certain conditions. Therefore, it is imperative to both collect new medical data and develop tools that facilitate the expansion of existing datasets while preserving the accurate characteristics of the diseases. This study focuses on leveraging Deep Convolutional Generative Adversarial Networks (DCGAN) to expand a dataset containing images of retinitis pigmentosa, a rare eye condition affecting the retina. Our research showcases that integrating Xtreme Gradient Boosting within the DCGAN framework enhances the clarity and quality of these augmented images. By employing VGG16 architecture alongside XGradient Boosting techniques during training, we observe improvements in detection accuracy, indicating enhanced reconstructed quality of the augmented images. The outcomes of the training process are highly promising, with the model achieving all key performance metrics surpassing the 90% threshold.

Keywords: medical image augmentation, rare eye disease classification, DCGAN.

3D MODEL FINGERPRINTING SCHEME

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Abstract: With the development of new technologies, 3D models are becoming increasingly important. They are used to design new models, document cultural heritage and scan valuable artefacts or evidence. They are also used in medicine. For these reasons, they are vulnerable to forgery. Protection against forgery can be done by encrypting the model or signing it digitally. Unfortunately, this may restrict access to the data or require additional files to store the signatures. A good way to confirm the originality of 3D models is fingerprinting. This technique involves attaching a fragile watermark directly to the watermarked data. This paper proposes a new fingerprinting method for 3D models. The method hides the fingerprint in the least significant digits of the coordinates of the selected vertices. The fingerprint is created by calculating the HMAC from the model textures and all vertex coordinates except the digits intended to attach the fingerprint. These digits are processed using discrete wavelet transform (DWT). The HMAC is attached to the selected DWT coefficients. The inverse discrete wavelet transform is then performed to obtain the new values of the modified digits. The digits are put back into the 3D model coordinates and the model is reassembled. Verification of the model originality is done according to the steganographic key used and consists of comparing the HMAC value extracted from the fingerprinted model with the HMAC value calculated from it. The same values of both HMAC values indicate that the model has not been modified. The proposed method allows efficient model fingerprinting and detection of changes made to any part of the model. The included fingerprints are transparent – the PSNR of a fingerprinted model can reach 150dB and its structural similarity can be over 99.8%.

Keywords: steganography, fingerprinting, DWT, 3D, HMAC, originality.

EFFICIENT SOUND CLASSIFICATION WITH MEL SPECTROGRAM DECOMPOSITION AND INNOVATIVE DATASET

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Abstract: Folk dances and music are essential aspects of intangible cultural heritage identifying the history and traditions of nations. Due to dynamic changes in the social structure, many national aspects are not cultivated and therefore forgotten. There is a need to develop methods to preserve these valuable aspects of culture. There are five Polish national dances: the Polonez, the Oberek, the Mazur, the Krakowiak, and the Kujawiak that reflect key elements of Polish intangible cultural heritage. They can be observed both in the way of performing dances as well as in music. There are many preserved audio and video files that differ depending on the multiple features such as composers or versions. The primary objective of this study was to apply machine learning approaches in order to distinguish the above-mentioned music of Polish traditional dances. The audio recordings dataset consisting of 137 dances in mp3 format was created. Each recording was divided into ten-second files reflecting the characteristic elements of each dance. The transformation of sound to the Mel scale improves human auditory perception. Thus, from every recording the Mel-spectrograms were generated. For the purpose of this study the most applied classification tools were compared such as VGG16, ResNet50, DenseNet121, and MobileNetV2. To compare the performance of the selected models, the following measures were applied: accuracy, precision, recall, and F1 score. ResNet50 achieved the best testing accuracy (over 90%), while DenseNet121 had the best testing loss (0.38).

Keywords: mel-spectrum coefficients, Fourier transform, music classification.

IDENTIFYING AND ANIMATING MOVEMENT OF ZEIBEKIKO SEQUENCES BY SPATIAL TEMPORAL GRAPH CONVOLUTIONAL NETWORK WITH MULTI ATTENTION MODULES

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Abstract: Folk dances, integral components of intangible cultural heritage (ICH), are both fleeting and fragile. However, with the rapid advancement of computer vision techniques, there arises an opportunity to document and safeguard these cultural expressions for future generations. This study aims to identify the distinctive dance sequences and characteristics of Zeibekiko, a popular Greek folk solo dance found in variations across Greece, Cyprus, and the Aegean region of Minor Asia, and translate them into a virtual 3D environment. Utilizing a state-of-the-art optical motion capture system featuring active markers (the PhaseSpace X2E system), precise recordings of the Zeibekiko dance are achieved. The three-dimensional spatial data derived from the dancer\'s movements serves as the foundation for classification, accomplished through a Spatial Temporal Graph Convolutional Network with Multi Attention Modules (ST-GCN-MAM). This innovative architecture strategically employs attention modules to extract key features of the dance from primary areas of the upper and lower parts of human body. With an accuracy exceeding 90%, the proposed tool accurately detected and recognized Zeibekiko sequences. Ensuring the precise alignment of captured points with corresponding bones or anatomical features in the 3D dancer model is essential for seamless and authentic animations. Advanced visualization and animation techniques are then employed to translate these points into smooth, realistic character movements, preserving their inherent dynamics and expressions. As a result, a faithful virtual rendition of the dance is achieved, capturing its authenticity and beauty. Such a solution holds potential applications in gaming, video production, or virtual museum exhibits dedicated to showcasing folk dances.

Keywords: graph convolutional network, attention model, motion capture, intangible cultural heritage, 3D model, animation, Zeibekiko.

AN ENSEMBLE TRANSFER LEARNING MODEL FOR BRAIN TUMORS CLASSIFICATION USING CNN

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Abstract: In the present era, convolutional neural networks (CNNs), a specialized class of deep neural networks, have emerged as highly effective tools for a variety of computer vision tasks. Nonetheless, CNN models are not often sufficient to achieve high precision and robustness for the classification task. Ensemble learning is a machine learning technique that can improve classification performance through combining multiple models into one. With this method, individual models exchange each other's best performance for each class, resulting in improved overall accuracy. In this work, we studied the performance of CNN models for brain tumor classification. As an outcome, we propose a novel ensemble CNN model for this purpose. We utilized the BraTS dataset that comprised 3064 MRI images categorized into three types of brain tumor (glioma, meningioma and pituitary). First, we assessed well-known CNN models to classify brain tumor, next, the most efficient models were employed to proposed a novel ensemble transfer learning model for this task. The comparative analysis of model performance demonstrated that the examined ensemble CNN models outperformed all single models. Regarding evaluation metrics, the proposed model achieved global accuracy of 94% and highest precision, recall and F1 score of 94%. Experimental results revealed that model architecture and ensemble methods have a significant impact on brain tumor classification performance.

Keywords: convolutional neural network, artificial intelligence, brain tumors, ensemble methods, hard voting, soft voting.

MAKING MANAGEMENT DECISIONS BASED ON ENVIRONMENTAL PARAMETERS IN A RETAIL OUTLET USING MACHINE LEARNING METHODS

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Abstract: Management decisions regarding environmental conditions, such as temperature or light intensity in commercial establishments, can be made based on solutions in the field of machine learning methods. It is these conditions that determine whether the customer will stay at the outlet longer and whether his shopping cart will reach the desired high value. Previous studies in the literature link certain environmental factors with customers' tendency to make purchasing decisions and allow us to indicate what influences customers when shopping and to what extent. Of course, when making decisions about the conditions in a retail outlet, the applicable legal provisions regarding occupational health and safety should also be taken into account. This was used to establish the limit values of the input parameters for the model. The authors isolated 5 environmental factors and, based on them, proposed a model predicting how long the client will stay in the facility. Then, this model will be used to create a model that optimizes the parameters in the facility so as to achieve the minimum set time the customer stays in the facility.

Keywords: machine learning, management decisions, retail, customer.

ADVANCED SYSTEMS SUPPORTING IMAGE ACQUISITION AND MANIPULATION IN THE STUDY AND MONITORING OF ACTIVATED SLUDGE

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Abstract: There are many ways to control parameters of activated sludge. One of them is to do screening tests using machine learning. In this case some automation of image acquisition is strongly recommended, as the measurement of quantity parameters within the samples will be conducted in hundreds or thousands for repetitions, and finally whole process of monitoring how organisms behave should work automatically. The presentation shows aspects of hardware and software solutions that support image acquisition and processing for use with trained machine learning algorithms.

Keywords: electronic eye, water treatment, image recognition.

APPLICATION OF MACHINE LEARNING METHODS IN THE ANALYSIS OF TRIBOLOGICAL PROPERTIES OF NITROGEN ION-IMPLANTED INCONEL 718 NICKEL ALLOY

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Abstract: Inconel 718, widely used in material engineering due to its exceptional corrosion resistance and high-temperature tolerance, underwent modification through nitrogen ion implantation. This study employed machine learning methods to analyze the impact of various doses and energies of implantation on the friction and wear parameters of this material. Diverse machine learning algorithms, such as neural networks, support vector machines, and ensemble learning methods, were utilized to identify key dependencies between the modified implantation parameters and the results of tribological tests. The application of these technologies enabled the optimization of processes and the selection of appropriate implantation conditions, which contributed to the improved longevity and efficiency of components made from Inconel 718. The findings are applicable in many industrial sectors where wear and corrosion resistance are critical.

Keywords: machine learning, Inconel 718, ion implantation, tribological wear, friction.

A NOVEL MACHINE LEARNING SYSTEM FOR EARLY DEFECT DETECTION IN 3D PRINTING

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Abstract: This paper discusses a comprehensive study to develop a machine learning model for detecting unwanted vibrations during the 3D printing process. Undesired vibrations can significantly degrade print quality, leading to defects such as void formation, poor surface quality and improper layer bonding. Identifying and mitigating these vibrations is essential to ensuring the reliability and precision of 3D printed products, which is particularly crucial in sectors such as healthcare, automotive, and aerospace. The study introduced a novel system with an inertial measurement unit (IMU) mounted on the printer head, which records acceleration and angular velocity in three axes. The data is transmitted to a microcontroller and then to an acquisition device that controls a controlled vibration generator. The collected information formed a dataset for training and testing various machine learning models. Of all the models evaluated, the Dense Neural Network (DNN) showed the highest performance in accurately distinguishing normal print vibrations from unwanted vibrations. The study underscores the critical importance of early defect detection, which saves time and reduces costs, being essential for the widespread adoption of incremental manufacturing technology. Early identification of defects enables immediate intervention and correction of errors before they become serious defects affecting the quality of the final product. This is particularly important in the context of increasing automation and optimization of manufacturing processes.

Keywords: 3D printing, extraneous vibrations, machine learning.

APPLICATION OF ARTIFICIAL NEURAL NETWORKS FOR WIND SPEED PREDICTION IN POLAND USING DATA FROM NEIGHBORING MEASUREMENT STATIONS

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Abstract: In this study, artificial neural networks (ANN) were applied to predict the mean monthly wind speed at any target station in Poland using data from neighboring measurement stations. Hourly wind speed data were collected by the Institute of Meteorology and Water Management (IMGW) at selected meteorological stations in northeastern Poland. The long-term wind data, containing hourly wind speeds, directions, and related information, cover the period from 2010 to 2020. These data were divided into two sets: training and test data. Based on correlation coefficients, reference and target stations were defined. In the input layer of the neural network, the mean monthly wind speeds from the reference stations and the corresponding months were used. On the other hand, the mean monthly wind speed of the target station was utilized as the output of the network. A backpropagation learning algorithm was applied in the simulation. The hidden layers and output layer of the neural network consisted of a logistic sigmoid activation function (logsig) and a linear transfer function (purelin), respectively. Finally, the values predicted by the ANN model were compared with actual data. The maximum mean absolute percentage error (MAPE) was found to be 12.75% for the Suwałki meteorological station, while the best result was achieved for the Białystok station with an error of 5.10%.

Keywords: Artificial Neural Network, wind speed prediction, meteorology, forecasting.

DETECTING CLUSTERED FRUITS USING A HYBRID OF CONVOLUTIONAL NEURAL NETWORKS AND MACHINE LEARNING CLASSIFIERS. CASE STUDY: GRAPES

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Abstract: The last and most important procedure during fruit or vegetable cultivation is harvesting. One of the basic challenges during grape growing is the use of agriculture 4.0 machines (including robots) during harvesting which is associated with the need for quick identification of berries or grape clusters. In this work, a convolutional neural network (CNN) and a machine learning classifier were suggested for the identification (detection) of individual grapes. A free data set (Iceland) was used, which included two classes with different lighting conditions and berry sizes. The integrated method included two types of deep learning models, i.e. CNN (AlexNet and GoogleNet). CNN models were used to obtain discriminative deep features from different layers. The combination of two models AlexNet-fc6 and LDA gave the highest accuracy, sensitivity and precision (mean ± SD) % of 99.1 ± 0.2, 99.28 ± 0.31 and 98.9 ± 0.32, respectively. The developed grape detector can be used for practical applications requiring high accuracy, e.g. in the process of yield estimation or detection of grape diseases.

Keywords: CNN, Grape detection, single grape detection, SVM, yield estimation, grape disease.

EVALUATION OF THE INFLUENCE OF THE SUPPORT ON THE AERODYNAMIC CHARACTERISTICS OF THE TESTED OBJECT

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Abstract: In wind tunnel experiments, test objects are typically mounted on a force balance, which can be positioned internally or externally. For an external balance, a connecting mast is required, which impacts the measurement of forces and moments across the entire setup. It is essential to understand how the mast affects the aerodynamic forces and moments; however, this influence is not always feasible to determine experimentally. Therefore, numerical analyses are frequently employed to assess aerodynamic interference between the test object and the mast. In this study, the Alenia Aermacchi M-346 Master aircraft was selected as a representative model for analysis. A computational mesh was generated in the Ansys Meshing module by selecting the appropriate element sizes according to the characteristic dimensions of the computational domain. Due to the specific nature of the calculations carried out, three independent calculation domains were prepared to determine the influence of the mast. Ansys Fluent software was used for calculations, enabling a thorough understanding of this phenomenon and its implications for aerodynamic tunnel testing. The developed aerodynamic characteristics can be used to verify the correctness of the algorithm for correcting wind tunnel test results to improve the quality of modelling of the real object under experimental conditions.

Keywords: wind tunnel tests, numerical investigations, computational fluid dynamics, CFD.

THERMO-HYDRAULIC INVESTIGATION OF MIXING EFFICIENCY AND ENTROPY GENERATION USING NON-NEWTONIAN FLUIDS IN SHORT MICRODEVICES

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Abstract: Thermal mixing fluids in chaotic microdevices have significant importance in many potential applications and have enormous utility in thermal engineering processes. In microfluidic devices, The Two-Layer with Crossing Channels Micromixer (TLCCM) emphasized its efficiency in homogenizing Newtonian fluids, which inspired us to investigate its performance using pseudoplastic fluids. A numerical comparative investigation has been carried out to evaluate the thermo-hydraulic mixing performances of pseudoplastic fluids in laminar steady flows using four chaotic microdevices: TLCCM, L, OH and OX. Experimental and numerical validations of Newtonian and non-Newtonian fluids within complex geometries have been done. Navier-Stokes, the mass conservation, energy and species transport equations have been solved numerically employing CFD code. The non-Newtonian fluids consist of carboxymethyl cellulose solutions, which are characterized using the power-law model, the flow behavior index ranging from 0.75 to 1 and the generalized Reynolds number ranging from 0.2 to 70. To quantify the thermo-hydraulic mixing efficiency, the effects of the fluid behavior index, the generalized Reynolds number, on the thermo-hydraulic mixing degrees for the proposed micromixers are presented, where high thermo-hydraulic mixing degrees have been obtained which evolve between 0.80526 and 0.99765 for the hydrodynamic mixing and between 0.9 and 0.99 for the thermal mixing. The entropy generation due to heat transfers and fluid pressure drops has been introduced versus the generalized Reynolds numbers for different fluid behavior indexes. The Bejan number values evolve close to 1. The probability density function PDF (%) at the TLCCM micromixer exit is localized in a narrow range that refers to the ideal temperature value for mixing, which is 315 Kelvin, whatever the fluid behavior index value.

Keywords: microdevices, chaotic advection, mixing degree, thermal mixing degree, non-newtonian fluids, entropy generation, bejan number.

CFD ANALYSIS OF THERMO-HYDRAULIC NEWTONIAN FLUIDS MIXING WITHIN SHORT MICROFLUIDIC DEVICES

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Abstract: Efficient chaotic microdevices have major importance across many potential applications in industrial processes and operations, which form essential parts of microfluidic devices. In microfluidics, The Two-Layer Crossing Channels Micromixer (TLCCM-X) exhibits notable characteristics in terms of Newtonian fluids mixing, which motivated us to improve its mixing efficiency by modifying the mixing unit structure and comparing its performances with recent potential micromixers. Thus, the examined micromixers are TLCCM-X, TLCCM-KX, and C-2D. CFD code is utilized to solve Navier-Stokes, mass conservation and species transport equations numerically. Therefore, the species transport model was selected to analyze the mixing process. The considered fluids in the simulations are Newtonian fluids with Reynolds numbers ranging from 0.2 to 70. The mixing efficiency was assessed by calculating the mixing degree "MD" for hydrodynamic mixing and the thermal mixing degree "TMD" for thermal mixing. For a perfect mixing quality, the mixing degree is equal to 1. The results show that the TLCCM-KX micromixer has the best mixing performances compared to the others. This micromixer strongly accentuates the secondary flows generated precisely at the crossing nodes. The analysis encompassed mass fraction contours, temperature distributions, velocity profiles, streamlines, pressure drops, and the associated mixing energy costs. Our findings report that the TLCCM-KX micromixer presents elevated mixing degree and thermal mixing degree, where their obtained values reach respectively 0.98665 and 0.99601. Moreover, it requires less mixing energy costs versus other recent micromixers, where their values vary between 0.000256444 and 42.4285 μW.

Keywords: CFD, TLCCM, chaotic advection, mixing degree, thermal mixing degree, newtonian fluids.

CFD INVESTIGATION OF THE TAIL GAS PURIFYING IN A NITRIC ACID PLANT

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Abstract: This study discusses the importance of CFD simulations in designing selective catalytic reduction (SCR) reactors used in purifying tail gases from NOx in nitric acid plants. The efficiency of SCR reactors depends mainly on the type of basket structure used to support the catalyst bed. The linear velocity through the catalyst bed influences gas purification efficiency from nitrogen oxides. In contrast, the flow resistance through this bed affects the energy balance of the industrial plant (energy recovery in the expansion turbine). These parameters depend on the method of distribution of tail gases in the SCR reactor. The effectiveness of purifying tail gases from NOx depends significantly on the process of installing the deNOx catalyst bed in the SCR reactor, i.e., on the design of the catalytic basket. Computational flow dynamics support the design of an appropriate catalytic basket structure. Due to its low cost and excellent reliability and flexibility, CFD simulation is essential for optimizing how gas flows through an SCR reactor. CFD analysis showed a significant impact of the catalytic basket design on the linear flow velocity, which translates into the catalyst's efficiency and the gas pressure drops over a packed bed. CFD simulations were carried out for several catalytic basket designs for the SCR reactor, characterized by different gas flow directions through the catalyst bed. Experimental studies using these basket designs in a pilot SCR reactor confirmed the results obtained from CFD simulations.

Keywords: nitric acid plant, SCR reactor, CFD.

THE IMPACT OF TUBE ARRANGEMENT IN LATENT HEAT THERMAL ENERGY STORAGE (LHTES) ON THE MELTING RATE OF PHASE CHANGE MATERIAL (PCM)

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Abstract: This paper analyses the impact of tube arrangement in a latent heat thermal energy storage (LHTES) system on the melting rate of phase change material (PCM). Numerical model was created in ANSYS Fluent 2023 R2, considering natural convection, to investigate the PCM melting process in LHTES. To validate the numerical model, a simulation of the PCM melting process around a single tube was conducted, and the obtained results were compared with experimental findings from other researchers. The validation showed good agreement, confirming the model's accuracy.

Next, the melting process of PCM in a latent heat thermal energy storage system constructed of 9 tubes arranged inline was examined. The effect of the distance between the axes of the heating tubes and the distance from the axis of the tubes in the lower row to the bottom edge of the LHTES was investigated to understand the impact of these parameters on the melting dynamics of the PCM. The study showed that lowering the tubes in the LHTES improves natural convection in the PCM, thereby accelerating the melting process, especially in the final stage. For the exchanger with lowered tubes, charging times were reduced by up to 53.7%, and the heat flux was more than twice as high compared to the classic inline tube arrangement. Increasing the distance between the tubes in the inline arrangement decreases the average heat flux, whereas for the lowered tube arrangements, increasing the distance between the tubes does not affect the average heat flux.

The conclusions drawn from this research can be used to optimize LHTES designs, contributing to the enhanced performance of thermal energy storage systems. These findings are particularly relevant for applications in renewable energy systems, where efficient thermal management is crucial for overall system performance.

Keywords: Melting process, Phase change material, PCM, Thermal energy storage, TES, LHTES, Time to completely melt.

OPTIMIZATION OF THE SHAPE OF A HIGH-PERFORMANCE VEHICLE USING CFD

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Abstract: Minimizing the environmental impact of road transportation is one of the main directions of scientific research and implementation work. Research is carried out in several directions: lowering the energy demand of a vehicle, using low- or zero-emission propulsion systems, and optimizing vehicle control. In order to carry out this type of work, it is necessary to develop a platform that allows the study of the impact of individual elements under repeatable conditions. This platform must have great flexibility in its ability to install a variety of propulsion systems and the possibility of introducing autonomous driving systems to test driving style on energy consumption. The unmodifiable element, however, must be the body of the vehicle, providing the basis for testing solutions but with the lowest possible energy requirements for movement from the start. This applies to both rolling resistance and drag resistance.

The article presents the results of simulation work on airflow around the body of the designed vehicle. The design work was conducted for a high-performance vehicle designed for the Shell Eco Marathon competition. This vehicle must have the lowest drag allowing the most efficient use of energy for driving. To achieve that, analyses were carried out using three-dimensional computational fluid mechanics. The article presents the vehicle model, mesh preparation, boundary and initial conditions, and simulation results of the initial shape and the shape after optimization. On the basis of the first analyses, areas of increased flow resistance were identified which were subjected to design changes. The range of changes is described, and flow analyses were carried out showing a reduction in the frontal drag coefficient of airflow from 0.19 to 0.18.

Keywords: vehicle, drag, optimization, CFD.

THERMIONIC ENERGY CONVERTER - MODEL STUDIES OF TEMPERATURE DISTRIBUTION OF CONVERTER COMPONENTS

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Abstract: Thermionic energy converters that directly transform heat into electricity are the subject of intensive research, due to their potentially high energy efficiency, high output power density, relatively small size, scalability, potential for cooperation with high-temperature heat sources, and hence potential application in electricity generators. Direct conversion of thermal energy into electrical energy, based on the phenomenon of electron thermionic emission, is being researched at the Lublin University of Technology. The key components of the experimental thermionic energy converter are two electrodes, dispenser cathode type model M 311, integrated with tungsten microheaters and placed in an ultra-high vacuum chamber at total pressure p<10-6 Pa. The electrodes used have a relatively high electron emission current density, up to 5 A/cm2 at 1200°C, but the value of the current density decreases drastically with increasing vapor pressure of some metals, including steel/iron, nickel, tantalum, among others. Hence, it is important to know the temperature distribution in the vacuum chamber, in the context of selecting the right materials for the construction of converter components, including electrode mounts, thermocouples.

This paper presents how the model was prepared for numerical testing and the results of thermal analyses using Ansys Fluent software. The simulation used an energy flow module, a laminar fluid model, a radial temperature propagation and heat transfer model. The temperature distribution was visualised according to NIST with a reflection of the ambient standard conditions in which the thermionic energy converter is placed. In the computational domain that represents the chamber inside, an Ultra High Vacuum was set. Tests were carried out for the emitter in the temperature range 900-1200°C.

Keywords: thermionic energy converter, thermal analyses, CFD, TEC.

APPLICATION OF CAD DESIGN IN MODELLING COMBAT DRONES FOR AERODYNAMIC CHARACTERISTICS IDENTIFICATION

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Abstract: This paper presents an overview of selected unmanned aerial vehicle (UAV) designs to show the development of unmanned aircraft. In this context, the paper describes the application of CAD design in creating a 3D model in order to perform basic aerodynamic CFD simulations. The IAI Heron was selected for geometry modelling. Based on digital analyses of publicly available design materials and photographs, simplified models of the selected structure were created using the SolidWorks software. Basic aerodynamic characteristics of the developed geometric model of the AIA Heron were obtained by calculations made with ANSYS Fluent. The prepared model will serve as a basis for future 3D prints. The developed CFD numerical model will be used for further comparative analysis and validation in wind tunnel tests.

Keywords: combat drone, IAI Heron, CFD, CAD, aerodynamic characteristics.

ENHANCING PIEZOELECTRIC ENERGY HARVESTERS WITH HYBRID VIBRATIONAL EXCITATION

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Abstract: This paper investigates the influence of hybrid excitation techniques on the performance of vibrational piezoelectric energy harvesting systems. In the experimental phase, two types of excitations were studied: pure vibrational excitation from a shaker and a hybrid method combining shaker-induced vibrations with airflow. Tests were conducted under varying excitation frequencies and airflow velocities, applied to five different masses that determined the system's natural frequencies. Results demonstrated that the hybrid excitation significantly enhanced energy harvesting performance, improving output by at least 27% compared to the shaker-only excitation. The study also identified optimal operating conditions, enabling the system to operate effectively in ambient environments where excitation sources may vary. Under these optimized conditions, the system achieved its highest voltage output, demonstrating its potential to power low-power devices such as wireless sensors using harvested energy. To further understand the system's behavior, Computational Fluid Dynamics (CFD) simulations were conducted, offering insights into the airflow streamlines and forces acting on the bluff body. These analyses supported the experimental findings, confirming the aerodynamic advantages of hybrid excitation. This research underscores the practical benefits of integrating multiple excitation sources to enhance the efficiency and adaptability of piezoelectric energy harvesters, making them more suitable for real-world applications, particularly in environments with fluctuating or multi-modal energy inputs.

Keywords: piezoelectric energy harvesting, hybrid excitation, airflow-assisted energy harvesting, CFD analysis.

COMPUTER SIMULATIONS OF PROCESSES AND PHENOMENA

NEW APPROACHES TO GENERALIZED LOGISTIC EQUATION WITH BIFURCATION GRAPH GENERATION TOOL

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Abstract: This paper propose two new generalizations of the logistic function, each drawing on non-extensive thermodynamics, the q-logistic equation and the logistic equation of arbitrary order respectively. It demonstrate the impact of chaos theory by integrating it with logistics equations and reveal how minor parameter variations will change system behavior from deterministic to non-deterministic behavior. As well, this work presents BifDraw – a Python program for making bifurcation diagrams using classical logistic function and its generalizations illustrating the diversity of the system's response to the changes in the conditions. The research gives a pivotal role to the logistic equation\'s place in chaos theory by looking at its complicated dynamics and offering new generalizations that may be new in terms of thermodynamic basic states and entropy. Also, the paper investigates dynamics nature of the equations and bifurcation diagrams in it which present complexity and the surprising dynamic systems features. The development of the BifDraw tool exemplifies the practical application of theoretical concepts, facilitating further exploration and understanding of logistic equations within chaos theory. This study not only deepens our comprehension of logistic equations and chaos theory but also introduces practical tools for visualizing and analyzing their behaviors.

Keywords: logistic equation, bifurcation, chaos theory, generalization, non-extensive thermodynamics.

ANALYSIS OF THE POSSIBILITY OF USING PV SOURCES FOR AUTONOMOUS CULTIVATION OF NEGATIVELY PHOTOBLASTIC SEEDS

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Abstract: Mung-bean sprouts belong to the group of negatively photoblastic plants whose cultivation on an industrial scale requires both the provision of specific microclimatic conditions and the supply of significant quantities of properly prepared fresh water. The process of growing Mung-bean sprouts cannot be subjected to electricity interruptions, which imposes the need to provide an alternative fully autonomous power supply. Building such a system based on renewable energy sources is a major challenge, especially in areas without geothermal sources, with low insolation and poor windiness.

This paper presents the possibility of using a stand-alone PV-system to secure the industrial cultivation of Mung-bean sprouts cooperating with an installation providing optimal plant growth conditions located in a temperate climate zone. A technological model of the plant (Fig.1) was built using FlownexSE simulation software, in which a transient model of the plant was formulated for full-scale production with a capacity of 100 tonnes of sprouts per week. The developed simulation model was used to determine the energy demand of the installation, taking into account the variable size of the crop and different production scenarios. The manageable solar resource was determined for the installation location based on insolation data of a typical meteorological year and correlated with electricity production data from a PV installation located close to the crop site. The analysis of the energy security potential of the crop was carried out for four selected periods of the year, represented by minimum (winter), maximum (summer) and average (spring/autumn) weekly insolation values. On the basis of the analyses of the energy demand of the installation and the availability of solar energy in the periods considered, the capacity of the autonomous PV system cooperating with the electricity storage was determined, enabling the full energy demand of the installation to be covered under the most unfavourable production conditions.

Keywords: Photovoltaic, Mung-bean sprouts, autonomous power supply, off-grid.

MICROCHANNEL BEAM HEAT EXCHANGER POWERED BY ENVIRONMENTALLY FRIENDLY REFRIGERANT (R290)

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Abstract: The paper presents an analysis of the cooling performance of a microchannel beam heat exchanger powered by the combustible refrigerant R290 (propane) as a function of design parameters. The exchanger is dedicated to refrigeration devices where waste heat from mechanical ventilation installations serves as the lower heat source. Performance analyses of the exchanger operating as a condenser in the refrigeration system were conducted based on its design parameters. Several design variations of the exchanger were examined, including different microchannel shapes. Simulation studies were also performed under various operating conditions. The mass flow rate of the refrigerant in the exchanger and the volumetric flow rate of ventilation air were varied. The aim of the conducted research was to reduce the dimensions of the heat exchanger, enabling a reduction in the mass of the combustible refrigerant in the exchanger. Simulation studies were conducted using SolidWorks software with the Flow Simulation library. Over 500 simulations were performed. Based on the obtained results, it was found that using hexagon-shaped or triangle-shaped microchannels with corrugated walls could double the cooling capacity of the condenser compared to the commonly used square or circular channels.

Keywords: evaporator, microchannel beam heat exchanger, R290, microchannel.

LONG-RANGE DEPENDENCIES AND STATISTICAL SELFSIMILARITY IN COMPUTER SYSTEMS PROCESSING

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Abstract: The existence of long-range dependencies in many natural systems was a very important discovery that introduced many interesting challenges and explanations about the behaviour of the systems. In the case of man-made systems such dependencies also can be visible, and one example is computer systems. Based on the time series collected during computer system processing by internal system tools, it will be seen that in the case of cache memory modelling, statistical models with long-term dependencies should be used. In successive parts of the paper it will be shown how to collect data, analyse, and build appropriate models taking into account some limitations related to data stationarity, interpretation of obtained result, efficiency of used methods and possible influence of long-range dependencies on computer systems performance. Obtained results are based on the set of 50 different processing machines with long-term workload (even milion of analysed records) generated by humans.

Keywords: Hurst exponent, long-range dependencies, systems performance, data analysis.

DESIGN AND STRENGTH ANALYSIS OF AN DEVICE FOR METAL FORMING OF HOLLOW PRODUCTS WITH FLANGES

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Abstract: Forming hollow flange products requires the use of appropriate tools to realize the designed manufacturing technology. Depending on the geometry of the forging, the workpiece material and how the process is performed, tools designs can be strongly variable. This paper presents the design and strength analysis (based on FEM) of a device for forming a flanged sleeve forging. The technology involves forming a tubular workpiece made of 42CrMo4 steel under cold forming conditions and consists of several stages. The implementation of each of them requires the use of a different set of tools. For this reason, a unique device has been designed that allows their replacement. It consists of a bottom plate and a top plate to which replaceable components are mounted. Positioning of the plates in relation to each other is ensured by the use of guide columns. They also ensure the concentricity of the tools that are attached to them. This is important in terms of ensuring the dimensional accuracy of the forging. Due to the high unit pressures exerted by the deformable material, the selected tools were made of carbide. In addition, pre-stressing of the tools was applied to ensure their strength. For this purpose, interference fit connections were used. Due to the relatively high values of pressing in, the contact surfaces were made as conical instead of cylindrical. In addition, two rings were used to strengthen the elements in direct contact with the workpiece. Due to the appropriately selected tooling materials and the values of pressing in, the expected and safe values of stress in the individual components were obtained, which ensures safe realization of the process.

Keywords: metal forming, hollow parts, tools, FEM.

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APPLICATION OF A DECISION CLASSIFIER TO EVALUATE ENERGY CONSUMPTION OF AN ELECTRIC VEHICLE UNDER NORMAL OPERATING CONDITIONS

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Abstract: The authors of the study undertook work on the development of a decision tree-based classifier for the evaluation of energy consumption by a vehicle traveling in real traffic conditions during normal daily operation over a period of one full year. Parameters affecting the speed profile in the form of power pedal position, averaged ambient temperature and averaged vehicle speed were used as classification parameters.

Since the energy consumption of an electric vehicle while moving in traffic depends on many factors. These factors include: the driver's driving style, as well as the prevailing weather conditions and terrain. An element of the driver's direct influence on the shape of the speed profile is the set position of the power pedal. The value of the power pedal position depends on the instantaneous load on the vehicle resulting from the terrain and the driver's adopted speed value. As a result, a power consumption rate can be obtained for the vehicle's moving conditions, for which the ambient temperature also has an influence.

Keywords: electric car,tree classifier,optimization,efficiency,multi-valued logic trees,energy consumption.

RESEARCH ON SELECTED LOCATION ALGORITHMS FOR THE UGV OPERATING IN A FOLLOW-ME SCENARIO BASED ON ULTRA-WIDEBAND POSITIONING SYSTEM

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Abstract: Ultra Wideband (UWB) technology is a highly developed wireless radio communication technology used, among others, in location systems. The article focuses on using UWB technology to construct a guide location system for an Unmanned Ground Platform (UGV). In order to carry out the research, the parameters of the measurement noise occurring in real UWB modules were determined. The mentioned noise simulated disturbed distance measurement indications, modelling real measurements. The paper presents the results of simulation research of selected location algorithms for a guide location system based on UWB technology. The work compares the total location errors of the guide of selected algorithms based on geometric methods, trilateration and optimization methods. Simulation studies allow for quick testing of algorithms, taking into account real disturbances and constitute the first stage of work on implementing various algorithms in a real positioning system.

Keywords: ultra wideband, UGV, positioning system.

SIMULATIONS OF THE GROUND PRESSURE EXERTED BY DEMINING ROLLERS WITH RIGID WHEELS

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Abstract: The effectiveness of conventional demining rollers, especially in real working conditions constitute an open scientific problem. As a background, theoretical analysis of dynamics factors which could have influence on the route clearance operations effectiveness, on both flat and uneven terrains were conduct. The paper provides a description of developed simulation model (simplified assumptions, it's kinematic and dynamic structures and interaction between separate bodies) of tracked vehicle equipped with a single demining section of roller systems with rigid wheels. This model was used for simulation assessment of possibility of mine pressure fuse activation during route clearance operations with different speeds and on different terrain profile and roughness.

Keywords: demining roller, route clearance, anti tank mine.

SIMULATION STUDIES ON THE INFLUENCE OF CLEARANCES ON THE STEERING STABILITY OF ARTICULATED TRACKED UGVs

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Abstract: The article presents the results of simulation studies on the influence of clearances in the steering and track systems on the directional stability of articulated tracked UGVs (Unmanned Ground Vehicles). The research was conducted using the MSC Adams multi-body system simulation environment. To this end, a model of an articulated UGV was developed, considering both the kinematics of the steering mechanism and the track system along with clearances and friction coefficients in the kinematic joints, as well as the track-ground interaction model. The study involved simulating maneuvers to avoid a selected set of obstacles. For this purpose, reference vehicle motion trajectories and corresponding steering control signals were developed. During the simulation studies, the clearance values of individual pairs of kinematic joints in the steering mechanism were varied, and parameters describing the motion of the UGV were recorded. The obtained results were compared with reference values. The researched aspect is important, especially in terms of UGV control precision and motion stability. The results of the conducted research can provide guidance useful in the design of articulated tracked UGVs.

Keywords: UGV, articilated vehicle, motion stability.

THE KINEMATICS OF THE MANIPULATOR WITH 1-DOF JOINTS AND CONTROLLED BY ELASTIC, INNER TIES

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Abstract: This document presents a mathematical model of forward and inverse kinematics for a manipulator composed of joints with one degree of freedom al-lowing only the rotation of a Cartesian coordinate system around one axis. The manipulator is controlled by means of internal ties running from the point of con-nection with the controlled arm to the place of connection with the mechanism regulating the length of the individual tie. This length is the basis in derived equa-tions, and its change is the direct cause of the movement of the described robot. In contrast to the commonly used arm drives, the articulated variable in derived kinematic equations is the length of the tie, which affects the change in the angle between the arms, while it is not the same value of this angle. In addition, these joints are arranged parallel to each other, which results in the working space of the manipulator in one plane. The kinematic chain, which is the object of the described research, consisted of three series connected joints enabling rotation around one axis of the coordinate system. However, dependencies and formulas enabling their application to the description of forward kinematics and inverse kinematic chains built from a larger number of similarly arranged joints have been demonstrated.

Keywords: 1-DOF joint, forward kinematics, inverse kinematics, ties, inner ties, manipulator.

SIMULATION OF TORQUE VARIATIONS IN A DIESEL ENGINE FOR LIGHT HELICOPTERS USING PI CONTROL ALGORITHMS

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Abstract: The article presents the results of simulation research of the diesel engine working parameters for light helicopter. The tests were performed using 1D software - AVL Boost RT. Engine model include the following elements: cylinders, turbine, compressor, inlet and outlet valves, defined ambient environment, fuel injection control strategy etc. Simulation tests were made for checking the engine response to the step changes in main rotor load. These changes were carried out for both, to increase and reduce the demand for power. During the study values such as deviation of power, torque and engine rotational speed and stabilization time of the main rotor rotational speed were analyzed. All tests were performed for one selected PID settings. Studies have shown that the all above parameters dependence in to the size of the step change in demand for main rotor load. The article compares the maximum size of the engine speed deviation, in the up and down directions from the nominal value, both with increasing and decreasing the main rotor load demand. On the basis of the results it can be concluded that the diesel engine in a light helicopter, greatly reduces the size of the main rotor speed deviation.

Keywords: Diesel, PID, algorithm, speed control.

SIMULATION RESEARCH OF THE TRUCK ENERGY EFFICIENCY

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Abstract: This paper analyses the problem of energy efficiency in heavy-duty vehicles. As part of the work, simulation studies of the energy efficiency of vehicle were carried out. The tests were carried out using the Vecto software. The research analysed the effects of air and rolling resistance on energy consumption expressed in kWh/km. The test object was a two-axle truck powered by a compression-ignition engine with a displacement of 6800 cm 3 . The highest load weight for this vehicle was 5430 kg. The vehicle's fuel consumption was shown to be mostly influenced by the rolling resistance force, with the differences obtained from the simulations reaching 8.5% compared to a standard vehicle.

Keywords: vehicle, truck, efficiency.

IMPLEMENTING AI COLLABORATIVE ROBOTS IN MANUFACTURING: MODELING ENTERPRISE CHALLENGES IN INDUSTRY 5.0 WITH FUZZY LOGIC

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Abstract: The purpose of this article is to propose a fuzzy logic system as a tool for automated risk identification of potential technical challenges and social barriers during the implementation of artificial intelligence-based co-bots on workstations in manufacturing enterprises. On the basis of an extensive literature review, as well as industry reports and expert consultations, the basic challenges and enterprise barriers occurring during the implementation of changes in enterprises, especially during the implementation of the latest technologies, were selected. A fuzzy logic model was then developed that, based on the values of the input factors, generates an answer as to whether there is a risk of technical or social challenges in an enterprise when implementing the latest technologies. The results generated by the developed model, when confronted with expert knowledge, experience and subjective assessments, showed that the model works as expected. The results of the study suggest that the use of fuzzy logic can effectively support companies in detecting challenges and obstacles, thereby facilitating decision-making in reducing the risk of their occurrence. Adaptation to the conditions currently prevailing in the company allows for dynamic adjustment of co-bot deployment strategies, which in turn can lead to more effective management of technological changes and minimization of potential operational disruptions.

Keywords: Industry 5.0, AI collaborative robots, Fuzzy logic, Manufacturing challenges, Co-bot implementation.

IMPACT OF REGRESSORS SELECTION ON SYSTEM IDENTIFICATION BY MEANS OF NARX-RF MODEL

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Abstract: This paper compares the quality of NARX-structured models with different regressor vectors. The object of modelling was a thermal plant used in temperature control systems with a Peltier module as an actuator. The object had non-linear static characteristics. The identification used a Pseudo Random Binary Signal as the excitation signal for the object. A random forest model with the LSBoost algorithm represented this non-linearity. Calibration of some hyperparameters, i.e. number of trees, tree depth, and leaf size, was done using a genetic algorithm. Four categories of regressor vector selection strategies were proposed. The strategies used linear and polynomial regressors. Based on the adopted strategies, 24 models were built and their quality was assessed using the Normalized Root Mean Square Error index. The best model was characterised by an 8% reduction in the number of regressors, with a 5% decrease in model quality.

Keywords: NARX, random forest, system identification, regressor selection, genetic algorithm.

EXPERIMENTAL AND NUMERICAL INVESTIGATION ON THE EFFECT OF PASSIVE JET CONTROL SYSTEM ON THE PERFORMANCE OF A VORTEX INDUCED VIBRATION ENERGY HARVESTER SYSTEM

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Abstract: The present study investigates the effect of various geometrical shapes of a bluff body and its passive jet control system on the performance of a vibration energy harvester system. The shape of a bluff body is responsible for the vortex shredding and the effect of passive jet control system would impact the dynamic behavior of vortices and resulting in enhancing or suppressing the performance of a bluff body oscillation. In this regard, initially a two-dimensional numerical investigation has been carried out to understand and optimize the dynamic response from the bluff body and its effect on the beam. The validation of numerical code has been carried out for a cylindrical shaped bluff body using ANSYS Fluent numerical modelling software and the numerically predicted results have been compared with literature and the same has been experimentally developed and tested in a wind tunnel. Upon validation, numerical simulations have been carried out on optimizing the geometrical shapes and passive jet control system of a bluff body. The lift, drag and displacement characteristics was observed and plotted for various flow conditions ranging between 2 m/s and 8 m/s with intervals of 0.5 m/s. The contours of vorticity, pressure and displacement have been presented and discussed. The optimized model has been developed and tested in a wind tunnel for various flow conditions and the results were presented and discussed.

Keywords: vortex induced vibration, energy harvesting, passive jet control system, computational fluid dynamics.

CONTROL OF AN AC POWERED DEVICE FOR ELECTROCONSOLIDATION OF CERAMICS

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Abstract: There is an increasing demand for nanostructured composites in a wide variety of technical and bioengineering applications. This article presents the concept of control of an electroconsolidation device. The feature that distinguishes the designed device from existing ones is the direct use of high-intensity alternating current. A program control system with a phase regulator was designed for control. It was assumed (based on preliminary research) that the design would be simpler and more economical than commonly used devices. Powder metallurgy enables control of structural features during the manufacturing process. Technological parameters have a significant influence on the properties of the obtained materials. The electroconsolidation technique in the designed device is characterized by the use of alternating current supplied directly to the graphite mold. The built prototype uses a transformer that reduces the voltage to approximately 10 V with a current of up to 9 kA. The current flow through the mould and the powder sample is controlled by a current regulation system in the primary winding of the transformer. The sample temperature is controlled by program regulation using a phase controller. The control system measures the mechanical pressure P, relative density $\Delta L/L0$ and temperature T. The height of the sample decreases under the influence of pressure and the processes occurring during the sintering. The presented electroconsolidation method seems advantageous due to its simple design and operation. Future studies will focus on specific compositions, as well as on the theoretical explanation and modeling of the physical phenomena accompanying this process.

Keywords: powder metallurgy; elecrtoconsolidation; sintering; ceramics.

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VERIFICATION OF TENSILE TESTING AND FEM MODELING OF SILICONE SKR-788 SAMPLES

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Abstract: The development of various machines and equipment containing parts or assemblies made of hyperelastic materials (e.g., rubber, silicone) is difficult because of the intricacies involved in the description of their mechanical properties. This is especially seen in calculations using simulation modeling. The behavior of hyperelastic materials is described by utilizing the results of research conducted with specialized equipment. This allows for the most accurate determination of their mechanical properties. Hyperelastic materials are widely used across diverse industries, encompassing mechanical engineering, the chemical and petrochemical sectors, cement production, and beyond. To determine the mechanical characteristics of SKR-788 silicone, batches of test samples were prepared, varying solely in the ratio of the base to the catalyst. Laboratory testing of silicone samples was performed on an Instron 4500 device, and data such as loads, displacements, and deformations were obtained. In order to verify the results of the tests against the results of simulation modeling in Ansys software, a model of the experimental sample was built. The obtained results of uniaxial tensile testing of the experimental sample were taken into account during the description of the material in the Mooney–Rivlin model. The calculation scheme for the test sample during simulation modeling is similar to the one used during its laboratory testing. Applying the load to the test sample during the simulation proceeded incrementally based on time. As a result of the work, the constants of the SKR-788 silicone material for the three-parameter Mooney–Rivlin model were defined. As a result of simulation modeling of the silicone sample, the values of its displacements and stresses were obtained. Upon comparing the stress values derived from

the results of laboratory testing on the Instron 4500 equipment with those obtained from simulation modeling, a discrepancy of up to 7% was identified

Keywords: yperelastic material, prototype test, silicone, simulation modeling, stress, strain, Mooney–Rivlin model.

THE NATURAL OSCILLATIONS OF PERFORATED SIFTING SURFACES WITH EPICYCLOIDAL HOLES

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Abstract: The use of vibrational perforated sifting surfaces with holes of complex geometry provides intensive separation of loose materials by particle size and increases the technological efficiency of separating equipment. The lack of research methodologies and data on the oscillations of such perforated surfaces limits their application in practice, requires reliability studies and the derivation of appropriate patterns. The reliability analysis was conducted by studying the natural oscillation frequencies of perforated surfaces and checking for the absence of resonance phenomena. For the research, the methodology is based on numerical finite element methods in Abaqus_CAD and allows analyzing the natural oscillations of the structure when its structural parameters and boundary conditions are varied. To study the level of influence of the design of epicycloidal holes on the natural oscillations of perforated sifting surface, the identification of their values for round, epicycloidal (with a modulus of 5, 7 and 9) hole shapes was carried out. Patterns of variation in the natural oscillation frequencies of perforated surfaces are obtained depending on significant factors: surface thickness, hole spacing and epicycloid modulus. In addition, the analysis involved studying eight common modes of oscillation encountered in practice. The results were a research methodology, mathematical expressions for simplified calculation and analysis, patterns of oscillation changes of perforated sifting surfaces with holes of complex geometry. Studies enable the prediction of resonance phenomena and damage between the holes of perforated sifting surfaces, the absence of which determines their reliability.

Keywords: epicycloidal holes, perforated surface, oscillation frequency, design parameters, finite element method, resonance phenomena.

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NUMERICAL ANALYSIS OF THE CRASHWORTHINESS PERFORMANCE OF MULTICELL TUBES UNDER OBLIQUE LOADS

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Abstract: When a car crash occurs, the probability that the collision will be oblique and not entirely frontal is high. In this way, the current article evaluates by a finite element analysis, the crashworthiness performance of multicell structures subjected to oblique loads. In this sense, five multicell structures manufactured with 6063-T5 aluminum alloy were designed and evaluated by an oblique compression test. During the analysis, special emphasis was placed on determining the effect of the cross-section and the angle of incidence of the load (θ) on the energy absorption of the structures. For this purpose, values of θ equal to 0°,5°,10° and 15° were analyzed. To guarantee a correct comparison between tubes, all the structures had the same mass equal to 0.80 kg. Thus, adjustments to the thickness were realized. In all cases, the most important indicators of impact resistance such as energy absorption (Ea), crushing force efficiency (CFE), and mean force (Pm) were calculated. According to the results, the angle of incidence of the load defined the plastic deformation mode of the structure. Thus, a decrease in the Pmax and Pm was observed as the θ increased. Lastly, at the end of the study, the MC-02 profile presented in average the best CFE value at different loading angles equal to 0.74.

Keywords: finite element analysis, thin-walled structures, oblique loads.

ANALYSIS OF UAV WATER LANDING

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Abstract: Unmanned aerial platforms, along with surface platforms, can be elements of rapid response force systems at sea. The USV-UAV-WIG (Unmanned Surface Vehicle, Unmanned Arial Vehicle - Wing in Ground Effect) platform is a type of vehicle that combines the features of an aircraft and a surface vehicle. In its operational range, it moves using the so-called ground effect. This phenomenon, in short, consists in increasing the lift of an aircraft moving at a small height above the ground or water (the height is assumed to be half the wing span).

To consider this problem, we first prepared a computational task for the impact of a ball-shaped body on water. The calculations were carried out using the finite element method using the capabilities of the LS-DYNA environment. Computer simulations of the impact of the ball on water were experimentally verified using the so-called high-speed camera and the image analysis system. Second, analytical calculations and numerical simulations of the launch of an example USV-UAV-WIG structure were carried out. For the purposes of the analyses, a numerical model of the structure and a model of the water-solid interaction were prepared. Based on the results of the calculations obtained, the launching of the loads occurring during the vehicle were defined.

Keywords: FEM, UAV-WIG, solid-water interaction.

INVESTIGATION OF THERMO-MECHANICAL EFFECT ON THE BUCKLING BEHAVIOR OF THIN-WALLED COMPOSITE COLUMNS WITH ASYMMETRIC LAYER CONFIGURATIONS

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Abstract: The research aimed to investigate the stability of thin-walled composite columns with a Z-shaped cross-section, subjected to axial compression under varying temperature conditions. The test specimens were fabricated using a carbon-epoxy composite with asymmetric ply arrangements. These specific configurations were chosen due to their resistance to thermal distortions, a result of the high-temperature curing process (HTCS laminates). The experimental setup included a universal testing machine for applying axial loads, a thermal chamber to control temperature conditions, and the ARAMIS optical system for 3D deformation measurements. The key outcome of the study was the identification of the effects of both temperature variations and the arrangement of unsymmetric composite layers with mechanical couplings on the structural stability of the columns. A significant contribution of the research was the integration of advanced experimental techniques to assess the critical buckling state of thin-walled composite structures with Z-shaped cross-sections. The study highlighted the influence of thermo-mechanical properties on both the stability and load-bearing capacity of these structures, offering insights for their application in high-temperature environments. The novelty lies in the interdisciplinary approach, combining material science and structural engineering to address stability challenges in composite structures.

Keywords: stability, mechanical coupling, buckling, thermal effect.

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MATERIAL PROPERTIES AND STRUCTURE RESEARCH METHODS

EFFECT OF THE AMOUNT AND LOCATION OF PHASE CHANGE MATERIALS IN A FIBRE REINFORCED COMPOSITE MATRIX ON ABLATIVE PROPERTIES

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Abstract: The research focused on a fiber composite consisting of 14 layers of aramid fabric and 6 layers of carbon fabric. Epidian 52 epoxy resin hardened at room temperature with TFF hardener was used as a matrix. The resin was modified with phase change material (PCM) in the form of Micronal DS5038X powder. Four series of 3 pieces each were prepared, differing in the amount of PCM in the composite matrix. The samples were exposed to a mixture of hot gases at a temperature of approximately 1000°C for 3 minutes. During the tests, the temperature of the material\'s ablation surface, the temperature of the back surface, as well as the temperature in 3 places. After the tests, the ablation mass loss and mass ablation rate were also analyzed.

Analysing the experimental results, it was found that the use of phase change materials in the composite matrix would significantly affect the ablative properties of the material. The average value of the back wall surface temperature of the fibre composite without the addition of PCM after 180 seconds was about 168°C. The average back wall surface temperature of all composites with the addition of phase change material PCM was in the range of 96 ± 10°C after 180 seconds. The ablative weight loss of the fibre composites without PCM addition was 31.7%. The highest relative ablative weight loss was achieved by polymer composites with 16% PCM addition up to half the thickness of 35.8 %, while the lowest with a value of 32.9% was achieved by composites with 16% PCM phase change material added throughout the thickness. The addition of PCM to the composite resulted in an increase in ablative weight loss of approximately 1- 4 % (relative to the original weight of the material tested).

Keywords: composite, phase change material, ablative properties, ablative weight loss.

IMPACT DAMAGE TOLERANCE OF MULTILAYER EPOXY-GLASS COMPOSITES WITH XPS CORE AND POLYURETHANE PREPOLYMER MODIFIED MATRIX

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Abstract: A significant need within the design of materials for vehicles or other engineering structures is to determine their potential to mitigate impact loads. The material acting as a shield during an impact absorbs energy, dissipating the excess in a process of irreversible deformation. In order to prevent this, or to limit the areas of damage as much as possible, have begun to be used materials that absorb impact energy without drastically compromising their strength. Energy Absorbing Composite Structures (EACS) have the ability to convert impact energy into some form of energy absorbed through deformation. Compared to homogeneous materials, a numer of factors also point to the increasing advantage of using composite sandwich structures, which, in addition to their high strength ratings, have a lower weight and a much more effective ability to absorb shock or impact load energy. This paper presents the results of damage tolerance testing of epoxy-glass sandwich composites with chemical modified matrix. The damage tolerance of the composites was determined using an Instron CEAST 9340 testing machine with an impact energy ranging from 5-35J and indicated the value at which visible damage to the composite occurs while it retains some of its strength properties. It was the most important test to determine the damage tolerance, but additional tests to characterise the strength of the composite more comprehensively were also performed. Experimental studies were used to present a methodology for the preliminary characterisation of the material strength and to analyse the relation between structure and mechanical response of the composite.

Keywords: composites, mechanical engineering, modification of composites, mechanical properties.

THE EFFECT OF KEY PROCESS PARAMETERS ON MICROSTRUCTURE AND PHOTOCATALYTIC PROPERTIES OF TiO_2 COATINGS MANUFACTURED BY APS

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Abstract: The paper describes the influence of the key parameters of the TiO2 coatings on its microstructure and photocatalytic properties. The deposition process was carried out by atmospheric plasma spraying (APS). The three-factorial design of the experiment, with the hydrogen flow rate, stand-off distance and powder feed rate as variables, was used. The obtained coatings were investigated in terms of the topography, microstructure and porosity, as well as its photocatalytic properties. A process response using a multiple regression method was used to investigate the influence of factors variation on coatings microstructure and functional properties. Moreover, the factorial regression models were prepared to investigate the standardized effects of the process parameters on the above mentioned features. For regression modeling, three levels of these factors were considered representing the effective range of each parameter. The research presented in this paper proves that there are statistical correlations between the examined factors that have a significant impact on the achieved photocatalytic performances. By the analysis of the process control parameters, it is possible to achieve an optimal level of photocatalytic properties of the TiO2 coatings.

Keywords: APS, titania coatigs, microstructure, photocatalysis, factorial regression models.

THE METHODOLOGY AND RESULTS OF DETERMINING THE GEOMETRIC DIMENSIONS OF LOOSE MATERIAL PARTICLES

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Abstract: The quality and productivity of technological processes of sifting, mixing, dosing, crushing, transporting of loose materials are determined by their properties, specifically the geometric dimensions of particles. The presence of such particles in loose materials changes dynamic characteristics and affects the efficiency of technological processes. The peculiarities of technological cultivation, extraction, or production of loose materials lead to the appearance of bulges, depressions, protrusions, and other deviations from the correct geometric shape. The presence of such particles in loose materials changes the dynamic characteristics and affects the efficiency of technological processes. An optical-electronic method is proposed for identifying geometric dimensions, which is implemented on developed and standard metrological equipment and follows this algorithm: preliminary analysis, obtaining an object's image, setting boundary conditions, automatic image processing, analysis, and obtaining specified object parameters, consolidation of values. The developed method was tested on biological objects such as seeds of agricultural crops. The research results include ranges of geometric dimensions and shape coefficients of loose material particles. The obtained methodology and values of geometric parameters of loose material particles will allow effective control of the quality of technological processes at the stage of equipment setup and adjustment, increase the accuracy of analytical calculations in research and design of appropriate machines.

Keywords: identification, geometric parameters, shape coefficients, optical methods, processing, loose materials.

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THE INFLUENCE OF RESISTANCE SPOT WELDING PARAMETERS ON THE MICROSTRUCTURE AND PROPERTIES OF STEEL JOINTS

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Abstract: Resistance spot welding is a leading joining method in thin structures made of structural steel grade S235JR samples, the heart of automotive bodies. On average, there are nearly 5000 resistance spot welds in steel body-in-white. The main welding parameters significantly influencing spot weld quality are welding current and welding time. Varying this parameter can greatly improve the spot weld strength and visual appearance and reduce production costs. This research aims to determine the optimal set of RSW (resistance spot welding) parameters for similar low-carbon steel joints. Experiments were conducted on steel sheets joined using various welding times, joining pressures, and current settings. Samples were then evaluated through visual inspection, tensile-shear testing, nugget size, and heat-affected zone measurement. Additionally, a metallographic microstructure examination on the joint cross-sections was conducted for specified samples, and Vickers hardness of samples was measured to analyse the effect of RSW parameters comparatively. The optimal set of welding parameters for high-quality RSW was successfully obtained. The joints ' process parameters and mechanical properties were investigated using artificial intelligence methods to establish the optimal resistance spot welding parameters.

Keywords: resistance spot welding, structural steel, steel joints, metallographic examination, hardness, artificial intelligence.

THE INFLUENCE OF 3D PRINTING DIRECTION ON THE MECHANICAL PROPERTIES OF MANUFACTURED ELEMENTS

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Abstract: The internal structure of a material is crucial in the design of a number of components, especially those that carry significant loads. Also, the design of such 3D printed components should take into account the type of internal structure of a printed piece. The aim of the study was to evaluate the influence of an internal structure (degree of filling and printing direction) of a 3D printed component on its selected mechanical properties. To carry out experimental research, a set of PLA filament samples was prepared using 3D printing, using a MakerBot Replicator Z18 printer. The test pieces were manufactured in both longitudinal and transverse printing; both the longitudinal and transverse printing were made in two positionings: plane and edge. In this case, four different internal structures were obtained from which static tensile strength and impact tests were carried out. In addition, the samples were made with three different filling options: 100%, 70% and 30%. As a result of the research, it was found that the strength of elements produced by 3D printing from PLA is higher if they are printed in an edge formula, which means that the speed of applying subsequent layers probably plays an important role in building strength.

Keywords: 3D printing, PLA material, mechanical properties.

SURFACE CHARACTERISTIC OF 17-4PH DMLS STEEL AFTER HEAT TREATMENT AND SHOT PEENING PROCESS

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Abstract: Increasing demands on engineering materials are making it more attractive to use additive manufacturing technologies that allow greater freedom to produce complex geometries. However, additively manufactured steel is not free of drawbacks and defects. Such disadvantages include high roughness and lower hardness compared to conventional steel. The 17-4PH steel is a grade designed for precipitation hardening. Application of 17-4PH steel ranges from turbine blades, pumps, valves and propellers for aerospace, maritime, nuclear power plant but also medical instruments. This grade of steel is often applied where high mechanical performance and good corrosion resistance are required. Taking these factors into account, it was decided to use a heat treatment designed for conventional steel of this steel grade, that is, a precipitation hardening process followed by shot peening. Parameters such as temperature and times of the solution treatment and aging processes were selected based on previous studies. The use of a constant solutionising temperature of 1040°C and aging at 450°C made it possible to evaluate the mechanical properties depending only on the type of treatment used. Different peening media were also used to determine the effect of the medium on the properties of the surface layer after the peening process. To determine the surface characteristics, tests were carried out using optical profilometry, above that, hardness was tested, and corrosion resistance was examined using electrochemical tests in a 3.5% NaCl environment.

Keywords: DMLS, Shot peening, Heat treatment, Additive Manufacturing, AISI 630, 17-4PH.

THE EFFECTS OF ADDING Ti ON THE CORROSION RESISTANCE AND HARDNESS OF Al0.7CoCrFeNi HIGH-ENTROPY ALLOYS

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Abstract: Corrosion is a common phenomenon of material deterioration in chloride-rich aquatic environments. High entropy alloys (HEA) developed in recent years based on multiple major elements in equimolar or near-equimolar fractions represent a new approach in the design of structural materials operating in aquatic flow environments. The base material for the study was a casting $Al_{0.7}$CrFeCoNi high-entropy alloy (HEA). The effects of the Ti content on the microstructure, the corrosion behavior and the hardness of the HEA+Tix (for x=0, 0.05, 0.2 and 0.5) high-entropy alloys (HEAs) were studied. The evaluation of the corrosion resistance was performed on the basis of potentiodynamic polarization tests using the Atlas 0531 corrosion test kit. The tests were carried out in 3.5% NaCl solution in a three-electrode electrochemical system. The results were then compared to the alloy $Al_{0.7}$CoCrFeNi and the austenitic steel AISI 304L. The $Al_{0.7}$CoCrFeNi alloys exhibited a mixed FCC and BCC phase. An increase in corrosion resistance and hardness of HEAs with increasing titanium content was recorded. Additionally, the corrosion resistance and hardness of HEAs is higher than the reference stainless steel grade AISI 304L.

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Keywords: corrosion resistance, high entropy alloys, microstructure, polarization test, casting.

THE INFLUENCE OF TEMPERATURE ON THE MECHANICAL PROPERTIES OF A GFRP MADE BY AN INFUSION METHOD

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Abstract: Composite materials are increasingly used in the aerospace industry. Laminates are the most commonly used. They often replace conventional materials, such as metals, because of their superior properties and performance. Composite materials help reduce fuel consumption and improve aircraft performance. It is important that composites used in aircraft structures have very high creep resistance and strength, due to the high loads they carry. Composites with the highest mechanical properties can be obtained using an infusion method. In the infusion process, the mold is prepared (together with the reinforcement made of the material from which the composite is made, e.g. glass fibre), which is tightly closed with a vacuum bag, and the equipment supplying the previously mixed resin with hardener is connected to the injection points. This study describes the main issues related to composites, characterizes in detail the infusion method and the laminate manufacturing process. Sandwich composites using infusion method can be made at various temperatures. This work describes the effect of the applied different temperature on the mechanical properties obtained of a composite reinforced with fiberglass. It turns out that the best strength properties of the material are obtained with the use of high temperature. Research and analysis of visual, tensile and flexural strength tests are also presented.

Keywords: sandwich composite, laminate, infusion merthod, glass fibre, temperature.

THE INFLUENCE OF THE MATRIX PROPERTIES ON MECHANICAL PROPERTIES OF A GFRP MADE BY THE INFUSION METHOD

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Abstract: At every stage of the development of modern aerospace structures, engineers are keen to obtain the lightest possible product while maintaining high strength. In order to meet such requirements, composite materials are now widely used in the aerospace industry, with manufacturing methods constantly evolving. This thesis aims to investigate and analyse the influence of the matrix on the strength of a layered composite made using the infusion method. In the infusion process, the mold is prepared (together with the reinforcement made of the material from which the composite is made, e.g. glass fibre), which is tightly closed with a vacuum bag, and the equipment supplying the previously mixed resin with hardener is connected to the injection points. This method is currently one of the most popular and effective. The technique makes it possible to produce a strong laminate using optimum labour and favourable costs. However, a number of rules must be followed during the production process to produce a satisfactory product. In relation to the objective of the thesis, three different composites were produced and tested, which differed in the properties of resin composition used. The matrixes were different in terms of the use of processes such as venting and the ratio of epoxy resin to hardener. This work shows that there are slight differences in the mechanical properties and structure of the obtained composite.

Keywords: sandwich composite, matrix, infusion method,.

PROPERTIES OF THE SURFACE LAYER OF TITANIUM ALLOY Ti-6Al-4V PRODUCED BY DMLS TECHNOLOGY AFTER THE SHOT PEENING TREATMENT

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Abstract: While considerable progress has already been made in the field of additive manufacturing further development is needed. There is a huge demand in the global market for the production of high-quality components with complex geometries. The post-production surfaces after fabrication by AM technologies require finishing treatment due to the presence of defects on the surface layer. Therefore, a series of studies have been carried out to analyze the effect of shot-peening treatment on DMLS-manufactured titanium specimens. Shot peening process were carried out using three different working media: CrNi steel shot, crushed nutshells, ceramic with working pressure of 0.3 MPa. The study included examination of surface roughness, Vickers hardness, phase composition and SEM analysis of the obtained surfaces. Analysis of the surface roughness showed a decrease in roughness using CrNi steel shot and ceramic balls. The use of nutshells resulted in an increase in roughness due to the sharp shape of the grains used. An increase in the surface hardness was observed for all modified surfaces. The least strengthening effect was obtained with nuthsell shots. XRD phase analysis indicates that a two-phase structure of α\'+β was identified in the post-production condition. There has been an increase in the share of the β phase for all treated samples. The greatest increase of the β phase was obtained for steel shots and ceramic balls. Changes in the percentages of the phases in the treated samples are the results of the induced phase transformations. The shot peening process also induces plastic deformation on the surface and forms a nanocrystalline layer, as demonstrated by SEM analysis. The overall results after the shot peening treatment indicates a favorable effect on the properties and the state of the surface layer of the Ti-6Al-4V titanium alloy for ceramic and steel shots.

Keywords: additive manufacturing, titanium alloys, DMLS, shot peening.

EFFECT OF CURING TEMPERATURE OF AERONAUTICAL EPOXY RESIN USED FOR ABLATIVE SHIELDING ON SOFTENING AND DEFLECTION TEMPERATURE

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Abstract: This paper presents the results of a study to determine the heat deflection temperature (HDT) and Vicat softening temperature (VST) of the LH285 MGS aerospace polymer resin used as a matrix for ablative shielding composites. This issue is of particular relevance because the composite material is partially burned (ablative layer) during ablative testing. However, its other parts are additionally heated to a higher temperature, with a consequent change in viscoelastic properties that depend, among other things, on VST and HDT temperatures. In their study, the authors used aerospace resins cured under different conditions according to the manufacturer\'s recommendations. In addition to observing the thermal properties, which can change as a result of the influence of material conditioning, the effect of the material heating rate and load magnitude was also investigated in accordance with the applicable standards for this type of material. It was observed that the heating of the resin affects the HDT and VST temperature values. It is also noticeable that the shape of the indentation into the material depends on the material conditioning temperature. The dependence of the choice of heating rate as well as the load did not affect the results so much.

Keywords: epoxy resin, Vicat softening temperature (VST), heat deflection under temperature (HDT), surface profile examination.

ANALYSIS OF JAPANESE QUAIL BONE MECHANICAL PROPERTIES

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Abstract: Japanese quail (Coturnix japonica) is a valuable bird for researchers because of their small size and rapid growth rate. The Japanese quail undergoes an aging process similar to that of mammals with deterioration of reproductive functions, metabolic functions, and sensory systems. The mechanical strength of quail bones may depend on genetic factors, supplementation, age, and diseases. In the case of lying birds deterioration of skeletal integrity occurs as large amounts of calcium are exported for eggshell formation. A loss of structural bone during the laying period is characteristic of osteoporosis and results in the weakening of the skeleton and increased fracture.

This work presents the results of a three-point bending test of the quail femur. Bones from females and males of two quail lines were analyzed: the meat breed Pharaoh (F) and the laying type of Japanese quail (S). Bone mechanical properties were determined from the load-deformation curve. A maximum force recorded in the test, bending moment, stiffness, strain, and modulus of elasticity were analyzed.

Based on the performed tests, it was found that female bones were characterized by lower mechanical strength, bending moment, stress, and elasticity modulus compared to males in both tested groups. In the case of stiffness, the higher values of this parameter were obtained for females, but observed differences were not significant.

Keywords: bone strength, mechanical load, impact.

THE STUDY OF THE MICROSTRUCTURE AND FUNCTIONAL PROPERTIES OF BIODEGRADABLE PSYLLIUM/THERMOPLASTIC STARCH FILMS

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Abstract: Due to the pro-ecological changes in packaging materials, starch films are becoming increasingly important. Research efforts are focused on improving the functional properties of starch materials to make them competitive with traditional polymer packaging materials. For this purpose, various functional additives are used to modify film's basic physicochemical properties.

The presented studies concern the effect of psyllium flour (PF) on the structure and physical properties of thermoplastic starch films manufactured by the casting method. Detailed structure analysis was carried out on the macro, micro, and nanoscale using a stereoscopic microscope, scanning electron microscope, and atomic force microscope. Additionally, low-velocity impact tests were conducted using an Instron-Ceast 9340 drop weight testing machine. An impactor with a mass of 3.4 kg and 10 mm diameter was employed, following the ASTM D 7136 standard. An impact energy of 1 J was used, corresponding to an impact velocity of 0.767 ms−1. Water contact angle (wettability) measurements were carried out using a goniometer (Drop Shape Analysis System DSA100, Krüss, Germany). The measurement device included a camera for recording and image acquisition.

The studies showed a noticeable influence of PF concentration on the macro- micro- and nanostructure of the films and their mechanical properties. In the case of all tested samples, the initial value of water contact angles (WCA), measured immediately after water drop contact with the starch film surface, exceeded 100o. Simultaneously, a decrease in WCA values over time was observed. The dynamics of WCA decrease was the smallest for the films with a higher amount of psyllium flour. That makes them a potentially promising packaging material due to their greater hydrophobic nature.

Keywords: biodegradable films, TPS films, psyllium, microstructure, mechanical properties, physical properties.

EFFECT OF THE REFINING PROCESS ON POROSITY AND SELECTED MECHANICAL PROPERTIES OF ALSI7MG ALLOY PRESSURE CASTINGS

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Abstract: The presence of hydrogen and other metallic inclusions (sodium, calcium and lithium) and non-metallic inclusions, e.g. borides, carbides, nitrides, oxides, salt inclusions and intermetallic compounds deteriorate the properties of aluminum and its alloys, therefore refining is an important stage of metallurgical processing. It is a technological process that aims to clean the metal of admixtures and impurities in order to obtain its purity by grinding the grains of the Al(a) solid solution and changing their shape. Depending on the type of metal and impurities, the refining process can be carried out in different ways. The most commonly used method is mechanical refining (also called barbotage), which involves introducing an inert gas (nitrogen or argon) into the liquid alloy using a lance. The article presents the influence of the purity and type of gas refining agents used on selected mechanical properties (Rm; R0.2, A) and the reduction of various impurities in the AlSi7Mg alloy used for low pressure castings.

Keywords: foundry aluminum alloys, refining, barbotage refining, mechanical properties.

STUDY OF THE EFFECT OF MICROENCAPSULATED PHASE CHANGE MATERIAL PARTICLES ADDITION TO EPOXY RESIN ON THE EFFECTIVE THERMAL DIFFUSIVITY OF THE RESULTING COMPOSITE STRUCTURE

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Abstract: The work concerns the study of the effect of the addition of microencapsulated phase change material (PCM) granulate to epoxy resin on the effective thermal diffusivity of the resulting dispersed composite structure. The matrix material of the tested structures were commercially available Diall make epoxy resins: pure and with the addition of metal powder. BASF Micronal DS5038 X phase change microgranulate (Micronal) was used as a filler. The temperature dependence of the thermal diffusivity was determined for four test cases. Two are resins without additive, two with Micronal filler. Since the tests covered the range from 0°C to 35°C, i.e. the area of the main PCM phase transition, the determined parameter should be considered as the effective or apparent thermal diffusivity. For selected measurement cases, this range was extended to the interval from -10°C to 75°C. The measurements were carried out by applying temperature oscillation i.e. modified Ångström method. The method enables accurate identification of heat transfer phenomena in the area of phase transformations. The obtained results are not only of practical importance, but also form the basis for theoretical considerations.

Keywords: Phase Change Material (PCM), epoxy resin composites, dispersed filler composite, thermal diffusivity, temperature oscillation method, microencapsulated PCM Micronal.

USING THE ANALYSIS OF COVARIANCE IN THE MOISTURE DETECTION TECHNIQUE

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Abstract: In the article is presented the assessment of the moisture content of selected building materials using Analysis of Covariance (ANCOVA). The readings show the relationship between the moisture content of the material, assessed gravimetrically, and the values of apparent permittivity obtained using the TDR method. Due to the ANCOVA method, it is achievable to establish the moisture content of individual materials independently of the sensor design and type of examined material. Moreover, for the purpose of comparison, the data analyzed during the experiment were also evaluated using standard linear regression equations.

Keywords: Analysis of Covariance (ANCOVA), moisture detection, Time Domain Reflectometry (TDR), linear regression analysis.

CALIBRATION FORMULAS IN MOISTURE DETECTION TECHNIQUE IN BUILDING MATERIALS IN TERMS OF POLYNOMIAL REGRESSION MODELS

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Abstract: The paper contains the description of one of the non-invasive moisture detection technique in building materials, namely Time Domain Reflectometry (TDR) technique, and two determined calibration formulas. By applying the TDR device, the proper software and also the calibration equations, moisture tests of building materials can be carried out. The readouts present the relationship between the moisture of clinker brick sample evaluated gravimetrically and permittivity and also signal voltage values designate by TDR technique. The aim of this work is comparison of two calibration models describing the relationship between apparent permittivity and material moisture. In order to determine the calibration formulas, the regression analysis were applied. The obtained models are of the polynomial type. First model involves one independent variable and the second model contains two independent variables. The detailed comparison of obtained two polynomial regression models is presented. The most common parameters, such as the determination coefficient, the Root Mean Square Error (RMSE) and the Residual Standard Error (RSE) were determined and analyzed. As a consequence, the quality and the property of the obtained polynomial regression models is presented in detailed. The comparison of obtained two regression models also includes the correlation analysis which concerns the correlation between the moisture content determined by the TDR and the moisture content appointed gravimetrically.

Keywords: moisture detection, polynomial regression, Time Domain Reflectometry (TDR).

EFFECT OF HEAT TREATMENT AND MWCNT REINFORCEMENT ON THE TRIBOLOGICAL PROPERTIES OF MGS L285 EPOXY RESIN

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Abstract: The study aimed to investigate the effects of heat treatment temperature and the addition of multi-walled carbon nanotubes (MWCNTs) on the tribological properties of epoxy resin. MGS L285 epoxy resin, commonly used in aviation, was selected for this purpose. Modern trends in composite aircraft design, such as aeroelastic tailoring, require accurate and reliable material data. Conducting extensive numerical studies without a thorough understanding of the underlying physics of material characteristics can lead to inaccurate or misleading conclusions. Therefore, comprehensive research into the properties of epoxy resins, which are frequently used as matrices in aerospace composites, is essential. Additionally, advancements in nanotechnology highlight the potential for polymer matrices to be enhanced with carbon-based nanoadditives. Carbon nanotubes, one of the most commonly used nanostructures, have demonstrated significant potential to improve the properties of epoxy resins. The MWCNTs used in this study were provided by ITP-System, and their properties were characterized using Raman spectroscopy and high-resolution transmission electron microscopy (HR-TEM). In the first phase of the study, the effect of heat treatment at temperatures up to 100°C was evaluated. In the next phase, the influence of MWCNTs at concentrations of up to 4% by mass was analyzed. Tribological properties were assessed using the ball-on-disc method, while hardness was measured using the Shore D method. Material degradation was examined through optical microscopy, scanning electron microscopy (SEM), and optical profilometry. The results indicated that heat treatment improved performance only at elevated temperatures, while it worsened performance at ambient temperature. The effect of MWCNTs on tribological properties and hardness was nonlinear, with a clear correlation between wear resistance and hardness. The best wear protection was observed at MWCNT concentrations of 0.75 wt.% and 2.50 wt.%.

Keywords: composites, carbon nanotubes, epoxy resin, heat treatment, wear.

THE INFLUENCE OF SURFACE LAYER PREPARATION AND THERMAL SHOCKS ON THE STRENGTH OF THE ADHESIVE JOINT

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Abstract: Nowadays, a geometric structure of surface is quite important because of the following significant reasons: functional, exploitative and esthetic. Recently, an intensive development of various metrology techniques for a surface layer gives the opportunity to predict the functional and the exploitative attributes of the surface. Selected 2D and 3D surface roughness parameters were analyzed after various methods of preparing the surface layer in terms of adhesive joints.

The bonding technology, thanks to a progress in the adhesive materials chemistry is continuously developing. The effectiveness of bonding depends largely on proper selection of adhesive joint, as well as an adequate technique of surface treatment. Many factors have effect on this, first of all increasing the bonding effectiveness thanks to the modern, fast curing adhesive joint, an ease of tailoring the adhesive joint properties, through a simple and cheap chemical or physical modification, as well as the growing trust to the discussed joining technology. Adhesive bonding is increasingly being applied as structural joining technique in highly reliable machines and appliances operating in the circumstances of variable thermomechanical loads.

The manufactured specimens of the epoxy material had been subjected to cyclic thermal loading, with respect to a defined program, in a thermal shock chamber within a temperature range of 40°C to +60°C in a different number of cycles. The strength of the adhesive connection after various methods of preparing the surface layer of construction materials as well as after thermal load was analyzed.

Keywords: surface layer, thermal shocks, adhesive joint.

THE INFLUENCE OF RESISTANCE PROJECTION WELDING PARAMETERS OF STEEL NUTS ON THE MICROSTRUCTURE AND PROPERTIES OF JOINTS

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Abstract: The ever-increasing development of technology in industry is pushing more and more companies to seriously consider the automation of many production processes in order to minimize production costs and remain competitive in the market. The spot welding process is quick and easy to automate, so it finds its place in more and more production plants. The purpose of this paper is to perform projection welding of nuts (M5) to S235JR steel sheets with various parameters in order to determine the parameters at which we obtain the best joint quality. Over a hundred welds were performed in this study (all steel sheets were cut to size according to the standard PN-EN ISO 14270:2005). All samples were visually inspected shortly after spot welding to determine the accuracy of the nut welding joint, and then selected sheets were intended for strength testing (performed according to standard PN-EN ISO 14270:2005). Selected projection welded joints undergo metallographic investigations and then are subjected to hardness testing using the Vickers method (according to standard PN-EN ISO 1427:2002). The research effects are presented graphicly, which simplifies the process of comparison. The obtained set of process parameters, as well as the results of mechanical properties of joints, were analyzed using artificial intelligence methods to select the optimal projection welding parameters.

Keywords: spot welding, projection welding, image analysis, artificial neural network.

MICROSTRUCTURE OF 42CrMo4 STEEL AFTER DIFFERENT HEAT TREATMENT PROCESSES

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Abstract: The research investigated the effect of heat treatment parameters on the microstructure of 42CrMo4 steel, a material widely used in engineering due to its favorable mechanical properties. The work was divided into two main parts: theoretical review and experimental analysis. The theoretical part discussed various heat treatment processes, including methods, parameters and tools. It provided a basic knowledge of the effects of various heat treatment methods on the properties of steel, especially in the context of microstructure. In the experimental part, selected heat treatment processes were applied to 42CrMo4 steel samples. Detailed metallographic analysis was then carried out to observe the resulting microstructures. The samples in the as-delivered condition were characterized by a ferritic-perlitic structure. Quenching resulted in a martensitic structure, characterized by high hardness, while tempering led to the formation of a sorbitic structure, which increases fracture toughness. The annealing process resulted in a ferritic structure with spheroidal cementite precipitates. Microstructural changes significantly affect the mechanical properties of steel, highlighting the key role of heat treatment parameters in tailoring the material's performance for specific applications. The research highlights the complex relationship between heat treatment processes, microstructural evolution and mechanical properties of 42CrMo4 steel.

Keywords: heat treatment, microstructure, metallographic analysis, 42CrMo4 steel, mechanical properties, annealing.

MICROSTRUCTURE AND PROPERTIES OF YSZ CERAMIC COATINGS DEPOSITED BY APS

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Abstract: This work investigated YSZ (yttrium-stabilized zirconium oxide) coatings deposited by atmospheric plasma spraying (APS), with a particular focus on the influence of spraying distance on their microstructure and wear resistance. The suspension plasma spraying (SPS) technology utilizes easily evaporated suspensions to transport submicron and nanometer-sized particles. The theoretical part of the work characterizes the types of wear and methods of producing coatings, emphasizing thermal spraying techniques, including SPS. The experimental part includes a description of research objectives, spraying processes, microstructure observations, chemical composition, microhardness measurements, roughness, and wear resistance studies. The obtained results show that smaller spraying distances lead to finer and better-melted grains, resulting in improved hardness and reduced roughness. However, a greater porosity and cracks due to thermal stresses were also observed. Notably, the YSZ40 coating exhibited more than a sixfold lower wear rate and better cavitation resistance compared to YSZ60.

Keywords: YSZ (yttrium-stabilized zirconium oxide), coatings, atmospheric plasma spraying (APS), spraying distance, thermal spraying techniques, microstructure, cavitation erosion.

COMPARISON OF CAVITATION EROSION RESISTANCE OF POWDER PLASMA TRANSFERRED ARC DEPOSITED NiCrBSi AND AISI 316L STAINLESS STEEL LAYERS

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Abstract: This study meticulously compares the influence of microstructure and hardness on the cavitation wear resistance of PTA (Plasma Transferred Arc) deposited films. Deposits were made on a substrate of S235JR structural steel. Two types of feedstock powder were used, i.e. material of the chemical composition of AISI 316L steel and a nickel-based powder type NiCrBSi; both were deposited using the PTA method. This study carried out cavitation erosion tests on a vibratory test rig following ASTM G32 standard using the stationary specimen method. Metallographic investigations confirmed the austenitic dendrites and delta ferrite precipitation in the microstructure of AISI 316L and hard carbides, borides located in the nickel-based matrix of NiCrBSi hardfacing. It can be seen that the AISI 316L layer, having a much lower hardness at 250 – 280 HV1, achieved poorer cavitation erosion resistance results compared to the NiCrBSi layer, having a hardness in the range of 820 – 890 HV1. So on, the NiCrBSi coating shows four-fold higher cavitation erosion resistance than the stainless steel coating. In the case of different types of overlay materials, i.e. stainless steel and NiCrBSi, the higher hardness and fine-hard particle-rich microstructure improves the cavitation erosion resistance of PTA overlays.

Keywords: cavitation erosion, hardfacing, stainless steel.

PRODUCTION ENGINEERING, MANAGEMENT AND QUALITY CONTROL

USING BUSINESS PROCESS MODEL AND NOTATION 2.0 TO DEPLOY COBOTS IN A MANUFACTURING SYSTEM – CASE STUDY

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Abstract: This study examines the application of BPMN 2.0 notation within the implementation process of modern Industry 5.0 solution – cobots (collaborative robots). The research aims to compare the operational efficiencies of traditional human-only production processes with those augmented by cobots. The authors analyze two variants of furniture production processes: one involving only human workers and another combining cobots and human workers. The efficiency of these processes was assessed in terms of production time and output quantity. The investigation revealed that the production process incorporating cobots was more efficient, with a reduction in production time by 4.76% and an increase in the amount of products produced by 35.5%. The study concludes that integrating cobots into production processes can significantly enhance efficiency, reducing time and increasing output. BPMN 2.0 notation is a critical tool for modeling, automating, and monitoring these improved processes, aiding organizations in making strategic decisions towards adopting robotic solutions to boost productivity and competitive edge in the marketplace.

Keywords: industry 5.0, process, manufacturing, cobots, BPMN 2.0.

CONCEPT OF PROCESS OPTIMIZATION IN A MINING MACHINERY PRODUCTION COMPANY USING SELECTED LEAN MANUFACTURING TOOLS

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Abstract: The main intention of the work was the concept of implementing selected Lean Manufacturing tools in an enterprise, which produces mining machines in order to optimize the machining process. The proposed optimization was dedicated to eliminate the disruptions occurring during the shaping of the pin wheel body and shorten the production time. Selection of appropriate methods of Lean Management was required by the specificity of an enterprise that does not have modern technologies and mass production. The main strategy of the actions taken was to identify activities in the process that generate losses and downtime.

To identify activities that do not bring added value, in the first stage of the work, the structure of the mining company in which machine components are manufactured was analyzed. On the basis of the results obtained from the analysis of the employee opinion survey and the 5 Why method the places of the greatest wastes were indicated. After identifying defects occurring in the process, selected Lean methodology tools were applied, including, computer-aided: Kanban Card (Just In Time) and TPM (Total Productive Maintenance). They allow to reduce the number of activities performed during the process and to minimize the production time of the pin wheel body.

The implementation of Instruction Cards for periodic inspection and maintenance of machines and the development of a Schedule for their performance have a positive impact on streamlining the process and maintaining the optimal condition of the machines. Regular, planned inspections minimize the risk of failure of machines used in the process. In turn, the introduction of a Kanban card improves the flow of the manufactured element between stations and results in a reduction in the machining time of the pin wheel body by up to 45.3%.

Keywords: Lean Management, Lean tools, Kanban Card, TPM (Total Maintenance), machining, pin wheel body, 5 Why analysis, production process.

OPTIMIZATION OF QUALITY CONTROL PROCESSES USING THE NPGA GENETIC ALGORITHM

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Abstract: In the article, the problem of multi-criteria optimization of quality control mechanisms is analyzed. The presented method assumes the use of the NPGA genetic algorithm to simultaneously manage costs and the level of detecting non-conformities. The main assumption of the presented approach is to treat individual quality control procedures as vectors, whose elements are probability generating functions of defect detection. Each of these procedures generates certain operational costs and covers specific types of defects within its scope. The task of the presented algorithm is to indicate which procedure and to what extent should operate to ensure an appropriate level of non-conformity detection while minimizing costs. The article presents the theoretical foundations of the developed algorithm and the results of its implementation. The software has been developed in C++ with a particular focus on performance aspects. Its essence lies in the implementation of data structures introduced in the theoretical part, as well as methods for their rapid processing. Thanks to this approach, the entire program is scalable and can be used to solve multidimensional optimization problems. The presented approach may also find application in other areas of enterprise management. This will be possible primarily where the essential measure of the effectiveness of procedures or devices is probability. Therefore, the presented methods can provide effective optimization of other areas related to enterprise management.

Keywords: quality control; enterprise management; process optimization; genetic algorithm; NPGA.

APPLICATION OF NEURAL NETWORKS FOR DEFECT DETECTION IN ROTATIONALLY SYMMETRIC COMPONENTS

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Abstract: Industrial quality control systems in mass production facilities must exhibit a very high level of defect detection efficiency. The continuous increase in quality control and process automation requirements is leading companies to increasingly experiment with artificial intelligence methods to boost efficiency. One potential application area for AI is visual inspection, which is an essential element of almost every quality control process. In this article, we propose the use of neural networks for the visual inspection of rotationally symmetric components. The presented method leverages the existence of symmetry to represent images in a polar coordinate system and to implement the learning process on data modified in this way. An undeniable advantage of the proposed algorithm is also the transition from a two-dimensional to a one-dimensional representation, which significantly reduces the demand for memory resources and the required computational power. This is particularly important in mass production processes, where the time for data analysis is relatively short. The high repeatability of images due to the mass production nature makes this model exceptionally effective, allowing not only to confirm the presence of defects but even to locate them. The obtained results are compared with the results achieved using a convolutional neural network operating on two-dimensional images.

Keywords: defect detection; quality control; neural networks; computer vision; mass production.

ANALYSIS OF OPERATING PARAMETERS IN INNOVATIVE GEAR PUMPS WITH INVOLUTE PROFILES

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Abstract: Gear pumps are the most widely used energy generators in hydraulic drive systems. Despite numerous patents, literature, and the vast number of gear units currently manufactured, technical methods ensuring optimal internal sealing, maximum operating pressures, minimal flow pulsation, and noise emission have not yet been fully explored. In previous proprietary publications, authors have presented possibilities and methods to reduce flow pulsation and propose new design solutions to increase operating pressures while ensuring high internal sealing. These tasks required solving a series of technological, design, and construction problems. Previous research and projects have focused solely on optimizing the manufacturing technology of gear pumps with involute profiles, without analyzing the impact of operating parameters on overall efficiency.

The aim of the current project is to determine the optimal values of operating parameters: working fluid viscosity (kinematic ν [$m^2 \cdot s^{-1}$] and dynamic μ [Pa·s]), discharge pressure pt [MPa], and rotational speed n [min^{-1}] of gear units with involute profiles to achieve the highest overall efficiency.

The present article introduces an innovative prototype unit: a gear pump with an polyinvolute profile. The focus is on analyzing the performance of the prototype unit and presenting results that can be applied both in a research and practical context. In the further part, the inductive tree method and multi-valued logic trees will be applied as part of the data analysis.

Keywords: gear pumps, involute profile, optimization, operational parameters, efficiency, performance, multi-criteria decision support methods.

ANALYTICAL, COMPUTER AND LABORATORY MODELLING OF THE EFFECT OF THE FUEL USED IN THE SPARK IGNITION ENGINE OF THE SELECTED VEHICLE ON THE OPERATING PARAMETERS AND EXHAUST GAS COMPOSITION

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Abstract: The purpose of the study was to determine the effect of the fuel used in the spark-ignition engine of the selected vehicle on the characteristics of maximum torque and power at the crankshaft of the engine as a function of crankshaft speed and the content of components in the exhaust gas. The vehicle engine was tested on a stand equipped with V-tech VT-2/B2 chassis dynamometer, MAHA MET 6.3 exhaust gas analyzer and engine parameter monitoring system using OBD standard. The tests used two commercial fuels with different test octane number (RON) values of 95 and 100 octanes. Measurement of the characteristics of the maximum torque, power on the crankshaft and the total power losses in the drive system, the contact of the wheels with the rollers of the dynamometer and the dynamometer as a function of the crankshaft rotational speed was carried out using the acceleration method with a dynamic load comprising the braking torque of the rotating masses and the electro-swirl brake. The parameters of the selected engine operating conditions are within the ranges specified by the software for generating the selected test runs. The content of selected exhaust gas components (carbon monoxide CO, carbon dioxide CO_2, other hydrocarbons, oxygen O_2, λ coefficient, nitrogen oxides NO and nitrogen dioxide NO_2) was measured for the selected operating parameters of the vehicle for the tested fuels. On the basis of the results of the toxicity measurements, analytical models determining the content of individual components in the exhaust gases as a function of the crankshaft rotational speed and the torque generated on the crankshaft and software simulating the exhaust emissions of the selected vehicle moving under dynamic conditions were developed.

Keywords: engine, fuel, emission, exhaust gases, analysis.

NEW ENERGY-SAVING TECHNOLOGY FOR INDUSTRIAL STRETCH FOIL PRODUCTION

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Abstract: The article presents a project of innovative technology and a line for the production of stretch foil. The technological innovation is that the foil is produced from a material consisting of primary raw material and up to 80% of recyclate. The new product cannot differ in terms of use from the traditional one, produced from 100% primary raw material. This led to the need for a new look at the traditional film production process, analysis of potential problems and adaptation of currently used solutions to new production requirements. Additionally, recyclate is produced from waste originating mainly from used in agriculture. The production line contains systems that allow the use of materials contaminated with organic particles, without the need for their thorough cleaning.

Another innovation is the use of low-temperature waste heat in the production process. It comes from the cooling of the first calender roll. Until now, this heat was dissipated in the atmosphere. In the line, low-temperature waste heat was transformed into high-temperature heat and used in the technological process for the initial preparation of the raw material. In order to transform low-temperature waste heat into high-temperature technological heat, a heat recovery line was designed based on two cascade-hydraulically coupled compressor heat pumps. The designed system can be expanded and adapted to current production needs. In accordance with the latest standards, the system uses only ecological refrigerants. The developed technological line solves several problems. It helps to utilize difficult-to-manage post-production waste from agriculture and other sectors of the economy. It reduces the consumption of energy and raw materials from non-renewable sources, which significantly reduces CO2 and other greenhouse gas emissions. This is in line with the assumptions of the European Green Deal, implements a closed-loop economy and is based on renewable energy sources. Currently, the developed technology is being implemented.

Keywords: energy-saving technology, stretch foil production, circular economy.

DEVELOPMENT AND IMPLEMENTATION OF THE INNOVATIVE SENDER RECEIVER ORGANIZATIONAL SYSTEM – ISNOO

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Abstract: In recent years, there has been noticeably dynamic growth in the e-commerce market. Similarly, the number of logistic operations related to the completion of orders in B2C (business-to-consumer) relationships is increasing at the same pace. In this area, a significant role is played by devices, commonly known as parcel lockers, designed for end customers to send and receive shipments. More and more often, parcel lockers are being enhanced with additional functionalities that, on one hand, meet customer preferences while on the other hand, allow the introduction of new services, such as advertising, announcements, etc. Additionally, to ensure delivery efficiency, so-called smart parcel locker solutions are being introduced. These enable the sending and receiving of diversified goods and feature intuitive systems for secure and efficient handling.

The article presents the assumptions and achieved objectives of the research project on raising the level of technology dedicated to the production of the Innovative Sender-Receiver and Organisational System (ISNOO). As part of the project, a demonstration technology line (DIT) consisting of modules designed to carry out selected technological operations was designed. The various DIT modules are characterised and the research carried out on them, which contributed to the achievement of the stated objectives of the various stages of the project is discussed. In recent years, Renz Sp. z o. o., as a manufacturer of parcel distribution systems, has focussed on designing and producing intelligent technical solutions tailored for a broad range of users. This contributed to the completion of a project involving the development of the Innovative Sender-Receiver Organisational System "ISNOO" and its proprietary production technology. In the article, the ISNOO system and key aspects of its manufacturing technology are detailed, highlighting its functionality, safety, reliability and versatility of application.

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Keywords: parcel locker, research project, ISNOO.

ANALYSIS OF THE REAL-LIFE MANUFACTURING PROCESS OF SPUNLACE NONWOVENS IN MODERN, DOUBLE-DRUM CARDS

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Abstract: Trends in the development of the textile industry, have focussed on the production of spunlace nonwoven fabric, aiming to reduce the amount of raw material introduced as much as possible and at the same time increase the mechanical strength of the nonwoven fabric produced. The desired performance properties of these nonwovens, i.e. quality and strength, depend to a large extent on the carding process, in which homogenised layers of properly mixed fibres are formed. In this article, a comparative analysis of two different designs of modern, double-drum carders and their impact on the quality of fibre mixing and on the strength of the final nonwoven fabric is made, based on research and tests carried out in a real company. To this end, mathematical models were developed for the relevant indicators (fibre lag time and average fibre circulation path length in the carding machine) that characterise the carding process. On the basis of numerical calculations, these ratios were determined for the actual geometry of the scrapers and the test process parameters, namely the scraper settings in the tests. A discussion was carried out to interpret the values of these indicators and their correlation with the strength of the nonwoven fabric produced, taking into account the different design of the carders used in the tests.

Keywords: mathematical modelling; data analysis; carding process; nonwoven fabric strength; manufacturing; nonwovens.

MODELLING THE MASS BALANCE OF A REAL-LIFE MANUFACTURING PROCESS OF SPUNLACE NONWOVENS ON A HIGH-PERFORMANCE PRODUCTION LINE

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Abstract: The purpose of this study is to model the mass balance in the production process of spunlace nonwovens, carried out on an actual high-performance production line. Nonwoven spunlace fabrics, characterized by high strength and flexibility, are widely used in industries such as medicine, personal hygiene and the automotive industry. The manufacturing process of spunlace nonwovens relies on the use of high-pressure water jets to bond the fibers, making it a technology that requires significant amounts of raw materials and energy. A key aspect of the spunlace nonwoven manufacturing process is the control and optimization of raw material consumption and waste minimization, which has a direct impact on the economic and environmental efficiency of the company.

The work presented here is based on the development of a comprehensive mass balance model to accurately determine the flow of raw materials, including natural and synthetic fibers, and water consumption. The actual process of spunlace nonwoven fabric production in an integrated process line consisting of a feed, mixing, two carding machines, a water needling machine, a dryer and a winder was modeled. In the process under study, two different high-performance carders were installed, configured in series in the nonwoven production line. This arrangement ensures that each carder can operate separately or two at the same time. If two carders are used, they can be loaded in different proportions resulting from the preset capacity of the production line. However, this requires adjusting the parameters controlling the carding process in each case. Modeling makes it possible to closely monitor material flows and identify where raw material losses occur.

This work represents an important step toward understanding and optimizing the production processes of spunlace nonwovens and can be used as a tool to improve production efficiency on other high-performance production lines in the textile industry. The results of the research have the potential to be applied to industrial practice, contributing to the competitiveness of enterprises through better management of resources and less environmental burden.

Keywords: nonwoven spunlace; mathematical modelling; data analysis; nonwoven fabric strength; manufacturing.

TECHNOLOGY MANAGEMENT IN ENERGY ACQUISITION PROCESSES

ML-BASED PREDICTION OF BIOGAS PRODUCTION BASED ON SLUDGE CHARACTERISTICS IN FOUR SLUDGE DIGESTION TANKS WITH SOFTWARE TOOL - SDT2BIOGAS PREDICTOR TOOL

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Abstract: One of the alternative ways to obtain low-cost energy is to use biogas generated by the digestion process from sewage sludge. This paper presents an analysis and simulation of the processes in four sludge digestion tanks (SDTs) - A, B, C and D. The study analyzed the amount of biogas produced in each digester tank and compared them with each other. Using data sets consisting of parameters relating to the pre-sludge and surplus sludge diverted to each tank, the effect of the proportion of these parameters on biogas production efficiency was studied. Based on this data, several models using different machine learning techniques were built and compared, which can be used to support the biogas production optimization process. A free convenient window tool written in Python language and Qt library - SDT2Biogas Predictor Tool - was also given away for wastewater treatment plants to conveniently estimate the predicted amount of biogas produced on a given day using the implemented models.

The main objective of the study is to understand how the studied parameters affect the efficiency of the process and identify potential optimization strategies, as well as to propose a model for biogas yield prediction based on sludge characteristics. The result of the study is to contribute to increasing the efficiency of sludge management in wastewater treatment plants and increasing biogas production, both in the form of developed models and a software tool.

Keywords: sewage sludge, biogas, anaerobic fermentation, sewage plant, machine learning, python, qt, software tool.

EVALUATION OF AGITATOR PERFORMANCE CHARACTERISTICS IN AN ACTIVATED SLUDGE BIOREACTOR DETERMINED BY BIOMARKERS

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Abstract: This paper presents a method for evaluating agitator performance in an activated sludge bioreactor based on organism abundance analysis. A vertical SBR-type bioreactor equipped with standard paddle agitators treated as a reference and a toroidal propeller agitator made with FDM printing technology was used in the study. Values of suspended solids concentration (TSS), turbidity index (NTU), and abundance of indicator organisms during sedimentation of the sludge were measured. The study showed that TSS and NTU values correlate with mixing intensity. An increase in mixing intensity favoured the growth of organisms preferring aerobic conditions, while it reduced the abundance of organisms preferring low oxygen concentrations. The results of the study indicate that biomarker analysis can be an effective tool for assessing agitation performance characteristics in activated sludge bioreactors. This method allows monitoring of bioreactor performance and identification of potential mixing problems, which can have a significant impact on the efficiency and stability of the wastewater treatment process.

Keywords: SBR bioreactor, activated sludge, mixing, FDM, biomarkers, TSS, NTU.

RESEARCH ON THE USE OF MULTIFREQUENCY EXCITATIONS FOR ENERGY HARVESTING IN AN COMBUSTION ENGINE

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Abstract: Research conducted around the world shows that energy harvesting (EH) systems can be used in modern vehicles powered by combustion, hybrid or electric engines. The efficiency of modern combustion engines is about 40%, the rest of the energy is lost and can be recovered to some extent. Therefore, the search is ongoing for systems that will use this part of the energy to power specific systems or microsensors installed in the vehicle. The article presents the possibilities of energy recovery from such vehicle systems as: energy recovered during braking, damping energy in the vehicle suspension, energy recovery from the exhaust system of an internal combustion engine and energy from the vibrations of the internal combustion engine. Based on the analysis of the literature on the presented research of various scientific centers and the author's experiment, it can be concluded that there is a huge potential for obtaining thermal energy from the engine exhaust system and the vehicle suspension system. A field that has not been explored much, but according to the authors also has energy potential, is energy recovery from the combustion engine suspension system in the vehicle\'s engine compartment. Preliminary research shows the possibility of mounting the energy recovery system in the engine compartment and the potential possibility of obtaining electricity in certain operating states of the combustion engine.

Keywords: diesel engine, electricity consumption, energy harvesting, mechanical vibrations, waste energy.

APPLICATION OF BIM SOFTWARE TO PROTOTYPE THE CONSTRUCTION SOLUTIONS RELATED TO SUSTAINABLE WATER MANAGEMENT IN URBAN AREAS

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Abstract: The presentation concerns the use of Building Information Modeling (BIM) software to prepare prototypes of virtual structures of single-family buildings, installations and infrastructure of housing estates for the implementation of solutions supporting sustainable water management in urban areas, including rainwater harvesting and Low Impact Development (LID) designs, counteracting the effects of climate change. Successful application of sustainable rainwater management, based also on LID designs, in urbanized or semi-urbanized catchments requires the careful planning during the decision-making process. Thus, application of BIM software may be useful in selection, design, dimensioning and validation of various LID and rainwater harvesting devices at the early stages of the designing process. Additionally, introduction of BIM to design may significantly improve communication between various steps of project management and decision-making, not only by a standard 3D visualization but also due to introduction of the detailed specifications and required quantities of materials and equipment. The developed BIM models of sustainable rainwater management in urbanized basins may be also used to mitigate risks and increase the possible benefits of managed systems.

Keywords: building information modeling (BIM), rainwater harvesting, 3D visualization.

APPLICATION OF 3D PRINTING FOR PROTOTYPING AND TESTING CONSTRUCTION SOLUTIONS IN THE FIELD OF LID AND RAINWATER HARVESTING

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Abstract: The problem of decreasing volume of water available for humans and environment is one of the most important present and future issues. In most cases, the rainwater appearing in urbanized areas is transported directly to rivers, causing its deficiencies in the ground reservoirs of mentioned areas. As the low impact development (LID) and rainwater harvesting become more popular, the proper use of collected water resources is becoming increasingly important. It is worth mentioning that solutions for collecting rainwater and creating projects that use rainwater for the needs of residents in single-family houses is one of the methods to minimize water uptake from ground reservoirs. The work concerns the use of 3D printing in the development and testing of building construction solutions along with water installations in order to implement LID and rainwater harvesting solutions in single-family housing estates. The elaboration is aimed at designing and developing solutions enabling the practical implementation of urban planning assumptions that counteract the effects of climate change and support the creation of self-sufficient settlements in terms of sustainable water management. Designed models and corresponding 3D prints allow finding better solutions in building holistic infrastructure for water harvesting system, and physically visualize the obtained results.

Keywords: water harvesting systems, 3d printing.

APPLICATION OF COMPUTER PROTOTYPING AND 3D PRINTING IN SAMPLING KITS AND PREPARATION TOOLS FACILITATING PERIPHYTON SLICES FOR BIOINDICATION STUDIES OF SURFACE WATER QUALITY

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Abstract: The work concerns the possibility of using computer prototyping and 3D printing of prepared models of periphyton sampling kits and tools that facilitate the preparation of microscopic slices that are used in bioindication studies of surface water quality. The presented examples refer to the design solutions of equipment and research related to the analysis of the impact of stormwater on the river. The influence of stormwater discharge into the receiver is assessed basing on the reactions of selected organisms present in periphyton samples collected using prepared devices. The above-mentioned analysis includes the use of methods for obtaining and processing multidimensional datasets describing structure of communities of microscopic organisms using entropy-basing algorithms. On the basis of the number of selected indicator organisms, the data on the Shannon Entropy index and its derivatives were developed, as well as changes in their values at subsequent measurement points located at different distances from the stormwater discharge were determined. The results summarizing the impact of urban stormwater networks on surface waters refer to the entire research cycle, presenting individual descriptive statistics of multidimensional data subsets accounting indicator organisms in the periphyton as well as descriptive statistics of entropy-based indices.

Keywords: 3D printing, computer prototyping, surface water quality.

THE CO_2 EMISSION BALANCE AND ABILITY TO CHIP WOOD BY 10 kW MACHINES USED IN URBAN AREAS IN TERMS OF INCREASING INTEREST IN USING WOOD BIOMASS RESOURCES FOR PERSONAL USE

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Abstract: Urbanized areas are spaces that provide interesting amounts of wood wastes to address as renewable resources. Due to limited working space in these areas, small, low-power wood chippers are used. Machines with similar power but different cutting mechanisms are available on the market. The article presents a study of four machines with four different cutting mechanisms: disc, drum, two cylinders, and flail. Wooden beams of three wood species (ash, pine, spruce) with varying hardness according to the Janka classification and ten cross-sectional dimensions ranging from 10×10 mm to 100×100 mm, along with a moisture content (MC) of 10±2%, were chipped. In the tested machines, stopping the working mechanism caused slippage of the V-belt transmission, protecting the machine from the consequences of overload. It was shown that in terms of chipping capabilities, drum, disc, two cylinders, and flail chippers, respectively, exhibit the highest to lowest capabilities. The range of materials shredded by the tested machines varies from 80×80 mm to 10×10 mm depending on the wood type and cutting mechanism. The average energy consumption of the tested machines is 2.07 ± 0.73 kWh, and the maximum value recorded for the drum chipper is 5.21 ± 0.2 kWh. Considering that the average emissions during the production of electricity from fossil fuels are 0.95 kg CO2 per 1 kWh, these machines produce from 1.97 kg CO2 h-1 to a maximum of 4.49 kg CO2 h-1. Assuming that one tree absorbs from 7 kg CO2 per year, it can be assumed that one tree reduces CO2 emissions from 3 hours of machine work over a year. This is a time significantly shorter than the time required to chip the branches of a single tree subjected to the pruning process. This allows for maintaining a positive CO2 reduction balance.

Keywords: wood chipper, wood shredders, energy consumption, overload of the drive system, cutting wood.

THE STUDY OF THE IMPACT OF OIL TYPE AND THROTTLING PRESSURE ON THE VIBRATIONS OF A GEAR PUMP

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Abstract: The aim of the article is to demonstrate the impact of the type of pumped oil on the values of kinematic excitations. Three groups of oils were examined: engine oils, hydraulic oils, and gear oils. The research methodology focused on measuring the average kinematic excitation and the dynamics of kinematic excitations for a fixed throttling pressure. The analysis of the results showed that the viscosity of the oil (ν) has a significant effect on the average kinematic excitation value (avg. R) in the group of oils intended for internal combustion engines, with $p = 0.0285$, while the influence of pressure (p) on avg. R was not statistically significant ($p = 0.0799$). However, for the dynamics of kinematic excitations (ΔR), pressure had a significant impact ($p = 0.00001$), while viscosity was not significant ($p = 0.9490$). In the groups of hydraulic and gear oils, none of the examined parameters showed a significant effect on avg. R. Pressure changes were significant only concerning ΔR in these groups. The highest ΔR values occurred at 0 bar pressure, indicating the influence of pressure on changes in kinematic excitations. It was also investigated that differences in the chemical composition of oils, although subtle, affect their physicochemical properties, which are important for cavitation occurrence and vibrations in the pump. Ultimately, selecting the appropriate oil, such as H2, significantly improves pump performance, which is crucial in hydraulic applications where operating pressure ranges from 100 to 300 bar.

Keywords: kinematic excitations of pumps, dynamics of kinematic excitations, choked flow, kinematic viscosity.