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CONTENTS

1. Angular Positioner Based on a Two-Drive System with Stepper Motors 9
Jan Wiśniewski, Maciej Bodnicki

2. Impact of Vibration Isolator Positioning on the Dynamic Response of Sensitive Loads in Transport Containers 10
Dawid Cekus, Marcin Dudek

3. Testing the Strength of T-Joints with Different Geometries 11
Tomasz Domański, Wiesława Piekarska, Zbigniew Saternus, Marcin Kubiak

4. In-Belt Sensors and Drive Unit Sensors 12
Paweł Domek, Piotr Krawiec

5. Modeling the Geometric Characteristics of Timing Belt Joints 13
Mateusz Domeracki, Grzegorz Domek, Elżbieta Gawrońska

6. Material Recovery of PVC Waste from Car Fillings to Elastomer Composites 14
Andrea Feriancová, Silvia Ďurišová, Jana Šulcová, Mariana Pajtášová, Katarína Moricová

7. Signal-Quality-Aware Adaptive Multimodal Fusion for Metal Active Gas Weld Quality Classification 15
Przemysław Frankiewicz, Michał Bembenek

8. Accuracy–Time Trade-Off in Reconstruction of the Heat Transfer Coefficient K Using ABC And ACO Algorithms 16
Maria Zych, Dyja Robert, Gawrońska Elżbieta

9. Effect of Transition Section Geometry on the Limit Force of Dry Ice Extrusion in Single-Channel Dies 18
Jan Górecki

10. CFD-Based Analysis of Pollutant Removal in a Photocatalytic Reactor 19
Anna Janicka, Rafał Mateusiak, Krzysztof Pawluk, Krzysztof Piekielniak, Maciej Zawiślak, Daniel Zybaczyński

11. Single-Frequency Smooth Ramps versus Stepwise TTS Multiplex: Monotonicity and Resolution Challenges in DMA Analysis of Elastomeric Systems 20
R. Janík, S. Ďurišová, M. Pajtášová, D. Ondrušová, P. Skalková, P. Matušíková

12. Design Consideration of Passenger Lift Platform for Mass Transport Application 22
Michał Kończak, Mateusz Kukla, Maciej Berdychowski

13. Trends in the Development and Applications of Belt Drives Using V-Belts 23
Piotr Krawiec, Grzegorz Domek

14. Numerical Simulation of Spring Elements with Elastomers 24
Jan Krmela, Darina Ondrušová, Vladimíra Krmelová, Terézia Matejíková, Rastislav Hruškovič, Daniela Marasová, Petr Jilek, Marek Makúch

15. Quantitative FTIR-Based Assessment of Storage-Induced Degradation in Cellulose Materials Using a Structured Analytical Workflow 25
Martina Fusková, Charles Lu, Vladimíra Krmelová, Jana Pagáčová, Jan Krmela

16. Comparative Analysis of Heat Source Models for Surface Laser Heating Using Single-Mode Core and Multi-Mode Ring Beam Configurations 27
Marcin Kubiak, Wiesława Piekarska, Tomasz Domański, Zbigniew Saternus

17. Preliminary Analysis of the Three-Dimensional Center of Gravity Position for Human–Wheelchair System: Implications for Stability 29
Mateusz Kukla, Michał Kończak, Maciej Berdychowski, Jan Górecki

18. The Numerical and Experimental Identification of Skid-Steering Parameters for an 8×8 Electric Unmanned Ground Vehicle 30
A. Zabrowarny, D. Minta, M. Macko

19. Analysis Of Deformations Of The Piston Geometry Of An Internal Combustion Engine Under Simulated Conditions Of Mechanical And Thermal Loads 32
Jarosław Markowski, Paweł Imiłkowski, Grzegorz Wieczorkiewicz, Krzysztof Jesionek, Paweł Wirkowski, Piotr Dlugiewicz

20. Influence of Natural Ageing on the Strength and Ductility of 1000 and 6000 Series Extruded Aluminium Profiles 34
Waldemar Matysiak, Jakub Kowalczyk, Dorota Czarnecka-Komorowska, Tomasz Tuński, Mladomir Milutinović

21. The Relationship Between Moulded Part Geometry and the Mechanical Properties of Amorphous Plastics in the Injection Moulding Process 36
Wojciech Zawalski, Dorota Czarnecka-Komorowska, Paweł Brzęk, Jana Petru, Waldemar Matysiak

22. Adaptive Flow Control of Axial Fans: Etaf Project Results 38
Piotr Odyjas, Ivan Kuric, Marek Macko, Damian Pietrusiak, Milan Sága, Andrzej Szczepańczyk, Zbigniew Szczepański, Mariusz Śliwiński, Kamil Urbański, Milan Vaško, Jędrzej Więckowski, Przemysław Moczko

23. Influence of Alternative Fillers on the Processing and Vulcanization of Elastomer Composites for Damping Element of Pipeline Conveyor Sliding Devices 39
D. Ondrušová, I. Labaj, M. Pajtášová, J. Krmela, R. Janík, D. Marasová, V. Krmelová, P. Matušíková

24. Rheological and Mechanical Properties of Rubber Composites Containing Aptes-Modified Bentonite 41
M. Pajtášová, Z. Mičicová, S. Božeková, D. Ondrušová, D. Marasová, R. Janík, S. Ďurišová, A. Feriancová

25. Discrete Element Simulation Sensitivity Analysis with Use of Design of Experiment 43
Damian Pietrusiak, Mateusz Pałowski, Michał Baranowicz

26. An Overview of the Space Engineering, Industry and New Space Economy Development 44
Damian Pietrusiak

27. Numerical Prediction of Stress State and Deformation in a Laser Welded Butt Joint of Dissimilar Materials 45
Zbigniew Saternus, Krzysztof Talaśka, Tomasz Domański, Marcin Kubiak

28. Strength Testing and Compliance Analysis of Cargo Securing Strap Components under Static Loading 46
Maciej Szulc, Dominik Wilczyński, Dominik Wojtkowiak, Krzysztof Talaśka

29. Mechanical Design and Analysis of the Test Bench for Evaluating the Performance Characteristics of Belt Drives 47
Krzysztof Talaśka, Dominik Wojtkowiak, Karol Konecki, Krzysztof Wałęsa

30. Measuring Internal Stresses In Modern Engineering Materials 48
Łukasz Urbaniak

31. The Influence of Discontinuity in Column Stiffness on Its Stability Taking Into Account Specific Load 49
Sebastian Uzny

32. Simulation Tests and Analysis of the Working Team of a Stone Collecting Machine 50
Konrad J. Waluś, Marek Gralak

33. Determination of Fuel Consumption Based on Exhaust Gas Concentration and Intake Manifold Vacuum Measurements 51
Łukasz Warguła, Aleksandra Świadek, Weronika Wiatrowska, Bartosz Wieczorek

34. Comparative Studies of Welded Joints in Drive Belts Made of Thermoplastic Elastomer 52
Krzysztof Wałęsa, Grzegorz Domek, Krzysztof Talaśka, Dominik Wilczyński

35. The Use of a Vision System and Laser Projection to Improve the Repeatability of sEMG Electrode Positioning 53
Weronika Wiatrowska, Bartosz Wieczorek, Aleksandra Świadek, Łukasz Warguła

36. Assessment of Muscle Effort Based on Cumulative Muscle Load (CML) in Wheelchair Motion Analysis 54
Bartosz Wieczorek, Weronika Wiatrowska, Aleksandra Świadek, Łukasz Warguła

37. Experimental Studies on the Efficiency of Threaded Connections 55
Dominik Wilczyński, Krzysztof Talaśka, Dominik Wojtkowiak, Krzysztof Wałęsa, Mikołaj Masztalerz, Bartłomiej Jętczak

38. Reclamation of Post-Mining Areas into PHS Energy Storage Facilities 56
Jędrzej Więckowski, Przemysław Moczko, Przemysław Szulc, Adam Bajcar, Marcin Baranowski, Tomasz Zawadzki

39. Integration of Fibre Optic Sensors in the Pultrusion Process: Preliminary Bending Test 57
Przemysław Moczko, Mateusz Mądry, Claudia Sbriglio, Bogusław Szczupak, Jędrzej Więckowski, Claudia Drebenstedt, Carsten Lies, David, Löpitz

40. Experimental Verification of a Methodology for Measuring the Mechanical Parameters of Belt Drives to Evaluate Their Performance Characteristics 58
Dominik Wojtkowiak, Krzysztof Talaśka, Karol Konecki, Krzysztof Wałęsa

41. Impact of Motion Profile Import Errors on Dynamic Loads in Hybrid Servo-Mechanical Actuators 59
Karol Wójkowski, Dominik Wojtkowiak, Dominik Wilczyński

42. CFD Analysis of Heat Transfer in a Thermoacoustic Refrigerator 60
Anna Janicka, Paweł Owczarek, Maciej Zawiślak

43. Evaluating Contamination Level of Engine Oil through Oxidation Parameters and Metal Content 61
Silvia Ďurišová, Iveta Papučová, Jana Pagáčová, Mariana Pajtášová, Róbert Janík, Andrea Feriancová

44. Multibody Dynamics in Designing and Validating a Laboratory Stand for Measuring Friction Coefficients via Torque Recording Method 62
Wiktor Łykowski, Łukasz Gierz

45. Upper Limb Positioning of the Wood Chipper Operator during Material Feeding 63
Aleksandra Świadek, Łukasz Warguła, Weronika Wiatrowska, Bartosz Wieczorek

46. Effect of Walnut Shell as Biofiller on Surface Free Energy Evolution and UV-Induced Degradation of Natural Rubber Composites 64
Jana Šulcová, Juliána Vršková, Petra Skalková, Slavomíra Božeková, Ivan Labaj, Andrej Dubec

47. Experimental Evaluation of Tensile Properties of Nylon White Produced by FFF 65
Jaroslav Majko, Milan Sága, Milan Vaško, Ján Mináriк

ANGULAR POSITIONER BASED ON A TWO-DRIVE SYSTEM WITH STEPPER MOTORS

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Keywords: angular positioner, stepping motor drive, positioning algorithm

Precise and fast angular positioners are used, for example, to determine the position of angular mirrors in laser systems. The use of stepper motors enables open-loop control. The concept and implementation of a two-stage angular positioner using two micro-stepper motors driving two series-connected drive stages are presented. The first stage performs the "coarse" motion, rotating the second stage with another micro-stepper motor coupled to a reduction gear – performing precise positioning. Both drives operate simultaneously – this configuration allows for maintaining high resolution and positioning accuracy while reducing the time required for its completion. Both micro-stepper motors were assumed to operate in full-stroke mode and in the start-up range. A significant element of the work was the development of a control algorithm for the positioner, determining the trajectories for the fastest achievement of the desired position by executing a combination of the coarse and fine motor steps based on the specified displacement and the current position. The design of the technology demonstrator and its test results are presented.

IMPACT OF VIBRATION ISOLATOR POSITIONING ON THE DYNAMIC RESPONSE OF SENSITIVE LOADS IN TRANSPORT CONTAINERS

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Keywords: dynamic impact, shipping container, shock isolation, finite element method

This paper analyses the arrangement of vibration isolators in shipping containers for sensitive cargo and their effect on the dynamic response resulting from rapid deceleration during ground impact. The containers under study feature an internal vibration-isolation system that uses springs made from specifically formed stainless steel wire rope. Since vibration isolators are costly components, tailoring their selection to cargo weight and predicted transportation loads is essential. Furthermore, isolator positioning plays a key role in mitigating impact amplitudes and preventing excessive cargo movement within the container structure. This study presents a case study of the consequences of non-optimized isolator quantity and placement, proposes alternative configurations, and evaluates their dynamic impact. The analyses focus on corner drops, as this configuration presents the greatest challenge for optimizing isolator layout. The results provide insight into the risks of improper configuration and offer design recommendations for building cost-efficient, custom containers that do not compromise cargo safety.

TESTING THE STRENGTH OF T-JOINTS WITH DIFFERENT GEOMETRIES

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Keywords: strength testing of T-joints; numerical modelling, laser welding

This work analyzes the strength of T-joints with varying geometries, with particular emphasis on the influence of shape, dimensions, and loading method on their load-bearing capacity and failure mode. The aim of the study was to determine how changes in the geometry of the joint components affect stress distribution, deformation, and the structure's resistance to static loads. The theoretical section discusses the basics of T-joint design, typical operating mechanisms, and the most common failure modes. A literature review on numerical and experimental modeling of such systems is also presented. The study included numerical analyses using the finite element method and experimental tests performed on samples with various geometric variants during a three-point bending test. The variables included web and flange thickness, varying weld parameters, and varying web geometry. The simulation results were compared with the experimental results, allowing for an assessment of the accuracy of the computational models. The obtained results demonstrated that the joint geometry has a key impact on its strength. Local stress concentrations in the transition zones and the ratios between the element thicknesses are of greatest importance. It was also demonstrated that appropriate modification of the shape can significantly reduce the mass of a T-joint without reducing its load-bearing capacity. Design recommendations for optimizing the geometry of T-joints were developed. The work confirms that T-joints can be effectively analyzed using FEM, provided the geometry and boundary conditions are properly represented. The research results can serve as a basis for further work on the optimization of steel structures.

IN-BELT SENSORS AND DRIVE UNIT SENSORS

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Keywords: sensors; belt; review; industry 4.0

This paper presents active (self-powered) and passive (unpowered) sensors. A comprehensive review and evaluation of sensors monitoring the operation of mechanical transmissions and belt systems has been conducted. Furthermore, the challenges of integrating and applying sensors within belts are addressed, alongside future development trends for sensor applications in industrial belting. Classification system for sensors in belt drives is proposed, based on the criteria of their location within the drive system, as well as their power supply and signal registration methods.

MODELING THE GEOMETRIC CHARACTERISTICS OF TIMING BELT JOINTS

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Keywords: timing belts; geometric modeling; dimensional analysis

This article presents an analysis of the geometric characteristics of joints used in drive belts, with particular emphasis on welded joints used in timing belts. The aim of the study was to determine the effect of finger joint geometry and belt end preparation parameters for the welding process on the load-bearing capacity and durability of the resulting joints. A dimensional analysis of selected structures was conducted, including an assessment of the geometric parameters responsible for load transfer and the shaping of the joint zone. The design solutions used were classified and their operational properties were assessed in terms of the strength and reliability of drive systems. The presented results provide a basis for the geometric modeling of timing belt joints and the identification of parameters that have a key impact on their performance. Despite the long-term use of drive belts in industrial practice, clear standardization guidelines for the design and construction of belt joints have not yet been developed, therefore this issue remains the subject of research and analysis.

MATERIAL RECOVERY OF PVC WASTE FROM CAR FILLINGS TO ELASTOMER COMPOSITES

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Keywords: PVC waste, recovery, recycling, elastomer composite

This study addresses the processing of PVC waste arising from the manufacture of interior door trim components of passenger vehicles. Using cutting mill, PVC manufacturing waste was ground into 3 various fractions (0.75; 1.0; 1.5 mm). PVC fractions were then analyzed by elementary and thermal analysis and employed in elastomer composites as fillers combined with carbon black and light filler kaolin. A PVC finer fraction (0.75 mm) was more suitable for maintaining stiffness and crosslinking level, while a coarser fraction (1.00 mm) contributed to improved processability, although the mechanical properties deteriorated. The composite containing 5 phr of PVC–0.75 mm fraction exhibited a slightly higher tensile strength and retained good ductility and hardness compared to standard. The finer fraction has a better reinforcing effect, when is more evenly dispersed in rubber matrix and ensures more efficient stress transfer. On the contrary, the coarser PVC fraction acts as a defect in the structure, which reduces the cohesion and strength of the material. PVC particle size is the key parameter governing the surface properties of the investigated composites. Larger particles (1.00 mm) lead to enhanced hydrophobicity and lower surface free energy due to morphological effects. The evaluation of rheological, vulcanization, physical and mechanical properties showed that the PVC waste can be reused as an filler in less demanding applications.

The authors thank to the Slovak Grant Agency for financial support KEGA 008TnUAD-4/2025, APVV-23-0342, and to the project "Centre for diagnostics and quality testing of materials" in the domains of the RIS3 SK specialization, code NFP313010W442.

SIGNAL-QUALITY-AWARE ADAPTIVE MULTIMODAL FUSION FOR METAL ACTIVE GAS WELD QUALITY CLASSIFICATION

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Keywords: MAG welding, multimodal sensor fusion, weld quality monitoring, explainable AI

Multimodal weld quality assessment systems that combine vision and process signals achieve high accuracy under stable laboratory conditions, yet their robustness to realistic measurement-channel perturbations, such as background noise, lighting variation, or degradation of a single sensor, remains poorly documented, as most studies validate models in a single controlled environment. This work proposes a quality classifier for welds produced by the Metal Active Gas (MAG) process, based on adaptive fusion of four signal modalities: welding current, welding voltage, arc acoustics, and post-weld vision. In the proposed architecture, the contribution of each modality to the final decision is computed per sample as a function of the estimated quality of the corresponding sensor signal, including the audio signal-to-noise ratio, image contrast and sharpness, and the root-mean-square level of background noise in the electrical acquisition channel. The probabilistic outputs of the classifier are additionally calibrated using temperature scaling to obtain reliable confidence estimates. Preliminary results indicate that single-modality classifiers show a marked accuracy drop between the reference measurement condition and the worst-case condition combining acoustic and visual perturbations; conventional fusion partially compensates for this drop, while the proposed signal-quality-aware adaptive fusion provides a measurable improvement over fusion that is not aware of the channel state, particularly under the worst-case condition. The architecture is computationally lightweight and feasible to deploy on a single embedded device, supporting its consideration as a candidate for integration with edge artificial intelligence systems for welding quality monitoring. Research project partly supported by program „Excellence initiative – research university" for the AGH University of Krakow.

ACCURACY–TIME TRADE-OFF IN RECONSTRUCTION OF THE HEAT TRANSFER COEFFICIENT K USING ABC AND ACO ALGORITHMS

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Keywords: swarm algorithms; time-varying thermal conductivity coefficient; thermal conductivity modeling; optimization of computational parameters

The accurate reconstruction of the heat transfer coefficient κ under the fourth-kind boundary condition remains one of the key inverse problems in heat conduction modeling, especially in applications related to the cooling of castings and imperfect thermal contact between the casting and the mold. In engineering practice, however, high solution accuracy alone is not sufficient. Equally important is the computational cost incurred to achieve such accuracy. This very problem serves as the starting point of this work. Instead of another classic comparison of optimization algorithm effectiveness, an assessment of their utility from the perspective of the trade-off between reconstruction error and computation time was proposed.

In the study, two swarm algorithms, Artificial Bee Colony (ABC) and Ant Colony Optimization (ACO), were considered and applied to the identification of the κ coefficient in the inverse heat conduction problem using tem-perature data. The calculations were performed in an original numerical environment based on the finite element method. As a quality criterion, the L2 error functional and the reconstruction error of the parameter κ relative to the reference value were adopted. The analysis was conducted for different population sizes, numbers of iterations, and levels of noise in the reference data. A key element of the work is the comparison of reconstruction quality with the time required to obtain a solution, and the determination of computational con-figurations that are most cost-effective from a practical standpoint.

The adopted approach allows moving away from the simplified criterion of "minimum error" and toward a more realistic approach to identifying the pa-

rameter κ. In many industrial tasks, a solution that is slightly less accurate but significantly faster can be more valuable than the numerically best result, even if computationally expensive. It is expected that the conducted analysis will identify the parameter ranges in which increasing the number of iterations or population size ceases to yield a proportional improvement in quality, and will also show which of the analyzed algorithms more frequently lead to solutions that dominate in the accuracy-time trade-off. In this context, the work contributes not only a comparison of two metaheuristics but, more importantly, a practical criterion for their conscious selection for tasks involving the reconstruction of thermal contact conditions.

EFFECT OF TRANSITION SECTION GEOMETRY ON THE LIMIT FORCE OF DRY ICE EXTRUSION IN SINGLE-CHANNEL DIES

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Keywords: dry ice extrusion, limit extrusion force, transition section geometry, conical–cylindrical die

This study investigates the effect of transition section geometry on the limit extrusion force in the dry ice compaction–extrusion process using single-channel conical–cylindrical dies. The analysis focuses on a comparative evaluation of the maximum process force recorded for a reference die with a conical–cylindrical channel and an outlet diameter of 16 mm, and three geometrically modified dies incorporating a convex transition section with different radii of curvature.

Particular attention is devoted to the influence of the geometrical continuity between the converging (conical) and calibration (cylindrical) zones on the stress–strain state of the compacted material and the resulting extrusion load. Experimental investigations were carried out using a proprietary test rig described in Patent No. Pat.243496, in conjunction with a dedicated experimental procedure ensuring repeatability of process conditions.

Each experimental variant was performed in 16 repetitions to ensure statistical robustness. The acquired data were subjected to statistical inference using analysis of variance (ANOVA), enabling the assessment of the significance of differences in limit force values between the examined die configurations.

The obtained results indicate that increasing the radius of curvature of the convex transition section leads to a statistically significant reduction in the limit extrusion force. This effect can be attributed to the mitigation of local stress concentrations and improved material flow conditions within the die. Consequently, the proposed geometric modification contributes to enhanced process efficiency, reduced mechanical loading of the extrusion system, and increased operational durability of tooling used in dry ice pelletization.

CFD-BASED ANALYSIS OF POLLUTANT REMOVAL IN A PHOTOCATALYTIC REACTOR

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Keywords: photocatalytic reactor, computational fluid dynamics, pollutant removal, air purification

Photocatalytic reactors are recognized as one of the most promising technologies for reducing gaseous pollutant concentrations and improving air quality in industrial and environmental applications. The objective of this study is to develop and apply a Computational Fluid Dynamics (CFD) model to investigate pollutant removal processes in a photocatalytic reactor. The numerical analysis includes the evaluation of flow velocity distribution, residence time within the active reaction zone, and coupled mass transport and heterogeneous reaction processes occurring on the photocatalyst surface. The proposed model enables the assessment of the influence of operating conditions and reactor geometry on pollutant removal efficiency while identifying design solutions that enhance reactor performance. CFD simulations provide detailed information on transport phenomena that are difficult to obtain experimentally and therefore constitute an effective tool supporting reactor design and optimization. The developed numerical methodology may contribute to the improvement of photocatalytic air purification systems and facilitate the development of more efficient environmental protection technologies.

SINGLE-FREQUENCY SMOOTH RAMPS VERSUS STEPWISE TTS MULTIPLEX: MONOTONICITY AND RESOLUTION CHALLENGES IN DMA ANALYSIS OF ELASTOMERIC SYSTEMS

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Keywords: DMA analysis, frequency; DCSBD plasma treatment; elastomeric vulcanizates

Dynamic mechanical analysis (DMA) combined with time-temperature superposition (TTS) represents an important approach for evaluating the viscoelastic behavior of elastomeric systems. However, the practical implementation of TTS through coarse stepwise multiplex measurements may introduce limitations affecting the continuity, monotonicity, and interpretability of relaxation-related parameters. This study compares two experimental approaches for DMA evaluation of elastomer vulcanizates: conventional stepwise TTS multiplex measurements and smooth single-frequency temperature ramps performed independently at multiple loading frequencies. The analysis focused primarily on the temperature evolution of tanδ maxima and on the suitability of the obtained datasets for manual shift-factor determination and subsequent overlay construction. The results demonstrated that smooth single-frequency ramps provided a continuous and physically consistent monotonic increase of the tanδ peak temperature with increasing logarithmic loading frequency. In contrast, the stepwise multiplex TTS approach generated discretized and partially segmented trends caused by coarse temperature stepping, leading to reduced resolution of Tg evolution and less reliable interpolation between intermediate frequencies. Manual shifting of smooth-ramp datasets enabled substantially improved overlap of viscoelastic response curves compared with multiplex-derived data; however, complete superposition of the tanδ profiles was not achieved,

particularly in the high-temperature tail region, indicating limitations of ideal thermo-rheological simplicity in the investigated elastomeric system.

This work was supported by the: Scientific Grant Agency (VEGA project No. 1/0251/26) of the Ministry of Education, Research, Development and Youth of the Slovak Republic and the Slovak Academy of Sciences; Cultural and Educational Grant Agency (KEGA project No. 009TnUAD-4/2026) and the project APVV-23-0342; Operational Programme Integrated Infrastructure, co-financed by the European Regional Development Fund by the project: Advancement and support of R&D for "Centre for diagnostics and quality testing of materials" in the domains of the RIS3 SK specialization, Acronym: CEDITEK II., ITMS2014+ code 313011W442.

DESIGN CONSIDERATION OF PASSENGER LIFT PLATFORM FOR MASS TRANSPORT APPLICATION

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Keywords: disability, passenger lift platform, transport platform kinematics, wheelchair

The development of public transport and the increasing requirements for vehicle accessibility have created the need for solutions enabling the transport of wheelchair users. This issue is particularly important in the case of intercity buses that are not low floor or low entry vehicles, where the height difference between road level and the vehicle interior floor makes the use of conventional access ramps impractical. The aim of this study was to analyse and evaluate different kinematic structures of transport platforms intended for this type of vehicles. Nine design variants were considered, differing in the method of motion execution and the possibility of integration with the vehicle structure. The assessment was carried out using five qualitative criteria, including the simplicity of the kinematic system, expected structural rigidity, simplicity of control, spatial requirements, and user ergonomics. Based on the analysis, a variant using two revolute kinematic pairs and one linear kinematic pair was selected. For the selected solution, a concept for integration within the passenger entrance area of the bus and a simplified dynamic model for determining the drive torque demand were presented. The study also indicates basic operational hazards and directions for further structural verification, including strength analysis, drive system selection, and assessment of the possibility of integrating the platform with an actual vehicle structure.

TRENDS IN THE DEVELOPMENT AND APPLICATIONS OF BELT DRIVES USING V-BELTS

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Keywords: Industrial Revolution, V-belt drives, power transmission

The Industrial Revolution saw the intensive development of steam engines, gear transmissions and belt drives. A key breakthrough in the use of V-belts occurred in 1917, when the American inventor John Gates patented the first belt of this type. His invention was based on a trapezoidal belt cross-section, which ensured better contact with the pulley and reduced the problem of slippage. It was successfully used in the drives of the first Mercedes-Benz car models. Today, V-belt drives are used in many different industries, including transport, the automotive sector, agriculture, as well as the food and textile industries. Modern, fully synthetic, high-performance V-belts are equipped with a durable and resilient carrier layer made of polyamide, polyester or aramid, and a wear-resistant, oil- and grease-resistant friction layer made of rubber. They ensure a high and constant coefficient of friction between the belt and the pulleys. Modern V-belts are manufactured as: toothed – externally or internally, composite, with bevelled sides, multi-groove, standard-profile (classic), open (very long belts), heat-sealable. High-performance synthetic V-belts are currently used in all areas of power transmission technology due to their versatility, excellent properties and exceptional reliability.

NUMERICAL SIMULATION OF SPRING ELEMENTS WITH ELASTOMERS

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Keywords: ANSYS, FEA, elastomer, Mooney–Rivlin

This paper presents the numerical simulation of spring elements incorporating elastomer components using the ANSYS finite element software. The hyperelastic behavior of the elastomer material is described by the Mooney–Rivlin constitutive model, whose parameters were determined from experimental uniaxial tensile tests. The developed numerical model is used to evaluate the mechanical response of the spring element and to assess the influence of the elastomer on its stiffness characteristics. This research work has been supported by the Cultural and Educational Grant Agency of the Slovak Republic (KEGA) under grant KEGA 001TnUAD-4/2025 and the Slovak Research and Development Agency (APVV) under grant APVV-23-0342.

QUANTITATIVE FTIR-BASED ASSESSMENT OF STORAGE-INDUCED DEGRADATION IN CELLULOSE MATERIALS USING A STRUCTURED ANALYTICAL WORKFLOW

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Keywords: FTIR, paper, degradation, mechanical properties

Cellulose-based materials undergo gradual physicochemical degradation during long-term storage, which affect structural integrity and mechanical stability. Although Fourier Transform Infrared (FTIR) spectroscopy enables detection of molecular-level changes, comparative evaluation of time-separated spectra is frequently qualitative and dependent on expert interpretation. This study presents a quantitative analytical workflow for degradation assessment implemented within a modular web-based environment. Two temporally separated FTIR datasets obtained from archival cellulose materials were analysed within a case study conducted in cooperation with the Public Library in Trenčín (Slovakia). Characteristic cellulose absorption bands were extracted and relative absorbance change (ΔI) was calculated to classify degradation trends. Results indicate increased O–H and C=O absorption, suggesting moisture interaction and oxidative ageing, accompanied by modification of aliphatic structures. The structured ΔI-based classification reduces subjectivity in spectral interpretation and supports material stability optimisation. The proposed framework demonstrates reproducible spectroscopic degradation assessment applicable to cellulose-based systems and materials engineering diagnostics.

This work was made possible through financial support from the MIT–Slovakia Seed Fund project, "Modular Web App and Material Innovation with AI Tools for Art Conservation and Preservation of Cultural Heritage Including Sustainable

Varnishes", implemented in cooperation with the Ministry of Investment, Regional Development and Informatization of the Slovak Republic, and from the Cultural and Educational Grant Agency of the Slovak Republic (KEGA) under Grant No. KEGA 001TnUAD-4/2025.

COMPARATIVE ANALYSIS OF HEAT SOURCE MODELS FOR SURFACE LASER HEATING USING SINGLE-MODE CORE AND MULTI-MODE RING BEAM CONFIGURATIONS

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Keywords: laser beam heating, heat source model, numerical modelling

Laser-based surface heating and melting processes are widely applied in advanced manufacturing and materials processing. The increasing availability of beam shaping technologies, including single-mode (SM) core beams and multi-mode (MM) ring beams, has created new possibilities for controlling heat input distribution and thermal gradients. However, accurate numerical prediction of thermal phenomena in such processes strongly depends on the selection of an appropriate heat source model. Existing formulations, including Gaussian, conical, Goldak-type, and composite multi-Gaussian models, differ significantly in their ability to represent localized and distributed energy inputs.

The aim of this work is to perform a systematic comparative analysis of selected analytical heat source models for numerical simulation of laser-based surface heating using single-beam core and multi-beam ring configurations. The study considers several commonly used formulations, including Gaussian surface models, volumetric conical models, Goldak double-ellipsoid sources, and composite models combining multiple Gaussian components. Additionally, a cylindrical-power-involution (CIN) formulation is introduced as a flexible approach for representing both concentrated and distributed heat inputs within a unified framework.

Numerical simulations are performed for bead-on-plate surface heating of structural steel, with separate analysis of single-mode core beam, multi-mode

ring beam, and combined core–ring configurations. The models are evaluated based on their ability to reproduce characteristic thermal features, including temperature distribution, fusion zone (FZ) geometry, heat-affected zone (HAZ) extent as well as penetration depth. Quantitative comparison is carried out using geometric metrics and error analysis relative to experimental measurements.

PRELIMINARY ANALYSIS OF THE THREE-DIMENSIONAL CENTER OF GRAVITY POSITION FOR HUMAN-WHEELCHAIR SYSTEM: IMPLICATIONS FOR STABILITY

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Keywords: disability; wheelchair, biomechanics, center of gravity, stability

Manual wheelchairs are critical for individuals with mobility impairments, offering independence and enabling social participation. Stability, significantly influenced by the center of gravity (COG), is a key factor in ensuring user safety. COG shifts, caused by user movements or external forces, can compromise stability, leading to accidents such as falls. This study aims to determine the three-dimensional COG position of a human-wheelchair system under various user postures, providing essential insights for improving wheelchair design and safety features. The study utilized a four-support weighing scale with force transducers to measure COG coordinates. Measurements were conducted in quasi-static conditions, altering the participant's posture while the wheelchair was inclined at a 15° angle. Various postures representing real-life activities were simulated, and the effects of an additional 5 kg external load were analyzed. The findings revealed that the baseline COG height of the wheelchair was approximately 379 mm, which dropped to 305 mm when occupied. Horizontal COG shifts ranged from 279 mm to 413 mm (front-back) and 428 mm to 602 mm (side-to-side) depending on the posture. Vertical COG variations were negligible under the tested conditions. The study highlights the importance of COG positioning in wheelchair stability, providing data to inform the design of safer mobility aids and associated infrastructure. Future research will expand to include a diverse participant pool and dynamic stability assessments.

THE NUMERICAL AND EXPERIMENTAL IDENTIFICATION OF SKID-STEERING PARAMETERS FOR AN 8X8 ELECTRIC UNMANNED GROUND VEHICLE

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Keywords: Skid-steering, unmanned ground vehicle, UGV, electric vehicle, trajectory prediction, mobile robotics

Skid-steering unmanned ground vehicles are mechanically straightforward and robust, but accurate prediction of their motion remains challenging due to lateral slip, wheel-ground interaction and surface-dependent turning resistance. Previous studies have addressed experimental kinematics and slip effects in skid-steered mobile robots [1]–[3], demonstrating the importance of experimental identification and model correction for reliable motion prediction. However, most available studies focus on four- or six-wheeled platforms, while heavy-duty 8×8 electric UGVs introduce additional challenges related to increased contact points, higher turning resistance and more complex slip behaviour.

This paper presents a numerical and experimental analysis of skid-steering dynamics of an electric 8×8 unmanned ground vehicle. The aim of the study is to develop and validate a simplified numerical model suitable for preliminary trajectory prediction and control parameter tuning of a prototype 8×8 UGV. The vehicle is modelled as a two-sided drive system, in which the longitudinal velocities of the left and right sides determine translational velocity and yaw rate. The ideal kinematic model is extended by introducing surface-dependent slip correction coefficients identified from experimental tests. The experimental campaign includes straight-line motion, constant-command turning and zero-

radius rotation on selected ground surfaces. During the tests, drive commands, motor rotational speeds, motor current, battery voltage, inertial measurements and vehicle trajectory data are recorded. Simulated trajectories and yaw rates are compared with experimental results before and after slip-parameter identification. The results demonstrate a practical modelling procedure for estimating skid-steering parameters of heavy-duty 8×8 UGVs and confirm improved agreement between numerical predictions and real vehicle behaviour.

Acknowledgements

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ANALYSIS OF DEFORMATIONS OF THE PISTON GEOMETRY OF AN INTERNAL COMBUSTION ENGINE UNDER SIMULATED CONDITIONS OF MECHANICAL AND THERMAL LOADS

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Keywords: simulations, deformations, thermal, piston

The deformation of an internal combustion engine piston depends on many factors: material, geometric shape, and mechanical and thermal loads resulting from the effects of thermal processes occurring in the combustion chamber. All of these factors are important and influence the operating conditions and service life of internal combustion engines. This is particularly important when adapting internal combustion engines to run on various fuels. Modifying the combustion process modifies the way thermodynamic parameters in the combustion chamber interact with the piston crown surface. This changes the piston's geometry during operation, affecting its interaction with the cylinder liner surface. These changes can cause piston deformation, which worsens the conditions for oil film formation, significantly reducing service life and increasing the likelihood of failure. Therefore, it is necessary to adjust the piston geometry so that dimensional changes resulting from material expansion resulting from changes in piston temperature occur within the accepted tolerance range. Therefore, a piston geometry model was developed, the thermal and mechanical loading conditions of the piston resulting from its operating conditions in a reciprocating engine

were analyzed, several piston load states were selected, and simulation studies were conducted using numerical tools enabling FEM analysis. The simulation studies assessed the relationship between the thermal and mechanical loading conditions of the piston and its deformation. The obtained results were compared with the permissible dimensional tolerances for the piston-cylinder pair of an internal combustion engine. The obtained characteristics of the relationship between the geometry deformation and the thermal and mechanical load were used in the design of the engine piston geometry.

INFLUENCE OF NATURAL AGEING ON THE STRENGTH AND DUCTILITY OF 1000 AND 6000 SERIES EXTRUDED ALUMINIUM PROFILES

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Keywords: Al-Mg-Si, natural ageing, mechanical properties, precipitation ageing

This publication aims to: compare the dynamics and extent of change in mechanical properties (Rm, $R_{p0.2}$, A, E) in extruded 6000-series (6060, 6063, 6005A, 6082) and pure Al (1070A) profiles during 20 days of natural ageing (NA); determine whether 6000-series alloys achieve performance according to standards or practical requirements after ~2 weeks without artificial ageing; discuss the influence of extrusion parameters (temperatures, velocities, cooling) on the supersaturated state and potential for NA, which a key phenomenon affecting the strength properties of Al-Mg-Si aluminium alloys (6000 series) after extrusion in the supersaturated solid solution state (SSSS). In the present study, four 6000-series alloys (EN AW-6060, 6063, 6005A, 6082) and one 1000-series alloy (EN AW-1070A - pure Al) were tested to determine the extent and dynamics of mechanical changes over 20 days of storage at room temperature (22 ±2°C). Measurements were taken every 2 days, analysing tensile strength (Rm), yield strength (Rp0.2), elongation (A5, A50) and Young's modulus (E). The results show that Al-Mg-Si alloys can achieve an increase in Rm of up to +30 MPa, while pure Al practically does not change the strength parameters. The paper also presents the role of extrusion parameters (speed,

temperature, cooling intensity) in obtaining a supersaturated state. Ultimately, the results suggest that, in many applications, 1–2 weeks of natural ageing is sufficient to achieve the requirements of EN 755-2 standards, thus reducing the time and cost associated with T6 processing, especially in less critical applications.

THE RELATIONSHIP BETWEEN MOULDED PART GEOMETRY AND THE MECHANICAL PROPERTIES OF AMORPHOUS PLASTICS IN THE INJECTION MOULDING PROCESS

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Keywords: injection moulding, amorphous plastics, die insert, MES

The paper presents the influence of molded-part geometry on the mechanical properties of selected amorphous plastics produced by injection molding. The study was conducted for three thermoplastics, such as poly(methyl methacrylate) (PMMA), polycarbonate (PC), and transparent acrylonitrile-butadiene-styrene copolymer (mABS). Specimens were manufactured using a modular injection mold equipped with an aluminum die insert containing different of forming-surface geometry. The insert was made from PA45 aluminum alloy by CNC machining and mounted in the mold cavity. In this paper the insert design, injection molding process, specimen preparation, and a static flexural testing was done. The objective was to determine the effect of the forming-surface geometry on flexural modulus, strength, and failure plastic behaviour. The results showed that the moulded-part geometry significantly affected the mechanical properties of amorphous polymers, and that this effect depends on the material structure.

For PMMA, the highest flexural modulus was obtained for geometry B, whereas geometry D resulted in the lowest stiffness and strength. For mABS, the highest flexural strength was also recorded for geometry B, while the material exhibited greater plastic deformability than PMMA. The experimental

results were supported by finite element analysis, which enabled assessment of stress distribution depending on specimen geometry and polymer type. The calculations confirmed distinct mechanisms of deformation response; for example, PMMA reached stress levels that led to brittle fracture; mABS exceeded the yield limit and underwent permanent deformation, whereas PC did not reach the yield limit under the adopted loading conditions. The results indicate that moulded-part geometry should be treated as a significant structural feature affecting a big impact on load transfer, stress concentration, and the final mechanical properties of injection-moulded products. The most favorable response was obtained for geometry B, particularly for PMMA and mABS, while geometry D reduced the mechanical parameters.

ADAPTIVE FLOW CONTROL OF AXIAL FANS: ETAF PROJECT RESULTS

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Keywords: axial fan, adaptive geometry, flow control, CFD, experimental validation, energy efficiency

The EUREKA project "Effective Technology for Flow Parameters Adjustment of Axial Fans" (ETAF) developed and validated a new regulation method for industrial axial fans. The concept uses divided impeller blades and guide vanes, with adjustment limited to selected blade portions: a movable trailing-edge part in the impeller and an adjustable inlet part in the downstream guide vane. The project combined analytical design, CFD simulations, FEM strength and modal analyses, mechanism development, prototype manufacture and standardized testing. A demonstrator with a 1000 mm impeller diameter, 10 impeller blades and 9 guide vanes was manufactured. Tests covered 122 adaptive geometry configurations and included measurements of pressure rise, flow rate, shaft power, efficiency, vibration and noise. The results confirmed that coordinated geometry adjustment shifts the fan performance curves and extends the controllable operating range without changing rotational speed. The developed solution was most effective in the lower-flow and lower-pressure range, while comparison with a reference fan having fully adjustable impeller blades identified limitations at the highest duty levels. The project confirmed the feasibility of partial-blade regulation and established a basis for scale-up to high-power industrial fans.

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INFLUENCE OF ALTERNATIVE FILLERS ON THE PROCESSING AND VULCANIZATION OF ELASTOMER COMPOSITES FOR DAMPING ELEMENT OF PIPELINE CONVEYOR SLIDING DEVICES

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Keywords: elastomer composites, alternative fillers, sliding devices, pipeline conveyor

This paper deals with the mixing and vulcanization processes of elastomeric composites intended for use as damping elements in sliding assemblies for pipe conveyor systems. The aim of the study was to analyze the effect of alternative waste-based fillers on the processing and vulcanization characteristics of elastomeric composite systems and to evaluate their potential as substitutes for the conventional filler, carbon black. Within the experimental part, elastomeric composite systems were prepared with partial and complete replacement of carbon black by alternative fillers. Their processability during mixing was monitored, followed by an investigation of the vulcanization process and the corresponding vulcanization characteristics. The results showed that both vulcanization behavior and processability were influenced by the type and amount of filler used. The alternative fillers demonstrated the ability to modify the course of crosslinking reactions and the rheological behavior of the elastomeric systems, while changes in the overall stiffness of the composite systems and their processing properties were also observed. The resulting systems were further analyzed in terms of carbon footprint reduction and raw material cost savings, representing key techno-economic and environmental benefits of the proposed elastomer compound formulations for the intended application.

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RHEOLOGICAL AND MECHANICAL PROPERTIES OF RUBBER COMPOSITES CONTAINING APTES-MODIFIED BENTONITE

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Keywords: APTES; bentonite; natural rubber; surface modification; rubber composites

This study investigates the surface modification of bentonite using (3-aminopropyl)triethoxysilane (APTES) and its application as a partial replacement for a conventional reinforcing filler in natural rubber composites. The objective was to improve the compatibility between bentonite particles and the rubber matrix through silane surface treatment and to evaluate its effect on the rheological and mechanical properties of the resulting composites. The modified bentonite was prepared using three APTES concentrations. The physicochemical changes induced by the surface treatment were characterized by Fourier transform infrared spectroscopy (FTIR) and thermal analysis. Rubber composites containing modified bentonite were prepared and evaluated in terms of their rheological behaviour during vulcanization using torque measurements. The mechanical properties of the vulcanizates were assessed by tensile testing. The results demonstrated that APTES surface modification enhanced the interaction between bentonite and the rubber matrix, resulting in improved reinforcing efficiency compared with unmodified bentonite. The composite containing bentonite modified with the lowest APTES concentration exhibited the most favourable balance of mechanical properties, whereas higher silane concentrations did not provide additional improvement. Furthermore, the surface treatment promoted better filler dispersion and stronger filler–rubber interactions. In conclusion, APTES-modified bentonite represents a promising alternative reinforcing filler for natural rubber composites and demonstrates the potential of surface modification as an effective strategy for enhancing composite performance.

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DISCRETE ELEMENT SIMULATION SENSITIVITY ANALYSIS WITH USE OF DESIGN OF EXPERIMENT

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Keywords: discrete element method, design of experiment, lunar regolith, static angle of repose

Numerical simulations of every process or structure bring the challenge of results accuracy and validity. The most common parameters of every numerical simulation are boundary conditions, which can be understood as external loads and constraints, material parameters, and interactions representing the physics behind properly defined phenomena, e.g., contact, electrostatics, etc. In the Discrete Element Method, great focus must be given to the material parameters. As the material is represented in the discrete domain, the interactions within each particle must be considered, which is not the case in Eulerian simulations. Moreover, the shape and size of discrete particles play an important role in simulation calibration. As a result, one can get hundreds or more combinations to test the model sensitivity. In the presented paper, the Design of Experiment methodology, based on the Plackett-Burman screening method, will demonstrate how to overcome this problem. The authors present how to identify the parameters with statistically meaningful influence on the process. Eventually, the number of simulations for the sensitivity analysis will be reduced to 24 in one run. The methodology will be presented using the example of static angle of repose simulations of lunar regolith.

AN OVERVIEW OF THE SPACE ENGINEERING, INDUSTRY AND NEW SPACE ECONOMY DEVELOPMENT

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Keywords: space engineering, new space economy

The history of space exploration can be dated to 1957, when the first satellite, Sputnik, was launched into space. That action started the politically driven space race between two superpowers, which brought great development in space engineering and ended with the Moon landing by the Apollo 11 mission crew in 1969. Since that time, development in the space industry has taken place at a slower pace and has been driven mostly by research and scientific missions. The last two decades have brought a paradigm shift in space exploration. The main role of national space agencies, such as NASA, has changed from a single technology developer to a leader that cooperates with private companies, which are now the developers of many technologies. As a consequence, a new market of the New Space economy has developed what accelerated again the space technologies development. The paper presents the historical, engineering, and economic background of the transformation from space science and engineering into a new space industry independent market.

NUMERICAL PREDICTION OF STRESS STATE AND DEFORMATION IN A LASER WELDED BUTT JOINT OF DISSIMILAR MATERIALS

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Keywords: laser welding, dissimilar materials, thermal phenomena, numerical modelling

Welded joints of dissimilar material have recently gained significant importance and widespread implementation in both the automotive and aerospace sectors. Depending on the material combination used, the thermo-mechanical and anti-corrosion properties of the resulting joint are required. The main aspect of the use of dissimilar components in the transport industry is the economic factor. Today, there are an increasing number of methods used to join these materials, one of which is laser welding. The laser beam creates a smooth weld that does not require additional finishing. The main objective of this paper is to present the results of a numerical prediction of the stress and deformation state in a laser welded joint made of dissimilar materials. The numerical studies carried out are based on experimental investigations, which are also used to verify the simulation results. As part of the experimental work, two butt welded dissimilar joints with thicknesses of 2 mm and 4 mm were produced. Macroscopic and microscopic examinations of the joint, as well as hardness measurements, were performed. Numerical models of the welded joints were developed in simulation software. The numerical analysis takes into account the thermophysical properties of plates made of two different materials: S355 structural steel and 304 austenitic stainless steel. Due to the structural changes occurring in S355 carbon steel during the welding process, the structural state of the welded joint was estimated numerically. Temperature distributions, the shape and size of melted zone, structural composition of the joint as well as residual stress and deformations are presented for analyzed elements. The numerical results obtained are compared with the results obtained experimentally.

STRENGTH TESTING AND COMPLIANCE ANALYSIS OF CARGO SECURING STRAP COMPONENTS UNDER STATIC LOADING

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Keywords: web lashing, strength testing, failure analysis, cargo securing system

This paper presents the results of strength tests conducted on components of a cargo securing strap used for load restraint applications. Experimental tensile tests were performed on three main elements of the system: the polyester webbing, the ratchet tensioner, and the fastening hook. The aim of the study was to determine the maximum failure load of individual components, identify the dominant failure mechanisms, and establish load–displacement characteristics enabling the assessment of their compliance.

The tests were carried out using a universal testing machine equipped with force and displacement measurement systems. Based on the obtained results, the stiffness of individual components, their contribution to the overall elongation of the assembly, and the load levels corresponding to the onset of permanent deformation and failure were determined. The analysis made it possible to identify the components most susceptible to deformation and to evaluate the safety margins with respect to the declared operational parameters.

The obtained results may provide a basis for improving the design of cargo securing straps, developing procedures for technical condition assessment, and enhancing the safety of cargo transportation and load restraint systems.

MECHANICAL DESIGN AND ANALYSIS OF THE TEST BENCH FOR EVALUATING THE PERFORMANCE CHARACTERISTICS OF BELT DRIVES

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Keywords: belt transmission, machine design, FEM analysis, test stand

The paper presents the mechanical design and structural analysis of a laboratory test bench developed for evaluating the performance characteristics of belt drive systems. The stand enables controlled investigations of parameters such as transmission efficiency, belt tension, slip, vibration, and temperature under variable operating conditions. Additionally, due to its modular design, the test bench can accommodate different belt types and pulley configurations, increasing its applicability for research and educational purposes. The developed system provides a reliable platform for experimental studies and validation of theoretical models related to belt drive performance and durability. The design process involved the selection of key mechanical components, including the frame, shafts, bearings, pulleys, tensioning system, electric and hydraulic drives, with emphasis on structural rigidity, operational safety, and measurement accuracy. A 3D CAD model of the test bench was developed to improve the construction and its manufacturing and assembly process. Finite Element Analysis (FEA) was carried out to evaluate the strength and deformation of the supporting structure under expected loading conditions. The analysis confirmed that the designed mechanical components meet the required stiffness and strength criteria, ensuring stable operation during experimental testing.

MEASURING INTERNAL STRESSES IN MODERN ENGINEERING MATERIALS

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Keywords: aluminium alloys, internal stresses, stress-relieved materials

The mechanical engineering and industrial automation industries are seeking lightweight, durable materials free of internal stresses. These characteristics are often mutually exclusive. Increasingly tight dimensional tolerances for machine parts and the time commitment of machining processes are placing pressure on the use of innovative materials. Material innovations are primarily related to production technologies and processes. Materials with the same chemical composition, known to engineers for decades, can currently exhibit very different technological and strength properties. Modern technologies enable the production of durable metal alloys while significantly eliminating internal stresses. These material characteristics make it significantly easier to achieve tight dimensional tolerances in parts manufactured from them, while simultaneously reducing the time and production resources involved. Internal material characteristics directly translate into external dimensional tolerances of the semi-finished product, the finished part, and the part during operation, for example, under difficult conditions associated with elevated operating temperatures. Plastic processing (forging, rolling) is used to strengthen the material. However, this treatment introduces undesirable internal stresses, which are released during machining and use of the part. On the other hand, eliminating undesirable internal stresses is associated with a loss of material strength parameters. Internal stresses occur to a greater or lesser extent depending on the technological processes used to produce the raw materials. Based on destructive testing, an attempt was made to measure internal stresses, as presented in this article using the example of tool-grade, structural aluminium alloys.

THE INFLUENCE OF DISCONTINUITY IN COLUMN STIFFNESS ON ITS STABILITY TAKING INTO ACCOUNT SPECIFIC LOAD

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Keywords: stability, column, specific load

This work considered a column subjected to a specific compressive load using a design variant of loading heads composed of circular elements. Cases of specific loading with a force directed towards the negative pole, both a generalized load and a follower force, were considered. Stiffness discontinuities were considered in the column, modeled using a rotational spring. The lower the stiffness of the rotational spring, the greater the discontinuity. The stability problem was formulated based on the principle of minimum potential energy. The effect of discontinuity parameters on the critical load of the considered column was numerically investigated. The column discontinuity parameters are: the size of the discontinuity, determined by the spring stiffness, and its location. The critical load is also influenced by the parameters of the system loading the column, which were also included in the numerical studies. The parameters of the loading system include the radii of the load-inducing and load-receiving heads, and the length of the rigid bolt connecting the load-receiving head to the column. One of the goals of this work is to locate the location of the stiffness discontinuity at which the critical load will be weakly dependent on the size of the discontinuity. Determining the location of a discontinuity that is weakly sensitive to its size is important because it seriously limits the diagnostic capabilities of the support system in the event of cracks or other factors causing disruption of the column structure.

SIMULATION TESTS AND ANALYSIS OF THE WORKING TEAM OF A STONE COLLECTING MACHINE

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Keywords: tractor, three-point hitach, stone harvesting machine, FEM analysis, agricultural implement

The presence of stones in the fields poses a threat to agricultural machinery and may limit the amount of harvest. The paper presents a conceptual design of a stone collection machine. The designed machine is characterized by a compact structure and geometry that allows it to move on public roads. The strength analysis using the finite element method FEM was performed on the working system and the basket for collecting stones. The presented tests showed that the bottom of the basket will withstand its filling with collected stones as well as the impact of a single falling stone weighing one hundred kilograms. In order to ensure the correct operation of the working system, an experiment was carried out to determine the working angle in real working conditions and it was shown that the best working angles are those with values of 20° and 30°. Three variants of the working unit geometry were presented and a strength analysis of the system was carried out. The study discussed the advantages and disadvantages of the developed design as well as legal requirements and standards for machine design in Europe. The aim of the paper is to numerically analyze the design of the stone collection machine, assess the state of stress and the value of displacements under the influence of load.

DETERMINATION OF FUEL CONSUMPTION BASED ON EXHAUST GAS CONCENTRATION AND INTAKE MANIFOLD VACUUM MEASUREMENTS

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Keywords: testing of combustion engine machines

The article presents a method for determining fuel consumption based on measurements of exhaust gas component concentrations and vacuum pressure in the intake manifold of an internal combustion engine. The developed method enables indirect determination of instantaneous and average fuel consumption without the need for conventional fuel flow meters. The paper describes the theoretical assumptions of the method, the measurement system, and the signal processing procedure. Pilot studies were carried out on a selected internal combustion engine under various operating conditions, including variable load and rotational speed. The obtained results were compared with those acquired using other fuel consumption measurement methods, including volumetric and gravimetric techniques. An analysis of the accuracy, repeatability, and practical applicability of the developed method in operational and diagnostic studies of internal combustion engines was performed. The results indicate that the use of exhaust gas concentration measurements and intake manifold vacuum measurements may provide an alternative solution for fuel consumption assessment, particularly in laboratory and pilot engine testing conditions.

COMPARATIVE STUDIES OF WELDED JOINTS IN DRIVE BELTS MADE OF THERMOPLASTIC ELASTOMER

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Keywords: hot plate welding, friction welding, static tensile test, thermoplastic drive belts

Hot-plate butt welding is a popular method for butt-joining drive and conveyor belts made of thermoplastic elastomers. In addition to this technology, friction welding is also widely known and used in the field of butt joining thermoplastics, as are variations of butt welding that utilize contactless heating of the material via infrared radiation. An important practical issue related to the analysis of butt joined belts using these methods is the evaluation of the joint's quality in terms of its stiffness and strength, including its response to tensile loads. This paper presents the methodology and results of experimental studies of butt welds, including the determination of stress-strain characteristics during tests with conditions analogous to a static tensile test. The authors conducted tests on both: continuous belts welded into closed loops and isolated single-joint specimens, using two testing methods. The examinations were performed on circular-section belts made of thermoplastic elastomers with urethane bonds, welded using the hot-plate and friction welding methods.

THE USE OF A VISION SYSTEM AND LASER PROJECTION TO IMPROVE THE REPEATABILITY OF SEMG ELECTRODE POSITIONING

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Keywords: surface electromyography, repeatable electrode positioning, vision-guided electrode placement, laser-assisted projection

Surface electromyography (sEMG) is a widely used method for assessing skeletal muscle activity in physical therapy and biomechanical research. The traditional approach to placing measurement electrodes is based on specific anatomical landmarks of the subject. For single-session studies, this approach is sufficient. In long-term studies, however, potential shifts relative to the original placement of the measurement electrode must be taken into account. The recorded EMG signal is sensitive to its position relative to the fibers of the muscle being examined, as well as to its position relative to other nearby muscles. Changes in electrode placement therefore affect the accuracy of studies conducted using surface electromyography. The aim of the anthropometric analyses and the review of the state of the art is to develop a concept for a testing station capable of recording individual configurations of measurement electrode positions and reproducing them for subsequent series of studies, while adhering to the principles of Human-Centered Design. The developed solution is based on an image processing module and a reference point projection module, enabling the reconstruction of measurement electrode positions on the upper limb. The article presents an analysis of other methods for improving the accuracy of electrode positioning on the human body. The design of the test rig and its operating algorithm are presented. The developed solution can be used in applications requiring high repeatability of test conditions, such as in biomechanics or in the verification of designs in anthropotechnical systems.

ASSESSMENT OF MUSCLE EFFORT BASED ON CUMULATIVE MUSCLE LOAD (CML) IN WHEELCHAIR MOTION ANALYSIS

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Keywords: cumulative muscle load (CML), electromyography (EMG), manual wheelchair, upper limb muscle activity, muscular effort, wheelchair motion analysis, assistive technology

The aim of this study was to evaluate the applicability of cumulative muscle load (CML) as a primary indicator for assessing muscular effort during dynamic activities performed in a manual wheelchair. The study was conducted with eight participants, analyzing upper limb muscle activity during both uphill propulsion and downhill descent under three conditions: without the module (NAR), with a flexible roller (EAR), and with a rigid roller (SAR). The EMG signal was used exclusively to determine CML and its time derivative (CML/s), interpreted as measures of total and instantaneous muscular load. In uphill conditions, no statistically significant differences in CML were observed between configurations ($p = 0.993$), with values for the entire upper limb ranging from 35.14 to 36.75, indicating no effect of the module on total muscular effort . In contrast, during downhill movement, the use of the module significantly reduced muscular load – the CML/s index decreased from 0.17 ± 0.036 in the NAR condition to 0.12 in both EAR and SAR, corresponding to a reduction of 29.4%. Additionally, analysis of the CML progression over time revealed a lower rate of accumulation in the module configurations (slope angle 2.65–2.73°) compared to the reference condition (3.41°), confirming a reduction in effort intensity. The results indicate that assessing muscle activity based on selected points of the EMG signal may be misleading and may not reflect the variability of human movement. In contrast, the use of CML, which accounts for the entire time course of muscle activity, enables objective evaluation and comparison of both patients and technical solutions. This approach is particularly important for dynamic tasks such as wheelchair descent on a slope, where muscle activity patterns continuously change.

EXPERIMENTAL STUDIES ON THE EFFICIENCY OF THREADED CONNECTIONS

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Keywords: threaded connection, efficiency of a threaded connection, friction coefficient, movable connection

This paper presents the design of a test stand that enables the indirect determination of the efficiency of a threaded connection depending on: the geometric parameters of the thread, the axial load value of the connection, the direction of the connection axis, and the material of the bolt and nut. The second part discusses the conducted experiments and the obtained results, which define the functional relationships between the above-mentioned parameters.

RECLAMATION OF POST-MINING AREAS INTO PHS ENERGY STORAGE FACILITIES

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Keywords: reclamation, water energy storage, open-pit mines, transition energy

The transition of energy to green energy sources is progressing every year. It requires investment in new facilities that produce energy and enable its storage. Storage is a key aspect of RES, resulting from their instability. As part of the CETPartnership Joint Call 2023 program, a project entitled "Pumped HYDRO-electric Storage in post MINEd areas to support re-gional net-zero emission energy systems development" with the acronym HYDROMINE will be implemented. Its aim is to propose an economically efficient conversion of open-pit mines to water energy storage. As part of the research and development work, a demonstrator of the described technology will be created. It will be built and tested on the premises of the Road Raw Materials Mine in Niemodlin. For this purpose, a complete pumped-storage power plant system will be created in the mine. A lower and upper water reservoir will be built on the site of the former excavation area. The lower one will be created by the lowest level of the exploited field. The upper one will require the construction of one of the four walls of the tank. The rest will be created by natural walls left over from the service life. The demonstrator will utilise a pump capable of operating in turbine mode, developed as part of a series of products.

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INTEGRATION OF FIBRE OPTIC SENSORS IN THE PULTRUSION PROCESS: PRELIMINARY BENDING TEST

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Keywords: pultrusion process, fibre optic sensors, fibre bragg grating, structural health monitoring

Monitoring the technical condition of engineering structures is an important operational aspect. Monitoring techniques must be dedicated to the construction materials used. For products made of metal, measurement techniques are well recognised and applied. A completely different approach is required for composites. This is because the mechanisms of defects are completely different. The research and development work as part of the project concerns the integration of a fibre optic sensor in the pultrusion process for diagnostic purposes. At this stage, flat profiles with a correctly integrated sensor have been obtained. The paper presents the preliminary results of the first bending tests. Presented the time courses of the sensor response during the trial. The first tests were carried out on the basis of a three-point bending test. They showed that the sensor has measurement capabilities after the integration process. Information on the problems encountered during integration is also included.

Project co-financed by the National Centre for Research and Development under the CORNET 36 program, DWM/CORNET-36/68/2024.

EXPERIMENTAL VERIFICATION OF A METHODOLOGY FOR MEASURING THE MECHANICAL PARAMETERS OF BELT DRIVES TO EVALUATE THEIR PERFORMANCE CHARACTERISTICS

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Keywords: belt transmission, flat belt, measurement; test stand

This paper presents the experimental verification of a methodology developed for measuring the mechanical parameters of belt drives in order to evaluate their performance characteristics. The proposed methodology enables accurate determination of key operational parameters, including transmitted torque, rotational speed, belt tension, slip, vibration, and power transmission efficiency under varying load conditions. The study aims to assess the reliability, repeatability, and applicability of the measurement procedure in laboratory investigations of belt drive systems. Experimental tests were conducted using a designed test bench equipped with measurement sensors and a data acquisition system made based on the Human-Machine Interface (HMI) panel. Different operating conditions and load levels were applied to analyze the dynamic behavior and performance of the belt drive. The collected data were used to validate the proposed measurement methodology and identify its accuracy and limitations. The obtained results confirmed that the applied measurement approach provides stable and repeatable results, enabling comprehensive analysis of belt drive performance. The verified methodology can be used in further experimental studies, optimization processes, and comparative analyses of various belt drive configurations. The developed approach also offers practical value for engineering applications, diagnostics, and research related to mechanical power transmission systems.

IMPACT OF MOTION PROFILE IMPORT ERRORS ON DYNAMIC LOADS IN HYBRID SERVO-MECHANICAL ACTUATORS

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Keywords: dynamic loads, motion profile, trajectory interpolation

This paper investigates the influence of motion profile translation errors on the dynamic behavior of servo-driven actuation systems used in industrial automation. Although modern trajectory generation methods enable smooth motion planning using spline-based, sinusoidal, and linear interpolation techniques, practical implementation within industrial PLC environments introduces significant deviations resulting from discretization, sampling limitations, and interpolation algorithms. The study focuses on the transfer of motion profiles into PLC-based engineering environments, such as Siemens TIA Portal, and evaluates the resulting impact on acceleration, jerk, vibration, and mechanical load amplification. The obtained results indicate that trajectory degradation occurring during motion profile import may significantly increase jerk peaks and dynamic instability, particularly in regions involving rapid direction changes. The paper further proposes trajectory optimization methods based on motion profile smoothing and adaptive trajectory modification implemented in the MATLAB environment. The developed algorithm enables automatic selection of the number of trajectory points and their spatial distribution within the working area, thereby reducing interpolation errors, improving motion smoothness, and minimizing dynamic loads acting on mechanical system components. The presented approach provides a practical framework for integrating motion control engineering with mechanical durability analysis in modern hybrid automation systems.

CFD ANALYSIS OF HEAT TRANSFER IN A THERMOACOUSTIC REFRIGERATOR

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Keywords: thermoacoustic refrigerator, computational fluid dynamics, heat transfer, numerical simulation

Thermoacoustic refrigerators represent a promising alternative to conventional refrigeration systems by utilizing acoustic waves to transport thermal energy without the use of environmentally harmful refrigerants. Their high potential for sustainable cooling applications has attracted increasing scientific interest in recent years. The aim of this study is to investigate heat transfer phenomena occurring in a selected thermoacoustic refrigerator by means of Computational Fluid Dynamics (CFD). The developed numerical model considers the influence of flow conditions and the geometry of selected device components on temperature distribution, velocity fields, and heat transfer performance. Particular attention is paid to the interaction between fluid flow and thermal transport processes responsible for the overall efficiency of the refrigeration cycle. The numerical simulations enable the identification of regions characterized by intensive heat exchange and provide insight into the mechanisms governing thermal performance. The proposed CFD methodology constitutes an effective tool for evaluating the impact of design parameters on thermoacoustic refrigerator operation and supports further optimization of their construction. The obtained results are expected to contribute to the development of energy-efficient, environmentally friendly refrigeration technologies based on thermoacoustic principles.

EVALUATING CONTAMINATION LEVEL OF ENGINE OIL THROUGH OXIDATION PARAMETERS AND METAL CONTENT

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Keywords: engine oil, service life, contaminants, FTIR analysis

Abstract: For the correct functioning of the car's internal combustion engine, the estimation of the quality and durability of engine oils is essential. The performance of engine oils is greatly affected by its physical and chemical characteristics relative to its original state. Multiple parameters like oxidation, nitration, viscosity, visual changes, and water content are used to assess the limits of deterioration in engine oil. As the oil ages, there are many contaminants such as wear debris, soot, water, and glycol affecting its the service life. Exceeding these limits indicates that the oil is unable to adequately perform its required lubricating, cooling, and protective functions and may additionally lead to increased mechanical wear. In this work, we collected random samples of engine oils at different time intervals to study its the contamination level and its effect on service life using methods of infrared spectroscopy (FTIR), elementary analysis (EDX), thermal analysis, oxidation stability, visual examination, water content by heating crackle test, and droplet tests. Investigation of the experimental data showed that the individual parameters are highly specific, and that timely analysis can be used to determine the exact service life of the engine oil.

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MULTIBODY DYNAMICS IN DESIGNING AND VALIDATING A LABORATORY STAND FOR MEASURING FRICTION COEFFICIENTS VIA TORQUE RECORDING METHOD

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Keywords: multibody dynamics, laboratory stand, friction coefficients, torque recording method

The design of irrigation and seeding systems for agricultural machinery requires a thorough understanding of the mechanical and tribological parameters of the granular materials and seeds. This paper presents the virtual prototyping and construction of a custom laboratory stand designed to determine the friction coefficients of granular and bulk materials using torque sensing. In the first stage, numerical analyzes were conducted using the Multibody Dynamics (MBD) method in SolidWorks Motion. On the basis of friction coefficients from the literature and modeling the contact between the granulate layer and a steel disc at a given rotational speed and normal contact pressure, the theoretical course of the reaction torque was determined. The results of the simulation analyzes served as direct guidelines for selecting the maximum parameters of the physical stand components, including the drive system with the required torque and the torque and pressure sensor system. The article presents the design of the completed stand and the results of preliminary pilot studies conducted using mineral fertilizer granules as an example. The developed test stand can be a tool that supports the design of dosing systems and the selection of materials that reduce movement resistance.

UPPER LIMB POSITIONING OF THE WOOD CHIPPER OPERATOR DURING MATERIAL FEEDING

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Keywords: wood chipper, grip configuration, hand grip types, material feeding

Wood feeding into a chipper can be performed with varying upper-limb postures. The operator's electromyographic (EMG) signal, reflecting muscle activation during feeding, can be utilized in a novel control strategy for regulating chipper rotational speed, thereby improving power demand matching and reducing idle operation losses. The objective of the study was to analyze methods of wood material handling by chipper operators, with particular emphasis on grip configuration and upper-limb positioning during the transport of branches to the feed channel. The study was conducted based on the analysis of 122 publicly available video recordings depicting real operating conditions involving drum, two cylindrical and disc chippers. Based on the observations, a classification of six primary material grip types was developed. The results indicate that the most frequently used configuration is a mixed two-handed grip, occurring in over 44% of cases, whereas one-handed grips were negligible. The findings reveal a clear relationship between feed channel design and material handling strategy. Biomechanical analysis suggests that grip configurations influence upper-limb movement patterns and the distribution of muscular loads. These results may provide a foundation for further research on adaptive chipper control systems utilizing operator-derived biomechanical signals.

EFFECT OF WALNUT SHELL AS BIOFILLER ON SURFACE FREE ENERGY EVOLUTION AND UV-INDUCED DEGRADATION OF NATURAL RUBBER COMPOSITES

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Keywords: natural rubber composites, walnut shell biofiller, accelerated aging, mechanical and surface properties

The work deals with the study of the influence of walnut shell-based as biofiller on the surface and mechanical properties of natural rubber (NR) elastomeric composites before and after accelerated aging. The biocomposites were prepared with different filler contents in the range 0–30 phr and subsequently exposed to UV radiation and elevated temperature in a QUV/SE device to simulate long-term weathering. Changes in surface properties were evaluated by measuring the contact angle and calculating the surface free energy, supplemented by microscopic analysis of the surface morphology. Mechanical properties were evaluated by measuring the hardness, tensile strength and elongation at break of the prepared composites. The work demonstrates the potential of using lignocellulosic materials as functional fillers in elastomeric composites and their influence on the long-term stability of the material under environmental stress conditions. This knowledge can be used to optimize the composition of elastomer composites with an emphasis on increased resistance to environmental stress.

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EXPERIMENTAL EVALUATION OF TENSILE PROPERTIES OF NYLON WHITE PRODUCED BY FFF

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Fused Filament Fabrication is widely used for producing polymer components; however, the mechanical response of printed parts is strongly affected by the deposition strategy and raster orientation. In this study, the tensile strength of Nylon White specimens manufactured by Markforged MarkTwo printer was experimentally evaluated. For this purpose, several raster orientations (0, 45–45 and 0/90) were investigated in order to assess their influence on the maximum tensile load and calculated tensile strength. The results showed that raster orientation has a clear effect on the tensile strength of the printed specimens. Specimens with filaments aligned with the loading direction are expected to exhibit higher tensile strength, while cross-ply raster configurations may show lower values due to the increased influence of inter-road bonding and shear-dominated deformation. The obtained results provide basic experimental data for Nylon White and can serve as a reference for further studies focused on additively manufactured polymer and composite materials.

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