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Foreword

Prof. Dr. Vasilios Spitas
Chair of Mechanical Design and Machine Elements
Vice-Dean of the School of Mechanical Engineering,
National Technical University of Athens
Director of the Machine Design Laboratory
President of BAPT

Dear friends and colleagues,

The 10th International BAPT Conference – Power Transmissions has been successfully completed. It was a great pleasure to witness the osmosis between acknowledged and young scientists from Greece as well as Serbia, Germany and India. After a two-year pause, the organizing committee of the 10th International BAPT Conference – Power Transmissions has presented a rejuvenated event focused on the front end of power transmission research including the latest trends of artificial intelligence and additive manufacturing applications. A special issue will also be announced shortly, so that participating scientists receive the well-deserved acknowledgement of their work.

Setting our sights to the 11th International BAPT Conference – Power Transmissions to be held in 2027, we promise to maintain momentum and continued working towards reinstating BAPT among the top and most prestigious International Conferences of Power Transmissions.

Finally, I would like to thank the members of the Organizing Committee for their efforts, as well as the organizers CONVIN S.A. and our sponsors whose contribution has been of the outmost importance for the successful organization of the event.

Acknowledgements

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Contents

AI Applications in Mechanical Engineering

"Quantifying the economic benefit of AI-powered surrogates in computational mechanics"

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Keywords: Computational mechanics, AI-powered surrogates, Energy efficiency, Sustainability in computation

ABSTRACT

The deployment of AI-powered surrogate models in computational mechanics has emerged as a promising approach for accelerating simulations in parametric problems, including optimization, uncertainty quantification, parameter inference, and sensitivity analysis. However, a rigorous quantification of their economic and environmental benefit remains underexplored. This work aims to establish a systematic framework to evaluate the energy cost and performance trade-offs between traditional numerical solvers and deep learning-based surrogates in parametric computational mechanics problems.

We propose comparing the cumulative energy consumption of (i) full-order numerical simulations for varying input parameters, and (ii) AI surrogates, where the total cost includes both training (as a function of the number of parameters, training epochs, and dataset size) and inference (online prediction cost). The analysis is conducted across representative problems (e.g., elastodynamics, fluid dynamics, heat conduction) and various surrogate architectures (e.g. Feedforward/Convolutional/Graph Neural Networks and Physics-Informed Neural Networks).

By incorporating metrics such as simulation wall-time, GPU/CPU energy profiling, and predictive error tolerances, we demonstrate the cost-benefit ratio of using surrogates. Our results aim to inform decisions on when the upfront investment in training AI surrogates is economically and computationally justified, especially in contexts where repeated queries are needed.

"A hybrid digital twin and AI-based framework for marine shaftline monitoring and bearing condition prognostics"

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Keywords: Marine propulsion systems; Shaftline monitoring; Journal bearings; Neural networks; Torque loss estimation

ABSTRACT

The reliable operation of marine propulsion systems depends heavily on the performance of shaftline components, particularly the journal bearings that support and stabilize the propeller shaft. To address the challenge of assessing bearing condition in real time, a hybrid methodology was developed, in the framework of the "S-PRISMoID" research project, that integrates physics-based modeling [1], simulation-driven data generation, sensor instrumentation, and data-driven inference using artificial neural networks (ANNs) [2].

The approach begins with the development of a detailed shaftline model, incorporating full-length shaft geometry, bearing locations, material properties, and boundary conditions derived from actual vessel configurations. In this work a case study bulk carrier vessel was utilized to demonstrate the effectiveness of the proposed method. The shaftline model is calibrated against operational constraints and is used to generate a comprehensive envelope of synthetic operating scenarios, including variations in loading, shaft speed, trim, sea state, and bearing misalignment. For each case, outputs such as the shaft inclination, shear forces, bending moments, and bearing performance parameters such as the Sommerfeld number, bearing loads, eccentricity, attitude angle, friction force, minimum film thickness and maximum pressure are computed.

To enable real-time predictive analytics, ANNs were trained using the simulated dataset. The input features include shaft RPM, oil temperature, lubricant viscosity, and friction torque losses. Feature importance analysis confirmed that bearing friction torque is a dominant indicator of bearing performance and a critical predictor of incipient failures. These models are capable of inferring the bearing loading state, utilizing direct measurements of the key parameters (features), offering a scalable solution for onboard condition monitoring. A conceptual representation of the suggested monitoring system for an intermediate shaft bearing, developed and tested, on a bulk carrier ship in the framework of the "S-PRISMoID" project, is illustrated in Figure 1.

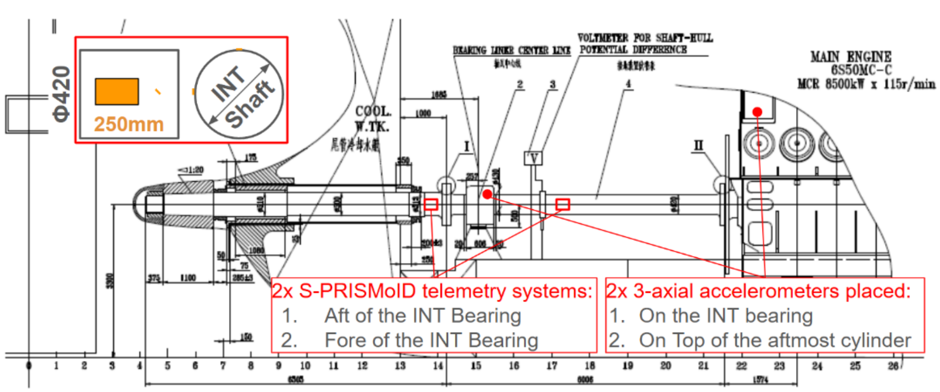

Figure 1. Conceptual monitoring system onboard a bulk carrier ship

To validate the process and generate experimental data on bearing behavior, the scaled test rig [3] presented in Figure 2 was developed, replicating key mechanical interactions in a controlled environment. A novel instrumentation setup employing hypersensitive strain sensors enhanced with nanoparticle (NP) additives was deployed upstream and downstream of the test bearing. This configuration enabled direct measurement of shaft torsion, allowing for the calculation of torque losses attributable to the bearing(s). This configuration facilitated sensor testing and validated the proposed methodology before the pilot installation onboard the vessel.

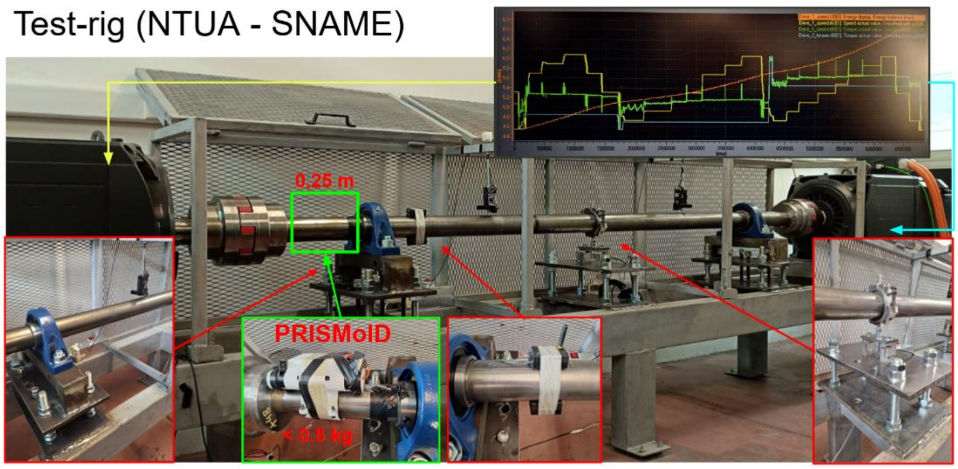

Figure 2. Experimental bearing test-rig in the Laboratory of machine elements of S-NAME NTUA

This combined framework enables near real-time estimation of bearing load and friction loss, offering new capabilities for condition-based maintenance and risk-informed decision-making in marine propulsion systems. This non-invasive and extensible method demonstrates strong potential for operational integration in existing, conventional, merchant marine shaftlines with fleet-wide scalability.

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This research work was conducted in the framework of the research Project s-PRISMoID, "Ship Predictive Intelligent Sensor Model Integrated Digitally" (Grant Number TAEΔK-06178). The project is implemented within the framework of the National Recovery Plan and Resilience "Greece 2.0" funded by the European Union – NextGenerationEU.

"High-fidelity graph neural network surrogate modeling for spur gear finite element analysis"

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Keywords: Graph Neural Networks, Spur Gears, Finite Element Analysis, Surrogate Model, Contact Mechanics, Computational Mechanics

ABSTRACT

Accurate stress prediction in meshing spur gears via Finite Element Analysis (FEA) is fundamental for design validation but remains computationally intensive, limiting its use in rapid iterative processes. This work presents the development and validation of a high-fidelity Graph Neural Network (GNN) surrogate model designed to significantly accelerate these predictions while maintaining accuracy comparable to FEA.

The approach leverages the inherent graph structure of FEA meshes. The interacting pinion and gear meshes are represented as graphs where nodes correspond to mesh points and edges capture element connectivity. A MeshGraphNet-inspired GNN architecture, featuring encoder, processor, and decoder stages, is trained on a comprehensive dataset generated from parametric FEA simulations. The GNN learns to predict nodal stress fields based on input features encoding gear geometry, material properties, loading conditions, and the mesh topology.

Achieving high fidelity, particularly for the critical peak stresses occurring at tooth contact points, required careful model refinement. Key enhancements included optimizing the GNN architecture (e.g., adjusting hidden dimensions from 32 to 128 and layer distributions) and explicitly incorporating mechanisms for inter-gear communication within the graph structure. This was realized by introducing "virtual edges" connecting spatially proximate nodes on the interacting surfaces of the two gears, allowing the GNN to directly learn from contact-induced stress patterns.

The resulting enhanced model demonstrates significant improvements over baseline implementations. Evaluated on unseen test data, it achieved a 67% reduction in Mean Squared Error (MSE) (0.012 to 0.004) and a 43% reduction in Mean Absolute Error (MAE) (0.074 to 0.042). Analysis showed markedly lower maximum prediction errors (both relative and absolute) and a more accurate safety factor distribution centered around 1.0. These improvements generalized robustly across training, validation, and test sets. Furthermore, despite increased model complexity (122k to 723k parameters), the refined model achieved significantly faster training times (14.2 vs 23.3 hours).

This study validates the potential of GNNs as powerful surrogate models for complex contact mechanics problems in gear analysis. By carefully integrating graph representations, architectural design, and explicit modeling of physical interactions, the developed GNN provides a computationally efficient and accurate alternative to traditional FEA for spur gear stress prediction.

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Design analysis and optimization

"Investigating the effect of the tooth flank profile on gear efficiency"

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Keywords: gears, power transmissions, efficiency, optimization, tooth flank

ABSTRACT

The ongoing transition to electrification, particularly in the automotive sector, has brought gear efficiency to the forefront of drivetrain design. Unlike internal combustion engine (ICE) vehicles, electric vehicles (EVs) operate under different torque-speed regimes—characterized by higher rotational speeds, more frequent start-stop cycles, and quieter operation requirements. These differences place new demands on gearing systems, where even small improvements in efficiency can lead to noticeable gains in driving range, thermal management, and overall energy consumption [1]. In this context, optimizing gear design has become critical for meeting the performance and efficiency standards of modern EVs.

Traditionally, involute gear profiles have been the industry standard due to their ease of manufacturing, ability to tolerate minor misalignments, and consistent transmission ratio. However, involute gears are not inherently optimized for efficiency. They experience significant sliding contact during meshing, which contributes to power losses through friction, heat generation, and wear. As the importance of mechanical losses becomes more prominent in EV drivetrains—where motors operate more quietly and make gear noise and inefficiency more noticeable—the limitations of involute gearing become increasingly evident.

The efficiency of a gear system is closely linked to several parameters of the tooth flank profile. These include the pressure angle, contact ratio, sliding-to-rolling ratio, and the curvature of the contact surface. By modifying these parameters, it is possible to reduce sliding losses, increase the duration of rolling contact, and improve load distribution. Alternative tooth geometries—such as cycloidal, parabolic, logarithmic, or even machine-optimized hybrid profiles—have shown potential in reducing contact friction and increasing efficiency, particularly when tailored for the specific operating conditions of EV drivetrains [2].

In our research, we investigate the influence of various tooth flank profiles on gear efficiency. By systematically analyzing a range of geometric parameters and profile types, we aim to quantify their impact on efficiency, identify the most promising profiles, and understand the trade-offs involved in adopting non-standard geometries.

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"Geometrical and topological optimization of a multi-stage wind turbine gearbox to improve weight and efficiency"

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Keywords: Gears; Planetary Gearbox; Wind turbines; multi-objective optimization, NSGA-II, Efficiency

ABSTRACT

In recent years, energy harvesting from renewable sources has experienced increasing demand. Wind turbines, as a key source of renewable energy, are characterized by considerable energy losses and structural weight constraints that limit their overall efficiency and performance. This study aims to optimize a three-stage gearbox utilized in wind turbines, designed for a rated power of 1 MW and a total transmission ratio of 1:75. The target is the reduction of the overall weight of the gearbox and minimization of power losses, benchmarking against results from existing literature. A multi-objective optimization approach was implemented using the Non-Dominated Sorting Genetic Algorithm II (NSGA-II) to evaluate the objective functions. The most important design variables include gear geometrical characteristics, number of planets used at every stage and topological configurations. More specifically, the algorithm can select either a simple or planetary stage and can define the component that operates as the power input and output, at the possibility of a planetary option. This choice corresponds to a specific, independent design parameter for each stage. To evaluate the efficiency using the Ohlendorf equation regardless of the oil viscosity, an indicator is introduced based on the Schenck's approach. This indicator is influenced by geometric characteristics of the engaged gears and the transmitted load. The bending and the pitting strength endurance of the gearbox are calculated by AGMA standards and are included as constraints. The study demonstrates the importance of topological parameters in gearbox optimization and suggests further investigation into more complex stage assemblies to enhance the performance of WTGs.

"Investigating the effect of profile addendum modifications to the dynamic response of spur gears"

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Keywords: Gears; Addendum modification; Profile shift; Static Transmission Error, Dynamic Transmission Error, Dynamic response

ABSTRACT

Vibrations in gear systems pose a significant challenge, as they disrupt smooth operation, reduce transmission efficiency, increase noise levels, and accelerate mechanical wear. One of the key parameters influencing the dynamic behaviour of gears is the profile shift coefficients. In this study, we investigate how variations in these coefficients affect the dynamic performance of gears. To assess dynamic behaviour, we focused on two critical metrics: the Static Transmission Error (STE) and the Dynamic Transmission Error (DTE). These errors quantify the deviation between the actual angular position of the driven gear and its theoretical ideal position. Such deviations are caused by elastic deformations of the gear teeth, as well as geometric inaccuracies resulting from manufacturing tolerances.

The simulations revealed that applying a simultaneous positive profile shift to both gears leads to a reduction in STE, as measured by its peak-to-peak value. Unlike the STE, the DTE does not exhibit a straightforward trend across all cases of operating conditions. For the DTE analysis, the root mean square (RMS) of the dynamic error signal was computed across several combinations of torque and rotational speed. Although the minimization of the peak-to-peak value of STE does not always align with the minimization of the RMS of the DTE, we observed that at higher torque and rotational speed, the DTE follows the same decreasing trend as STE with an increase in the positive profile shift.

These findings emphasize the value of profile shift optimization. Since adjusting the shift coefficients only requires axial repositioning of the gears—without incurring additional manufacturing costs—this approach provides an efficient and cost-effective design solution. The observed reductions in both STE and DTE demonstrate that even small adjustments can lead to significant improvements in gear performance, highlighting the potential for further research and development in this area.

"An implementation and comparison between two multiobjective optimization processes in water lubricated bearings design"

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Keywords: Marine propulsion systems; Journal bearings; Optimization; Evolutionary Algorithms; FSI

ABSTRACT

Water-lubricated bearings are increasingly favored in environmentally sensitive applications due to their eco-friendly properties and operational safety. However, optimizing their performance typically presents a challenging multiobjective problem aiming at minimizing friction while maximizing load-carrying capacity. This complexity is further complicated by the need to account for elastic deformations of the bearing structure, which significantly influence the development of hydrodynamic pressure. In this work, we investigate two distinct optimization strategies (a) Nash equilibrium-based multiobjective optimization and (b) the Strength Pareto Evolutionary Algorithm 2 (SPEA2), to identify efficient trade-offs between friction and load performance in elastohydrodynamic lubrication conditions.

In [1], the application of Nash equilibrium principles from non-cooperative game theory has been introduced, wherein two independent players—corresponding to distinct objectives such as friction and load capacity—optimize their goals independently. Through iterative "communication," the system converges toward a stable equilibrium state. On the other hand, evolutionary algorithms such as the Strength Pareto Evolutionary Algorithm 2 (SPEA2) operate through a cooperative, population-based approach that explores and refines a set of optimal trade-offs. The effectiveness of SPEA2 in solving multiobjective optimization problems is well-established in the literature [2], where its capabilities were pronounced compared to its predecessor (SPEA). In [3], authors implemented another well known evolutionary algorithm, NSGA2, in the case of EHD analysis of intact, worn and misaligned journal bearings.

In the present study, both methodologies are implemented using in-house computational tools. A finite difference method (FDM) solver is developed to resolve the Reynolds equation for journal bearings, coupled with the classical Winkler foundation model to estimate elastic displacements of the bearing liner. The necessity of accounting for elastic deformation for the solution of the FSI problem, is underscored by the inherently low elastic modulus of water-lubricated bearing materials, as highlighted in [4]. The comparative performance of the two optimization approaches is examined, with attention to the nature and quality of the resulting Pareto-optimal solutions.

The current study aims to provide insights into the effectiveness and characteristics of cooperative versus non-cooperative multiobjective optimization strategies when applied to elastohydrodynamic problems in water-lubricated bearing systems. Those principles, though, can be applied to the optimization of any engineering system.

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Metrology

“Investigation of flank and root accuracy of hobbed gears through CAD-based simulation”

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Keywords: Gear hobbing, simulation, gear topography

ABSTRACT

In modern engineering systems the use of high quality, precision transmissions are required not only to allow for high performance operation but also to improve the reliability, efficiency and cost of the overall system. This requirement is particularly true for the automotive, aerospace and wind turbine industry, where these factors play a pivotal role.

Among the various gear manufacturing techniques, gear hobbing has become the most widely adopted due to its versatility and efficiency in producing gears of various sizes and profiles. The inherent process kinematics develops a distinctive pattern on the flanks and root of the machined gears. Surface roughness of gears on the flank and root fillet influences a series of parameters such as the load-carrying capacity of the flank and tooth root, the scuffing load bearing capacity and the noise behavior.

The present research focuses the investigation of process parameters of gear hobbing on the resulting flank and root surface quality. The study has been facilitated through a CAD based simulation model. The developed simulation environment accurately models the intricate kinematics of the gear hobbing process, enabling the generation of high-fidelity 3D representations of the tooth geometry and surface characteristics post-machining.

A dedicated analysis module has been integrated into the simulation system to evaluate deviations in the generated gear geometry with respect to the ideal nominal profile. This module allows for detailed assessment of flank topography and root fillet deviations, facilitating the identification of geometric inaccuracies introduced by specific cutting conditions. The outcomes of this study contribute to a deeper understanding of the gear hobbing process and support the development of optimized manufacturing strategies aimed at minimizing flank and root deviations.

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"Design and optimization of the infill geometrical parameters for 3D printed spur gears"

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Keywords: Additive Manufacturing, gears, optimization, infill geometry

ABSTRACT

Lightweight performance engineering has been at the forefront of mechanical design during the last decades as all technology strives to create more efficient, versatile and highly optimized systems. Currently, Additive Manufacturing (AM) technologies play a crucial role in revolutionizing manufacturing and pioneering new design approaches. This research work aims to investigate the required guidelines that bridge the gap between cutting edge manufacturing and design principles with the current standardizations regarding power transmission and geartrains.

The authors aspire to establish functional tolerancing guidelines for power transmission spur gears that are manufactured through AM in conjunction with traditional subtractive methods. Taking advantage of the AM technological capabilities, the designed gears incorporate internal honeycomb structures to optimize weight, inertia and consequently dynamic performance while maintaining the state-of-the-art power transmission operational requirements. This is achieved through Finite Element Analysis by employing Representative Volume Element techniques, along with traditional computational methods in order to establish the tolerancing specifications of the flank geometry as parameters of rim thickness, tooth flank thickness and internal structure. Calculation of the static transmission error (STE) and flank Hertzian pressure along the path of contact of lightweight honeycomb gears for various transmitted torque levels are compared versus nominal conventional gears and the results are presented and discussed. The findings of this research study can provide a comprehensive understanding of the control parameters to the performance of each gear train and can allow for further optimization gains and generalization of the optimization process.

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"Reverse engineering of large internal gear by the combined use of articulated arm and laser tracker coordinate measuring systems"

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Keywords: Gears, reverse engineering, large scale metrology, articulated arm, industrial geodesy

ABSTRACT

Reverse Engineering (RE) of industrial large-scale (>2m) components present a set of complex and highly demanding technical challenges. The most significant ones are the limitations on physical access to the component, due to its overall size and weight, along with the diverse range *(e.g. from 2mm to 0,02mm)* of required accuracy for the digitization of its functional geometrical features. Focusing on the RE of gears that are used in large-scale industrial power transmission systems, the decision over the most appropriate measuring/digitization technology must certainly consider the logistical difficulties related to their mass and dimensions. For that reason, portable systems, such as articulated arm coordinate measuring machines (CMM), laser trackers and total stations that offer the option of in-situ measurements are strongly preferred over stationary systems, such as gear measuring centers or high accuracy cartesian CMM. However, due to their inherent limitations, none of the currently available portable instruments can be considered as universally suitable for all measurement/digitization tasks involved in the RE of large-scale gears.

This research work proposes a systematic approach for the combined use of articulated arm and laser tracker coordinate measuring systems, aiming at the cost and time effective RE of large-scale gears. The received sets of data are processed by commercially available, well-established metrology platforms such as PC-DMIS and SpatialAnalyzer of Hexagon MI. The current stage of the methodology is experimentally implemented in an industrial case study of an internal spur gear with 2200mm outside diameter and normal module 12mm (Fig. 1). To demonstrate the feasibility, the advantages and the limitations of the approach, the experimental results are presented and discussed.

Figure 1. Case study: internal large-scale spur gear

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"Generation of Damaged Gear Geometry using a Systematic Reverse Engineering Methodology"

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Keywords: Reverse engineering, Gears remanufacturing, Hybrid digitization method

ABSTRACT

In industrial power transmission systems, the geometrical condition of gears has a huge impact on their overall functional performance; therefore, every effort to get as close as possible to the nominal, as-designed geometry is technically justified. In the framework of Industry 5.0 and the pursuit of sustainability, gear remanufacturing is a cost-effective process that restores worn, damaged, or used gears to a functional state, ensuring optimal meshing performance with existing gears. This research work presents a comprehensive and systematic methodology for gear reverse engineering, focused on accurately recovering the original gear geometry from worn gears. Besides interchangeability, the most crucial challenge here is that the remanufactured gear safeguards the original, most commonly strict, demands on the characteristics of functional performance (e.g. transmission accuracy, driving stability, load uniformity).

The starting stage of the proposed approach is the digitization of the gear surface by using a hybrid method that combines non-contact laser scanning and contact-based measurements. The latter are performed via a touch trigger probe mounted on an automated cartesian coordinate measuring machine (CMM). This dual-digitization strategy enhances both the resolution and accuracy of the acquired data. An analytical reconstruction model is then employed to produce the optimal gear tooth profile based on the digitized worn geometry. Finally, the regenerated gear geometry is evaluated for dimensional accuracy and profile conformity in accordance with the key set of parameters established in the current ISO 1328-1:2013 and ISO 1328-2:2020 standards. The proposed methodology offers a reliable framework for restoring gear functionality while minimizing the need for original design data.

Acknowledgement

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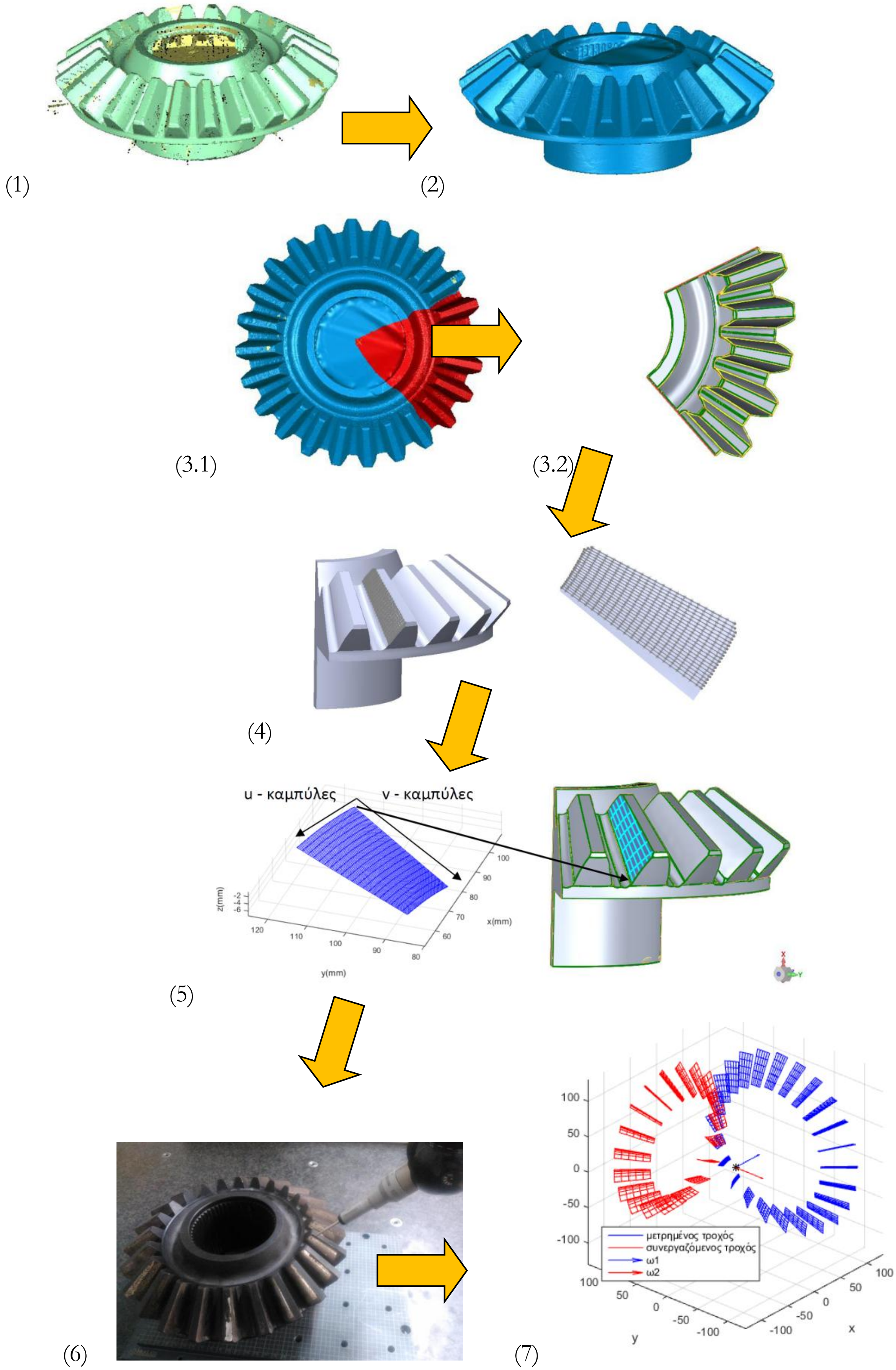
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Polymer gears

"Composite materials in gear design"

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Keywords: gears, composites, high stress, high strain

ABSTRACT

Composite materials, known for their high strength-to-weight ratio, corrosion resistance, and enhanced mechanical properties, are increasingly being employed in various high-performance applications. This review examines the state-of-the-art developments in composite gear design, focusing on the types of composites utilized and their applicability for high-stress and high-strain loading conditions. The aim is to provide a comprehensive understanding of the material properties, manufacturing techniques, and performance outcomes associated with composite gears. Composite materials have revolutionized gear design, particularly in applications involving high strain and high stress, such as power transmission systems. The application of composites in gear design offers significant advantages, including enhanced strength-to-weight ratios, improved fatigue resistance, and superior wear properties. This paper also focuses on the possibility of certification analysis of advanced composite gears subjected to high loads. The primary objective is to enhance simulation tools and numerical and experimental methods, facilitating the design of lighter, safer, and more energy-efficient structures. Additionally, the research aims to support and prepare the necessary standardization steps for the certification of composite structures, including gear transmissions made of composite materials.

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"Influence of glass and carbon fiber reinforcement on Nylon-6 gear performance"

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Keywords: Nylon 6, glass fiber, carbon fiber, reinforcements, gear performance, failure characteristics.

ABSTRACT

Polymer gears are gaining popularity due to their lightweight, lower noise levels, and cost-effective manufacturing. However, strength remains a major concern, impacting their durability and reliability. Therefore, it is crucial to conduct various combination tests involving reinforced polymer gears to address this challenge. The present study investigates the influence of varying degrees of reinforcement on the performance of Nylon- 6 polymer gears. Gears were fabricated with 25–35% glass fiber and 15–30% carbon fiber reinforcement to evaluate their mechanical behavior under different loading conditions [1-3]. Experimental testing was conducted at torque levels of 0.8, 1.5, 2.0, 2.5, and 3.0 Nm, and rotational speeds of 600, 800, 1000, and 1200 rpm. Performance and failure characteristics were assessed, followed by extensive numerical simulations to explore the gear response across multiple test iterations. Results indicate that glass fiber reinforcement enhances gear durability but reduces fracture strength beyond a certain threshold. In contrast, carbon fiber reinforcement offers superior resistance to tooth deformation, maintaining structural integrity under load. These findings provide critical insights into optimizing reinforcement strategies for improved gear performance.

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"Investigation on the effect of fillet radius on performance behaviour of asymmetric Nylon-6 gear"

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Keywords: Asymmetric gear, standard involute, root strength, fillet radius, numerical simulations

ABSTRACT

The popularity of polymer gears is steadily rising, thanks to their lightweight design, low noise, and cost- effective manufacturing. However, the root radius and root strength of both standard involute and asymmetric Nylon-6 polymer gears play a critical role in determining their durability and reliability, especially under medium to high loading conditions [1]. Therefore, comprehensive testing under varying loads and speeds is urgently needed to evaluate and improve their performance. Hence, this research examines the effect of fillet radius on the root strength of standard involute and asymmetric Nylon-6 polymer gears under varying torque and speed conditions. Experimental tests were conducted at torque levels of 0.8, 1.5, 2.0, 2.5, and 3.0 Nm, and rotational speeds of 600, 800, 1000, and 1200 rpm. The performance and failure responses of both gear types were evaluated, revealing that fillet geometry significantly influences stress distribution and failure initiation at the root. Asymmetric gear profiles demonstrated superior performance under increased loading, attributed to their modified geometry, but exhibited specific limitations when the fillet radius exceeded optimal values. Numerical simulations were also performed to support experimental findings. The results underscore the importance of optimizing fillet radius to improve durability and operational efficiency of injection-molded polymer gears.

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“Comparative Analysis of Dynamic Response between Polymeric and Metallic Involute Gears Using Lumped Parameter Models”

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Keywords: Plastic Gears, Dynamic Transmission Error, Lumped-Parameter Modeling

ABSTRACT

This study investigates the dynamic response of polymeric involute gears compared to traditional metallic gears using a lumped-parameter modeling approach. Plastic gears, increasingly preferred for their lightweight, cost-efficiency, and reduced noise potential, exhibit distinct dynamic characteristics due to their lower stiffness and higher damping properties. A systematic comparative analysis is conducted, focusing on dynamic transmission error (DTE) characteristics under varying operational conditions. Results are presented through detailed color maps and graphical representations, clearly demonstrating the operational regimes where polymeric gears offer significant NVH (Noise, Vibration, Harshness) advantages over metallic gears. Conversely, conditions highlighting potential disadvantages due to increased deformation or resonance susceptibility in polymer gears are also addressed. This comprehensive dynamic assessment provides valuable insights for gear designers, enabling informed material choices and optimized gear pair selection for applications demanding specific NVH criteria.

Additive manufacturing

"Experimental study on the correlation of printing head movements with vibrations level during FFM AM process"

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Keywords: Fused Filament Fabrication, printing head, vibrations, stability, printer structure dynamics

ABSTRACT

Product quality and properties are significantly correlated to the process conditions during manufacturing. Similarly, in the case of additive manufacturing (AM) processes and particularly Fused Filament Fabrication (FFF), the suitability of chosen parameters can have a considerable impact on the quality of the produced parts, such as dimensional accuracy, mechanical integrity and surface finish. Important factors include material properties, process parameters as well as printer structure properties, configuration and kinematics. The choice of non optimal conditions may lead to several defects and other relevant phenomena such as vibrations can cause inconsistency during printing and aggravate these defects.

Especially, vibrations can be a challenging issue when printing due to the particularities of the printer structure, leading to undesired responses when the frequency of the vibrations reaches the range of the structure eigenfrequencies, eventually causing resonance. In particular, in the case of experimental or less expensive printers, the limitations of the structure configuration and materials and also the specific kinematics of the printer can lead to instabilities during printing with an obvious impact on the part quality. Moreover, the sudden changes of movement when printing due to the particular part positioning or its complex features, giving rise to high acceleration magnitudes can be also detrimental to the stability of the printing process and to the part quality. Thus, it is necessary that the procedure of the printing process is correlated with a quantitative evaluation of the related vibration response in order to be able to eliminate most of the reasons for causing various instabilities.

In the relevant literature, a few studies were carried out relevant to the vibration monitoring of FFF process and the impact caused on the produced parts. Li et al. [1] developed a data-driven monitoring system based on vibration data for the fault diagnosis of FFF printing in real time. Srivastava et al. [2] carried out a study on the efficiency of vibration analysis for determining the quality of printed parts and strategies for the optimization of their properties. Waheed et al. [3] examined the effect of different motions during printing on the printer response using vibration and acoustic signals, determining the locations where higher levels of vibrations occur. Jhodkar et al. [4] used vibration signals to detect nozzle clogging during FFF printing at high feed rate and found that this method can also indicate non-uniform material deposition. Isiani et al. [5] verified the efficiency of using vibration sensors for fault detection and noted that the positioning of vibration sensors is crucial for the rapid and more accurate identification of faults. Although the

existing works indicate the capabilities of the AM process monitoring through the use of vibration sensors, the exact correlation of printing commands with vibration levels in real time for the detection of the particular motions which cause higher vibrations have not yet been carried out.

In the present work, a theoretical and experimental study was carried out in order to determine the motion of the printing head which causes high levels of vibration during selected cases of FFF printing. More specifically, the movements of the printing head which lead to increased vibrations and which should be avoided were identified based on a robust methodology. The identification of the undesired movements was determined in detail by correlating the GCODE commands with measured vibration signals during printing of selected parts, so that they can be systematically studied in order to determine suitable strategies for vibration reduction. This procedure was applied to several indicative geometries, which are printed under different conditions with emphasis on high printing speeds and then, the obtained results were analyzed and the identified unfavorable motions were evaluated. This study constitutes the first step towards the development of an automated algorithm for optimizing the printing speed and acceleration profiles for achieving increased quality and productivity in FFF AM.

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“Influence of infill density on the tensile strength of 3D-printed PLA specimens”

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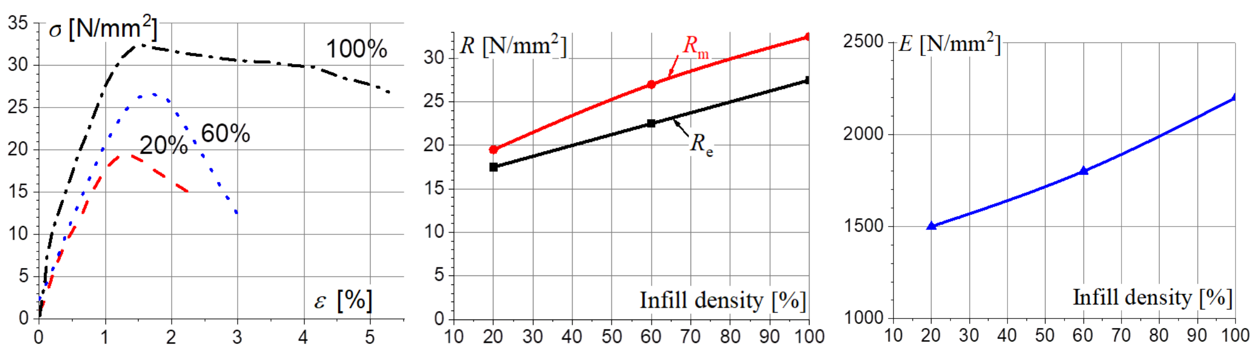
Keywords: additive manufacturing, FDM, PLA, infill density, tensile strength

ABSTRACT

Additive Manufacturing (AM), widely known as 3D printing, has significantly evolved, transitioning from model prototyping to the production of functional components. Fused Deposition Modeling (FDM), one of the most commonly used AM technologies, enables the fabrication of parts with varied mechanical properties depending on printing parameters. This study investigates the influence of infill density on the tensile strength of 3D-printed PLA (Polylactic Acid) specimens. A series of specimens were designed in SolidWorks, prepared for printing using Wanhao-Cura-18.04 software, and fabricated on a WANHAO Duplicator 6 printer. All samples were printed under controlled conditions, maintaining constant parameters such as layer height, shell thickness, and printing speed. The study focused on different infill densities (20%, 60%, and 100%). Tensile strength tests were performed following standardized procedures to evaluate the mechanical properties of the specimens. The results demonstrate a direct correlation between infill density and tensile strength, with higher densities exhibiting superior load-carrying capacity. The findings contribute to the optimization of 3D printing parameters for applications where mechanical performance is critical. Future research may explore the effects of other factors such as build orientation, material, infill patterns, and layer height to further enhance the mechanical properties of 3D-printed components.



Stress-strain diagram, Tensile strength, Yield strength, and Elasticity modulus depending on ifill density

Acknowledgement: This research was funded by the Ministry of Science, Technological Development and Innovation, Republic of Serbia, Grant number 51-03-137/2025-03/ 200105

"Ceramic gear research by the UNNC-NTUA joint International Laboratory on Advanced Vehicles and Powertrains (iLAVP)"

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Keywords: ceramic gears, additive manufacturing, DLP, ceramic coating, power transmissions

ABSTRACT

This study presents a collaborative effort by the UNNC-NTUA iLAVP to improve the wear characteristics of gears through the development of advanced ceramic components using additive manufacturing. The research explores two primary fabrication routes: Digital Light Processing (DLP) based 3D printing of ceramic precursor followed by debinding and sintering; and through Fused Deposition Modeling (FDM) of polymer gears with subsequent ceramic surface coatings. Each approach addresses different aspects of wear resistance, while presenting its own challenges—dimensional shrinkage during sintering for DLP parts and interfacial adhesion for FDM-coated gears.

To support successful fabrication, gear designs were down scaled to 20 mm in diameter with minimum feature sizes of 0.5 mm, and post-processing was employed to refine surface finish, which is critical for reducing friction and enhancing wear performance. Comprehensive characterization was carried out, including surface roughness (AFM), dimensional accuracy (CMM), microstructure (SEM, EDS), and hardness testing. Dynamic testing in a closed-loop setup evaluated gear performance under varying torque and alignment conditions, measuring transmission error, vibration, and noise.

Initial results demonstrate that 3D-printed ceramic gears can achieve promising wear-resistant performance, with further refinement needed for full integration into powertrain systems. This work advances the potential use of ceramics in lightweight, high-durability gear applications.

"Evaluation of sinter based additive manufacturing methods in the fabrication of dies for copper continuous extrusion"

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Keywords: Sinter-based Additive Manufacturing, Binder Jetting, Bound Metal Deposition, Copper Extrusion Tooling

ABSTRACT

The aim of this research is to evaluate the Sinter-based additive manufacturing techniques of Binder Jetting and Bound Metal Deposition, for fabricating continuous copper extrusion dies. Among additive manufacturing techniques, sinter-based methods are the most suitable for extrusion die production due to their high productivity, low cost, and favorable mechanical properties. Dies and samples were designed and fabricated using Binder Jetting and Bound Metal Deposition techniques by Stainless Steel 17-4 and H13 Tool steel respectively. Laboratory testing showed that 3D printed extrusion dies have 31-32% reduced strength compared to conventional dies, with a hardness reduction ranging from 34.8% to 59.2%. However, heat treatment increased the strength of St.17-4 steel by 25% and its hardness by 7%. These findings, combined with finite element analysis, service life estimation, and economic evaluation, suggest that additive manufacturing holds significant potential for rapid prototyping and small production orders, though it cannot fully match the performance of traditional dies in copper extrusion due to defects such as porosity and voids.

"3D Printed Linear Peristaltic Pump based on the principles of Compliant Mechanisms and Power Transmissions: Design and Manufacturing"

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Keywords: linear peristaltic pump, 3D printing, additive manufacturing, compliant mechanisms, power transmissions

ABSTRACT

The present research covers the design and manufacturing of a 3D printed linear peristaltic pump for general use based on the principles of compliant mechanisms and power transmissions. The design is based on the principles of additive manufacturing [1], compliant mechanisms [2], and power transmissions [3]. The aim of this research is the creation of a linear peristaltic pump which comprises of a smaller number of parts than its regular counterpart [4] and which is solely made using additive manufacturing methods. Along these lines, the linear peristaltic pump is divided into two main subsystems which are dealt with separately. The first subsystem is an array of compliant rotary elements connected with flexures which replace the traditional individual moving elements (Fig.1). This array is designed to be 3d printed in a single piece reducing the number of parts and, therefore, the complexity of the device. The second subsystem consists of a timing belt, along with its tension and transmission systems, which provides the actuation of the aforementioned array of rotary elements. This timing belt is designed to be 3d printed in a single piece and to have stiff flexures on the outside. These flexures are designed to be stiff enough to provide the harmonic actuation of the rotary elements, as well as to allow the motion of the belt itself. This is accomplished through the use of smaller supporting structures placed vertically to each flexure which distribute the force along all the belt's flexures (Fig.1). The stable motion of the timing belt is achieved through the use of two 3d printed gears, while its tension is accomplished by two screws and four nuts (Fig.1). For the manufacturing of the prototype, the Fused Filament Fabrication (FFF) method has been chosen due to its availability, cost, and variety of materials. Finally, the linear peristaltic pump has been 3d printed and it is shown in Figure 1.

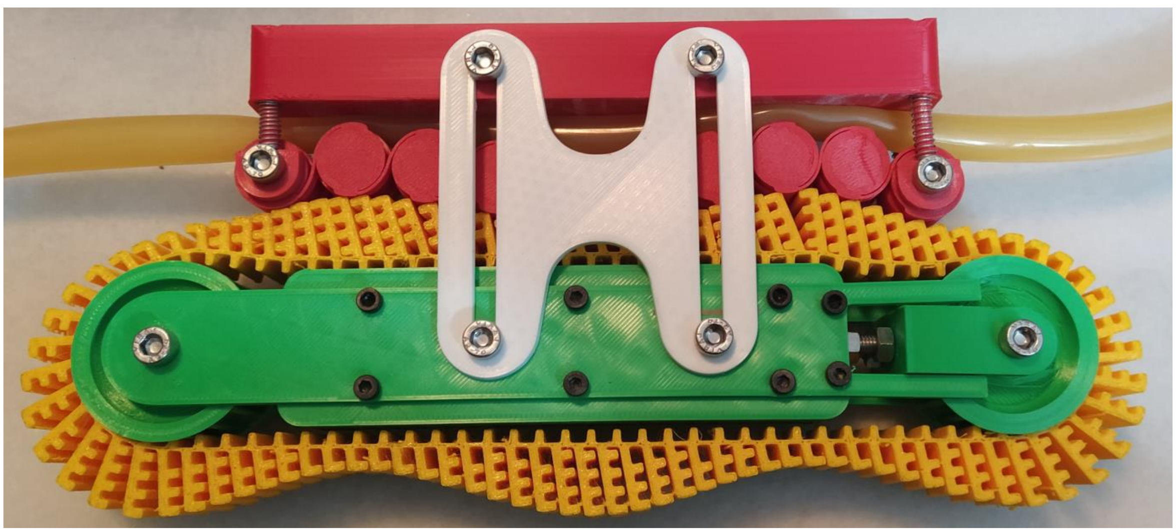

Figure 1: The 3d printed prototype of the linear peristaltic pump

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"Consideration of core functional requirements and operating restrictions, as criteria for AM-capable lightweighting of components"

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Keywords: Additive Manufacturing, Topology Optimization, Lattice Structures, Machine Elements, Lightweighting, Functional Requirements, Geometrical Configuration

ABSTRACT

Additive Manufacturing (AM) Technologies, since their introduction, have heavily contributed to the transformation of modern industry, by helping overcome conventional manufacturing restrictions, and thus enable the realization of modern digitally feasible geometries, incorporating them into complex machine elements, components and assemblies, that would otherwise be difficult, costly, or even impossible to fabricate.

Recent advancements in Shape and Topology Optimization, Cellular & Lattice Structures, Architected and Functionally Graded Materials, and their implementation within digital tools, have shaped a broad palette of capabilities for designers and engineers, for significantly improving and optimizing mechanical systems, especially in terms of weight reduction, but also for other tasks, such as vibration and noise control or insulation, physical shielding, cooling, lubrication, and more. Nevertheless, these new capabilities are, on the one hand, complex and multiparametric, and on the other hand impossible to calculate and utilize without adequate computing power for combined FEA and iterative optimizations. Furthermore, some candidate improvement/optimization strategies towards the same goal, could be directly competitive to each other, creating confusion and possibly misdirecting designers and practitioners away from the most beneficial "optimized" solution, with megative consequences in development time end expenses.

This is why it is useful to have a structured comprehensive framework available as a head start, that considers core functional requirements, as well as important operating restrictions for mechanical systems and their components, and characteristics of their primary candidate AM method, before the latter are subjected to any modern optimizing workflows, for lightweighting, or any other primary optimization task. Obviously, such a framework should also consider some information about the mechanical behavior of potentially competing alternatives.

The presented work, attempting to initiate the development of such a framework, reviews and highlights recent relevant scientific work, and systematically establishes groups and sub-categories of such "functionally-aware" criteria and their parameters, that can be utilized to potentially lead designers towards a more competent optimization alternative for components lightweighting with a specific AM method in mind.

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Tribology

"Concept, design and evaluation of meso-scale surface features for improved frictional performance in disc brake applications"

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Keywords: Brake system, Surface Engineering, Meso-scale surface features, Coefficient of friction, Tribology

ABSTRACT

Life is full of movement, but sometimes you need to stop. Every man-made modern vehicle utilizes a braking system to ensure safety and efficient movement. While braking systems are fundamental to vehicle dynamics, they often receive less public or media attention compared to engines or aerodynamics. Nevertheless, they are among the most vital systems, especially in high-performance applications like motorsport, where precision, and reliability are paramount. Traditional improvements have focused on advances in material science, aiming to improve thermal resistance, wear characteristics, and frictional performance. More recently, research has focused on modifying surface textures to control frictional behavior, giving rise to the concept of frictional meta-interfaces where geometry plays a central role in frictional performance [1,2]. Similar approaches have been explored in tribological systems involving hydrodynamic lubrication and drag reduction through bio-inspired textures [3]. Building on this idea, the present study investigates a geometry-based approach: enhancing braking efficiency by introducing macroscopic surface features at the disc–pad interface, without altering materials or component volume. This is especially relevant in motorsport contexts, where materials are typically constrained by regulations or already highly optimized. Finite Element Analysis (FEA) was performed using ANSYS Mechanical, simulating soft-hard, pad-to-disc contact to evaluate the effect of surface geometry on the coefficient of friction. Realistic material properties were applied to reflect motorsport-grade components. To validate the proof of concept, a series of experiments was conducted using metallic test specimens fabricated via Selective Laser Melting (SLM). After post-processing, surface was assessed using

3D optical profilometry. Frictional behavior was then measured using a pin-on-disc tribometer across a range of sliding speeds and applied forces. The preliminary results obtained suggest that engineered surface topology can meaningfully influence frictional performance, offering a promising route for optimization within existing material limitations.

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Exploiting Machine Learning Models to Predict Contact Pressure for Fretting Wear Assessment

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Keywords: Contact Mechanics, Fretting Wear, Hertzian Elastic Theory, Johnson-Kendall-Roberts (JKR) Adhesion Model, Derjaguin-Muller-Toporov (DMT) Model, Maugis–Dugdale (MD) Theory, Roughness, Greenwood-Williamson, Greenwood-Tripp, Archard Model, Machine Learning Techniques, Support Vector Machines (SVMs), Artificial Neural Network (ANN).

ABSTRACT

Fretting is a tribological phenomenon occurring at the interface of two contacting bodies subjected to a normal load combined with small-amplitude oscillatory tangential displacements. This micro-motion, typically ranging from nanometers to a few micrometers, induces surface degradation through mechanisms such as adhesive wear, abrasive wear, and surface fatigue. Fretting arises in engineering components exposed to vibration, cyclic thermal expansion, or repeated loading, including gears, bolted joints, bearings, and biological joints. The process leads to the formation of wear debris, often oxidized, which remains trapped in the contact zone and accelerates material removal. The primary failure modes associated with fretting are fretting wear, characterized by progressive surface material loss, and fretting fatigue, where crack initiation and propagation occur due to cyclic stresses localized at the contact interface. These phenomena significantly reduce the fatigue strength and operational lifespan of mechanical components.

This study introduces a methodological framework for systematically evaluating contact pressure distributions between interacting surfaces using four established contact mechanics theories: Hertzian elastic theory, Johnson-Kendall-Roberts (JKR) adhesion model, Derjaguin-Muller-Toporov (DMT) and Maugis–Dugdale (MD) theory. The multifactorial dependencies in tribological systems-including surface roughness, normal load, material properties, and lubrication regimes (here under dry condition)-create a high-dimensional parameter space that precludes exhaustive experimental characterization of all possible loading scenarios. The investigation proposes a systematic computational framework to automate contact mechanics analyses through parametric variation across multiple tribological parameters (e.g., normal load, surface roughness, material properties). The methodology will generate an extensive dataset of numerically derived loading scenarios ($\sim 10^3$–10^4 cases) encompassing diverse metallic tribopairs. This structured database will serve as the training substrate for implementing supervised machine learning algorithms, with emphasis on Support Vector Machines (SVMs) and feedforward Artificial Neural Network (ANN) architectures. These Machine Learning Techniques aim to establish nonlinear mappings between input tribological variables and output performance metrics-specifically probabilistic wear prediction and frictional force estimation. The proposed framework integrates first-principles analytical modeling with data-driven techniques to enhance wear and friction prediction accuracy across unvalidated loading configurations. This data-driven approach seeks to overcome combinatorial limitations of experimental testing by enabling rapid assessment of unvalidated loading configurations through trained network extrapolation.

In the meanwhile, an experimental rig is currently being assembled in the Machine Design Laboratory to study friction-induced wear mechanisms. The setup comprises a cantilever beam rigidly clamped at one end, with a harmonic oscillator (modal shaker) attached to the free end to induce controlled oscillatory motion. The beam's free end is equipped with a flat metallic contact surface, which interfaces against a spherical counterface subjected to a normal load applied via a preloaded spring. This configuration facilitates reciprocating sliding contact under controlled normal force and oscillation amplitude. The experiment aims to characterize the wear behavior of the frictional pair by applying Archard's wear equation, enabling quantitative assessment of wear volume as a function of contact parameters and sliding conditions.

In conclusion, this investigation aims to address three interconnected research priorities: Computational Automation: Implementation of an automated computational framework for multiscale contact simulation. Tribological Informatics: Construction of a standardized materials repository (tribopairs) quantifying frictional behavior and surface degradation patterns across binary metallic systems (ferrous/non-ferrous alloys, coatings) in terms of fretting regime, through computational analysis of contact pressure for the aforementioned contact mechanics theories. Predictive Analytics: Deployment of supervised learning architectures, to establish statistically robust relationships between tribological operational variables (contact pressure, material properties, Young Modulus, surface roughness) and mechanistic wear response (adhesive, abrasive, fretting fatigue-based modes). The integration of machine learning-derived constitutive models is hypothesized to significantly enhance prognostic capabilities in wear evolution analysis, thereby optimizing reliability-centered maintenance protocols for high-stress mechanical interfaces.

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"Understanding the Role of Al-CuSn10 Metal Powder in Enhancing Mechanical and Tribological Properties of Glass/Carbon Fiber Reinforced Polymer Composites."

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ABSTRACT

A promising method for enhancing structural and tribological performance for advanced engineering applications is the incorporation of metal powders into Fiber-reinforced polymer composites. The impact of hybrid copper-tin (CuSn10) and aluminium (Al) metal powders on the mechanical and tribological characteristics of glass/carbon Fiber reinforced epoxy composites is examined in this work. To determine the ideal level of reinforcement for attaining the greatest performance benefits, the Al-CuSn10 blend was introduced in three different variations with 5 wt.%, 10 wt.%, and 15 wt.%. Hybrid composite laminates with woven glass and carbon Fibers in a fixed Fiber-to-matrix ratio were created by vacuum resin transfer moulding. Before being distributed throughout the epoxy matrix, the Al and CuSn10 powders were first combined in a 1:1 weight ratio. Tensile strength, flexural strength, impact energy, and hardness testing by ASTM standards were all part of the mechanical characterization. A pin-on-disk wear tester was used to assess tribological behaviour in dry sliding conditions by examining wear loss and the coefficient of friction. Filler dispersion, interfacial bonding, and wear mechanisms were examined through microstructural and phase analyses using SEM, EDS, and XRD. According to preliminary findings, when compared to non-filled Fiber composites, 10 weight percent filler loading produces the best balance between mechanical and tribological improvements, with up to 25–35% increases in tensile and flexural strength and 40–50% decreases in wear rate. Particle agglomeration and interfacial stress concentration marginally impair performance at 15 weight percent. Better load transfer, consistent filler dispersion, and CuSn10's solid lubricating function in lowering friction are all responsible for the enhanced behaviour. To design high-performance Fiber-reinforced composites for structural and tribological applications, this study shows that Al–CuSn10 powder is a viable functional filler.

Keyword: Hybrid composite, Al–CuSn10 metal powder, Glass/carbon fiber reinforcement, Polymer matrix composites (PMC), Mechanical properties, Tribological behaviour, Wear resistance, Metallic fillers.

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"Tribological Study on the Influence of Solid Lubricants over Hybrid Aluminum Metal Matrix Composites."

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Keywords:

Aluminum metal matrix composites, Tribology, Al7075 Alloy, microstructural properties, mechanical behavior, Stir casting process.

ABSTRACT

Aluminum Metal Matrix Composites (AMCs) exhibit significantly enhanced properties, including high specific strength, specific modulus, damping capacity, and wear resistance, all while maintaining a good strength-to-weight ratio compared to unreinforced alloys. This study investigates the impact of reinforcements on the microstructural, mechanical, and tribological properties when compared to the base material, Al7075. In this research, the Al7075 alloy is reinforced with 5 wt.% Boron Carbide (B4C) and 5 wt. % Molybdenum Disulfide (MoS2) as a solid lubricant. These particulate reinforcements are incorporated using the stir casting process. Microstructural analysis is conducted using both optical and scanning electron microscopes, and the findings are presented. The effectiveness of the reinforcements is evaluated through various mechanical tests, including Brinell hardness, tensile, and compression tests, all carried out in accordance with ASTM standards. The results demonstrate that the addition of graphite and boron carbide to the aluminum alloy matrix significantly enhances mechanical and tribological properties, outperforming other aluminum hybrid composites

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Materials and technological processes

“Convergence analysis of 3D-printed stochastic Voronoi structures for biomedical implants: effect of representative volume element size and porosity”

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Keywords: Voronoi cellular structures, additive manufacturing, biomedical implants, 3D printed titanium, Representative Volume Element, computational homogenization, porosity

ABSTRACT

This study investigates the influence of porosity on the Representative Volume Element (RVE) size requirements and mechanical properties of 3D-printed stochastic Voronoi cellular structures made from Ti-6Al-4V. Porous metallic structures fabricated via 3D printing have revolutionized biomedical implant design by addressing critical challenges such as stress shielding and osseointegration in orthopedic applications. While previous studies have examined either fixed porosity values or regular lattice structures, this work addresses the critical knowledge gap regarding stochastic Voronoi structures across a wide porosity range (50-90%) relevant to bone tissue engineering. Computational homogenization was employed to design cubic RVEs with varying porosities, analyzing elastic properties (Young's modulus, Poisson's ratio, shear modulus) across multiple random seeds until convergence was achieved. The results demonstrate that minimum RVE size requirements increase significantly with porosity, with higher porosity structures requiring substantially larger RVEs to achieve statistical convergence. Virtual compression testing revealed a predictable trend of decreasing compressive strength with increasing porosity, providing critical design parameters for load-bearing implants. All elastic moduli exhibited substantial decreases with increasing porosity, with values at higher porosities approaching those of natural bone. These findings provide qualitative and quantitative guidelines for efficiently modeling 3D-printed stochastic cellular materials, enhancing the design process for patient-specific

implants where optimizing both stiffness and strength while promoting biological integration are paramount considerations.

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"Prediction of Drilling Induced Delamination of Carbon Fiber Reinforced Polymer Matrix Composite"

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Keywords: CFRP composites, Drilling, Point angle, Finite element analysis, Delamination.

ABSTRACT

Composite materials are generally chosen over conventional materials because of their greater strength-to-weight ratio. However, because of their tremendous variety, businesses face significant challenges when it comes to machining composite materials such as carbon fiber reinforced polymer (CFRP). When the composites are put into use, several machining operations are needed, drilling is one of the main procedures that is frequently needed during assembly. To achieve higher-quality drilling on composite materials, several researchers have optimized process parameters. Experimenting with CFRP requires significant time and financial investment for manufacturing and testing for which researchers are increasingly using high-performance computing to simulate drilling processes. In this work finite element analysis is used to numerically model the drilling process for CFRP laminate using three cutting speeds (500,750 & 1000 rpm) and three different point angles (85,118 & 135 degrees). Finally, from simulation cutting speed with point angle 118 degrees resulted with minimum delamination. This will provide the researchers with a one-stop learning solution to various methods for machining numerical modeling.

“Fabrication of novel hybrid composite to understand the mechanical and Microstructural Properties of Glass/Carbon Fiber Reinforced Polymer Composites Using Inconel 718 Metal Powder: A Comparative Study.”

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Keywords:

Inconel 718, hybrid composites, microstructural properties, mechanical behaviour, nickel-based powder, glass fiber, and carbon fiber.

ABSTRACT

Fabrication of high-performance novel hybrid polymer composites has drawn significant attention for advanced mechanical and microstructural applications in aerospace, automotive, and defence sectors. In this study, a novel hybrid composite was fabricated by incorporating Inconel 718 nickel-based metal powder into glass and carbon fiber reinforced epoxy composites to investigate the effects on mechanical and microstructural properties. Inconel 718, known for its superior strength, thermal stability, and wear resistance, was introduced as a secondary particulate reinforcement in varying weight percentages (0 wt%, 1 wt%, 3 wt%, and 5 wt%) to assess its influence on the composite matrix. The composite laminates were fabricated using a vacuum bagging process followed by curing at room temperature and further sintered at 60^0-80^0 degrees temperature in the oven for 1 hour. Both bidirectional and woven glass and carbon fibers were used as the primary reinforcements, while epoxy served as the polymer matrix. Mechanical properties, including tensile strength, flexural strength, impact, and hardness, were evaluated as per ASTM D3039, ASTM D790, and ASTM D256 standards. Microstructural analysis carried out by using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS) was conducted to examine filler dispersion, fiber-matrix interaction, and wear surface morphology. The results are expected to show a significant enhancement in tensile and flexural strength (up to 20–30%) and hardness (by 15–25%) at optimal filler loading, attributed to improved load transfer, interfacial bonding, and the self-lubricating properties of Inconel 718 particles. However,

excessive filler content may lead to agglomeration and reduced mechanical integrity. This study demonstrates the potential of Inconel 718 powder as an effective filler to develop multifunctional fiber-reinforced polymer composites with enhanced structural and mechanical performance, suitable for demanding engineering applications.

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"Development of an algorithm for the positioning of parts for the efficient use of motors based on specific FFF printer kinematics"

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Keywords: Fused Filament Fabrication, motors, printer kinematics

ABSTRACT

Due to the ever evolving requirements for high quality manufacturing of demanding mechanical parts, it is essential to constantly improve the capabilities of manufacturing processes so that higher levels of dimensional accuracy, surface quality and productivity are achieved. Especially in the case of additive manufacturing (AM) processes, the quality of the final product and its properties are considerably dependent not only on the process conditions but also on other parameters, such as the part orientation or build strategy, support structure design, and material selection. Part orientation, for example, can significantly influence surface finish, mechanical strength, and the amount of post-processing required, while the choice and placement of support structures affect both print stability and ease of removal. Therefore, a more general approach that optimizes all these factors with the suitable limitations is vital to extend AM capabilities and meet the stringent demands of high-end industries.

In specific, efficiency during FFF AM process is dependent not only on the process parameters but also on the appropriate utilization of the printer motors, based on the printer kinematics. However, the orientation of parts with complex features can be rather controversial for some printers as it will require increased load on the motors to print some special features, leading to the reduction of process efficiency. Thus, optimizing part positioning to enhance motor usage in Fused Filament Fabrication (FFF) printing is a crucial advancement, especially given the diverse kinematics employed across different printer architectures such as Cartesian, XY, Delta, and Polar systems. Each kinematic setup presents unique motion characteristics and constraints, directly impacting print speed, accuracy, and mechanical wear. By developing an algorithm that intelligently arranges parts on the build platform tailored to these different kinematics, it is possible to minimize unnecessary motor movements, reduce print times, and improve overall energy efficiency.

As the current specifications of FFF 3D printed have several limitations, especially on their stability at high speeds, in the relevant literature several authors investigated ways to overcome the limitations of AM process, including the maximum speed based on the manipulation of the motors' operation or the optimization of the path depending on specific kinematics. For example, Go and Hart [1] proposed various modifications in a desktop scale FFF printer in order to overcome limitations during FFF printing and achieve high cost-effectiveness. Among other modifications they used a servo-driven parallel gantry system to increase the printing speed capabilities. Monterio et al. [2] created an FFF printer based on cylindrical coordinate frame with multiple print heads achieving high versatility and production rate as different materials could be used for a single part which could be processed in the same area. Kuznetsov et al. [3] focused on the effect of the printer hardware on the part strength and underlined that the same code for printing a mechanical part can lead to considerably different properties of the part even for the same process parameters. Maravi et al. [4] developed a PID control system in order to avoid steps loss from a Core XY printer

motors when high speeds are selected, something that may occur in less expensive printers. Rooney et al. [5] correlated the loading on the stepper motors with defects and failures during the printed process in order to avoid the waste of resources when these defects remain undetected for long time.

In this work, a theoretical model, based on different FFF printer configurations kinematics was developed in order to improve motor utilization by optimally positioning the desired parts. In specific, the STL file used for printing the parts is analyzed regarding the necessary movements during printing and the best possible orientation of the part is suggested by an automated algorithm. The necessity of such an algorithm grows as the demand for faster, more reliable, and cost-effective 3D printing solutions increases across industries. As traditional slicing software often overlooks the interplay between part orientation and positioning and kinematic-specific motor dynamics, lower performance can be expected. Thus the proposed algorithm addresses this gap by providing a systematic way to determine the unique positioning of parts according to the motion profiles of different printer types, ensuring that motor usage is balanced and optimized throughout the printing process in order to increase the capabilities of FFF printing.

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"Experimental study on the mechanical behavior of additively manufactured polymer rivets"

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Keywords: Fused Filament Fabrication (FFF), thermoplastic polymer, rivet, mechanical properties

ABSTRACT

Fabrication of mechanical parts is always of major importance in various advanced industries as they require improved or more specialized machines with increased capabilities. Apart from the conventional methods, additive manufacturing methods can be nowadays applied for producing complex and customized parts but not to all types of materials or mass production due to existing limitations and cost despite that they are capable of creating parts with superior mechanical properties and design flexibility. Various mechanical parts can be successfully manufactured by relevant processes depending on their material and level of complexity and the specific additive manufacturing technology used.

The widespread use of various polymer types as well as polymer composites for a variety of engineering applications leads to the need of studying and optimizing the different manufacturing processes in order to overcome various challenges which are related with the fabrication of functional polymer parts. Additive manufacturing processes and especially FFF are nowadays a feasible way to create functional parts with sufficient strength, flexibility and sufficient resistance to heat, depending on the material used [1]. For example parts created by polyamide, PEEK or polymer composites can be used as enclosures, brackets, supports, bushings, connectors, panels, in ventilation systems, parts of medical devices (biocompatible materials), jigs, tool handles and grips. The use of polymer functional parts has been studied for various applications in the relevant literature [2]

However, polymer-printed functional parts face a range of technical and practical challenges that impact their performance, scalability, and adoption in demanding applications. The main challenges include the limited availability of functional polymers, the relatively inferior mechanical properties, the anisotropy, increase surface roughness or higher porosity, various defects and part distortion, lower productivity and need for post-processing [3]. Addressing these challenges requires ongoing advances in materials science, printer technology, post-processing methods, and design strategies to expand the capabilities and reliability of polymer-printed functional parts [4].

Rivets are mechanical fasteners used to join two or more materials together permanently. They consist of a cylindrical shaft with a head on one end, and when installed, the opposite end is deformed to hold the materials securely. Rivets are widely used in construction, aerospace, automotive, and manufacturing industries due to their strength, durability, and ability to distribute loads evenly. These mechanical parts can offer a durable connection for various conditions, even in the case of vibrations, do not require threading, so that they can be used for joining thin or soft parts.

Especially plastic rivets are lightweight, particularly resistant to corrosion, low cost can be employed in a wide variety of applications such as car components, fastening of circuit boards or securing panels among others [5].

In the relevant literature, the capabilities of printed functional mechanical parts such as rivets has not been thoroughly explored yet, despite that FFF is a promising alternative method for polymer processing. Thus, in the present work, an experimental study is carried out to determine the impact of printing parameters on the strength of joined polymer parts by polymer rivets. The polymer rivets are fabricated under different conditions such as infill density, number of shells and layer height and afterwards the mechanical properties of the joint produced by the use of the printed rivets are determined through tensile tests, by the use of a special tensile specimen, presented in Figure 1, and analyzed by appropriate statistical methods. The results of these investigations are expected to be crucial for the study of the capabilities of 3D printed functional polymer parts and can constitute the foundation for further studies e.g. with different materials and geometries.

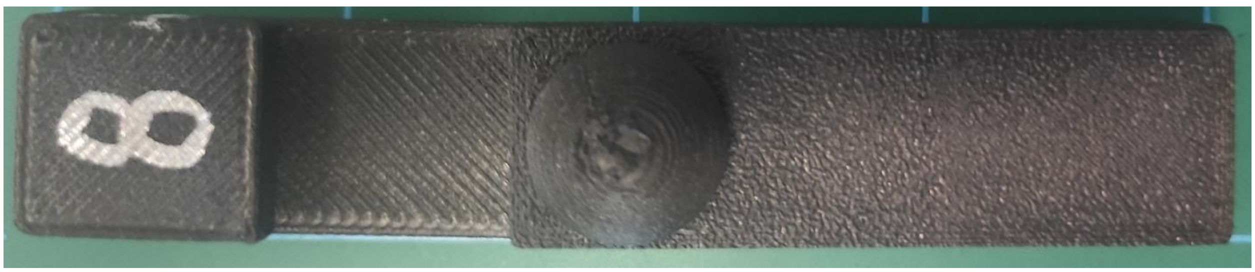

Figure 1. Tensile test specimen for testing the strength of rivet joint.

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"The effect of ply overlap on mechanical properties of composite material structures"

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Keywords: Overlap effect, Three point bending, Composite materials, Flexural strength, Mechanical testing

ABSTRACT

At the designing process of CFRP structures an important factor to be determined is the geometrical interconnection of plies. It is where the structure is expected to fail under excessive loading due to the discontinuous character of the fibers. Different geometrical concepts of ply overlap produce structures with different mechanical properties, corresponding the strength and modulus of elasticity. This work reports experimental research of the effect of ply overlap on the mechanical properties of CFRP plates. Two geometrical concepts of ply overlap were examined in the serial and the successive one. For each concept four groups of specimens were manufactured with the length of the joint varying for each subcase. An additional number of specimens were manufactured without ply overlap. All of the specimens were subjected to 3-point bending test to determine their flexural strength and modulus of elasticity. The results were compared to those obtained for the specimens with continuous fibers - no overlap respectively. The serial overlap proved to be better in all cases compared to the successive concept, while increasing the overlap length, also increases the flexural strength of the structure.

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Industrial applications

"Design and development of a prototype condition monitoring system for large gear pairs operating under harsh environments."

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Keywords: large gears, helical gears, condition monitoring, DAQ, FFT, flank wear

ABSTRACT

The present study involves the design, development and installation of a prototype condition monitoring system for the estimation of the structural integrity of large gear pairs, through the periodic measurement of the vibration levels. Estimation of the wear levels in mating gears has been an ongoing subject of international research [1],[2],[3]. Multiple methodologies have been introduced and experimentally validated [4],[5],[6]. However, very few works can be traced to applications involving large scale gear pairs operating in the high-torque low-speed area. In the present work the estimation of the structural integrity is performed though the accurate measurement of the vibration levels of the mating gears during operation using a single axis accelerometer. In order to have full control over the required characteristics of data acquisition a complete DAQ system was designed, tested and validated in laboratory conditions. The purpose of the design of the prototype DAQ system was to be able to adjust to the specific operating conditions of variable applications including harsh environments and low frequency responses. One of the main attributes of the prototype DAQ system is the use of the commercial microcontroller Arduino Uno R3 that enables easy operation and low development cost without sacrificing the measurement accuracy.

The prototype condition monitoring system was installed on the final drive stage (helical gear pair) of the ski lift at the ski resort of Velouchi, Greece. As shown in Figure (1) the mating gears already exhibited quite high levels of flank wear thus making it impossible to calibrate the measured spectra in the nominal conditions. The operational characteristics of the gear pair were considered for the meticulous tuning of the condition monitoring system shown in Figure (2) and are discussed in depth. As already mentioned, the installation site presented a challenging environment including very low temperatures (down to -10ºC), low quality mounting surfaces (highly oxidized) and incapacity to access the bearing mounting points (see Figure (3)). Nevertheless, measurements taken on site clearly captured the fundamental principle excitations of the system as previously calculated during the design phase. The time series data of the measured accelerations are manipulated using the Fast Fourier Transformation (FFT) to calculate the excitation frequencies and the respective amplitudes as shown in Figure (4). Since the system was installed on site during the late winter period, no significant variations of the measured vibration levels have been recorded

yet. A proper measurement plan has been formulated and is going to be modified in accordance with the wear progression.

Figure 1: Initial conditions of the ski lift wheel.

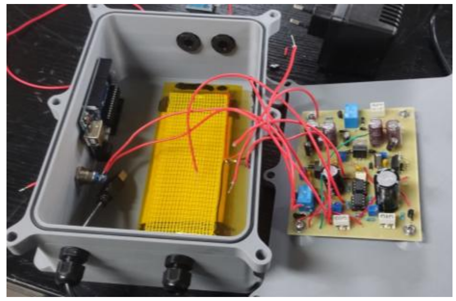

Figure 2: Prototype data acquisition system

Figure 3: Mounted accelerometer.

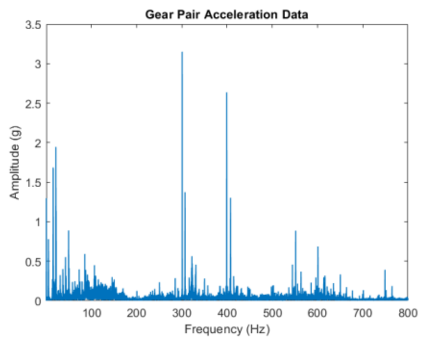

Figure 4: Indicative frequency diagrams taken on site. The fundamental frequencies are visible along with their respective harmonics.

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"Concept and design aspects of High Temperature Heat Pumps in the EU-PROJECT SOLINDARITY"

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Keywords: High temperature heat pump, Solar Energy-based Heat Upgrade System, industrial demonstration applications

ABSTRACT

The EU-Project SOLINDARITY will develop, demonstrate and validate the feasibility of an integrated Solar Energy-based Heat Upgrade System (SEHUS) comprising solar energy resources (High Vacuum Flat Solar Panels and Photovoltaic), innovative High Temperature Heat Pumps (HTHP), Thermal Energy Storage and Waste Heat Recovery for the deep decarbonization of industrial processes with temperatures up to 280°C. The pilot system to be developed will demonstrate its effectiveness, robustness, sustainability and cost-efficiency in three industrial sites, belonging to different industrial sectors (Food, Paper, Rubber industries) and climatic regions (Germany, Greece, Italy). This publication presents initial results from the development of a reversed Brayton HTHP regarding the SEHUS, while considering different industrial applications. The integration concept and a preliminary dimensioning, based on steady-state simulations, cover the configuration of the HTHP and serve as the starting point for the design phase, particularly regarding the turbo machinery and the drive system. Results from the system's initial design iterations are also presented, allowing conclusions to be drawn about the process integration of HTHP and its components into different industrial applications.

“Methods for power transmission shaft repairing”

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Keywords: power transmissions, shafts, repair, welding, machining

ABSTRACT

Power transmission elements endure high stresses during regular working life and unpredictable working issues. Despite advances in mechanical design, good operational practice, and developed operation procedures, failures of power transmission elements occur. The detailed failure analysis of such elements is the first step and the basis for the feasibility analysis of the repair method. The appropriate feasibility analysis must give an optimal repair solution, considering the direct and indirect costs of the repair and post-repair conditions of the repair. The feasibility analysis, which must have an in-depth analysis of technical and economic aspects, must answer whether it is possible to repair a power transmission element to obtain a fully operational element and how the optimal repair strategy can be determined. This paper compares the repair of two failed shafts and examines and compares two repair approaches with a full-force field analysis.

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"Analysis and Design of a Hydrogen Fuel Tank with Cellular Structure for the Automotive Industry"

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Keywords: hydrogen, tank, automotive, strain-hardening, homogenization, RVE

ABSTRACT

The present study examines the analysis and design of a high-pressure gaseous hydrogen fuel tank with cellular structure for the automotive industry. As seen in Figure 1, the current conventional cylindrical gaseous hydrogen tanks used in hydrogen vehicles induce packaging issues due to tank's geometry and volume, resulting in the reduction of passenger, luggage space and comfort, in comparison to conventional vehicles. Research has been conducted regarding the design and analysis of various conformable hydrogen fuel tanks [1], [2], [3] and conventional cylindrical hydrogen composite fuel tanks [4], [5], [6]. However, there is insufficient research about the design and analysis of conformable low height high-pressure gaseous hydrogen fuel tanks for the automotive industry, complying with the specifications about hydrogen's working pressure (700 bar) and vehicle's desired range. Therefore, the aim of this work is to design a fuel tank with flat geometry and low height, utilizing the flat space of the vehicle and increasing the passengers' and luggage space. Considering the mechanics of shell pressurized structures, a flat cellular aluminium structure is proposed, which consists of repeating thin-walled small-diameter spheres intersecting with each other (Figure 2). Pressurized hydrogen is occupied inside the cavity that is created. To achieve low mass without structural failure, material's plasticity model is considered using Ansys software. Since filling pressure is 875 bar and working pressure is 700 bar, filling pressure is used as the strain hardening triggering mechanism, so plasticity is induced inside the cavity, reducing stress gradients across the area, while keeping the value of maximum Von Mises Stress below material's Ultimate Tensile Stress (Figure 3). To analyze tank's structural behavior from external loading (vehicle's maneuvers) and design the mounting points of the tank, homogenization techniques using Representative Volume Elements (RVEs) are applied because of the complexity of the geometry and the existence of pre-stress from hydrogen pressure (Figure 4). Vehicle packaging with the proposed cellular tank in comparison to a conventional tank is presented in Figure 5.

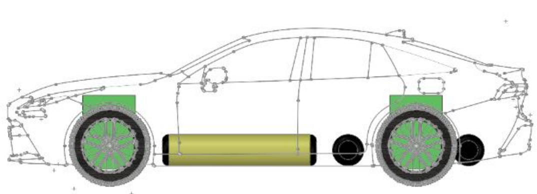

Figure 1. Fuel tank layout of hydrogen vehicle

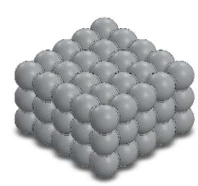

Figure 2. Model of cellular multi-sphere structure

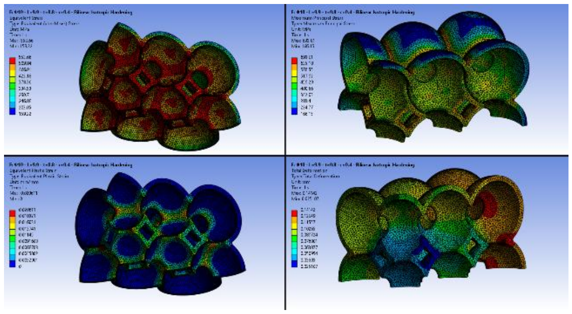

Figure 3. Structural simulation of induced internal pressure using plastic model

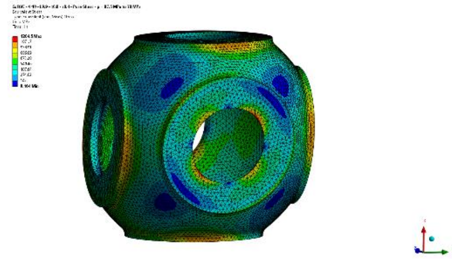

Figure 4. Homogenization of RVE - Pure Shear

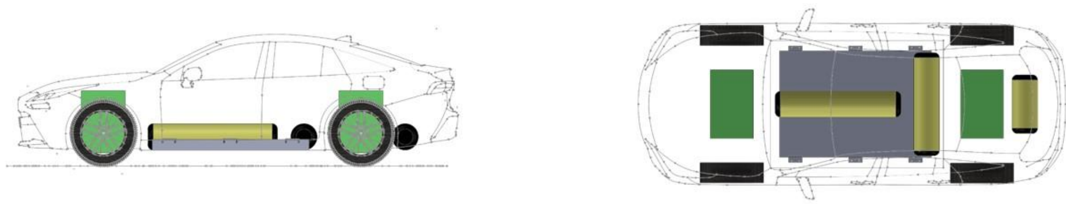

Figure 5. Flat cellular fuel tank in comparison to a conventional cylindrical fuel tank

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"Additive manufacturing technology for unmanned aerial vehicles and missiles: challenges, open issues and limitations"

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Keywords: unmanned aerial vehicles, missiles, additive manufacturing, conventional manufacturing, composite materials

ABSTRACT

Additive manufacturing (AM) has become an attractive production technology for the aerospace sector, particularly in the area of unmanned aerial vehicles (UAVs) and missiles. AM is being used to produce a growing range of components for light-weight UAVs and missiles to enhance flight and aerodynamic performance. However, light-weight aerial structures with complex inner features are hard to fabricate using conventional manufacturing methods. Recent developments in composite and multi-material printing opens new possibilities of fully printed light-weight UAVs and missiles with desired features.

The present work provides a short introduction on state-of-the-art AM technologies and techniques for UAVs and missiles, through innovations in materials and structures, and how they differ from conventional manufacturing methods. Particularly, the advantages and potential of AM technologies on the improvement of aerodynamics and structural efficiencies of UAVs and missiles are emphasized. The paper also highlights open issues, challenges and future directions for the realization of fully printed lightweight UAVs and missiles with desired features.

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Education

"Contemporary Approaches in Engineering Education: Integrating Large Language Models to Foster Inquiry-Based Learning through the Study of Gears"

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Keywords: Abstract, guidelines, power transmissions

ABSTRACT

This study explores the role of Large Language Models (LLMs), such as ChatGPT, in applying inquiry-based learning (IBL) within the context of engineering education. Gears are selected as the learning object due to their inherent complexity and pedagogical value, serving as a bridge between mechanical engineering, physics, and mathematics. LLMs are employed as intelligent assistants that support critical thinking and provide personalized feedback, guiding students through the process of knowledge construction via exploratory learning pathways. The integration of LLMs into IBL environments enables students to formulate hypotheses, analyze systems, and draw conclusions grounded in experiential engagement. Furthermore, the study highlights the potential of gears as a didactic medium even in early childhood education, facilitating the intuitive understanding of foundational mathematical operations such as multiplication and division, as well as basic physical principles like force transmission and rotational motion. In conclusion, the incorporation of LLMs into engineering education enriches the IBL process, fosters learner autonomy, and cultivates deep conceptual understanding through active, discovery-driven learning experiences.

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"The prospect of generative AI in assisting the creation of Laboratory Exercises in Power Transmissions"

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Keywords: planet gear train, experimental based learningmodel, generative AI, educational desing, laboratory exercises

ABSTRACT

In recent years, large language models have infiltrated a wide variety of sectors, from assisting deep research in academia to helping the average person in everyday tasks. AI has shown incredible capabilities that can be useful for educators both in facilitating their work and improving it. The purpose of this article is to present a novel approach to the educational design of mechanical engineering laboratory exercises by employing the use of generative AI and also to showcase the capabilities, possible limitations and educational outcomes that AI has in doing so. This work can serve as a future reference for curriculum planning, course design, and laboratory educational design, among other applications. The process used consisted of four parts. Firstly, the physical experimental model of the Planet Gear Train (PGT) was studied so we had a general idea of what to ask and expect from ChatGPT. Thereafter, using suitable prompts in each step, AI a) generated the general overview of the exercise with a worksheet, b) found additional/preparatory learning material, c) analyzed the expected educational outcomes, d) generated an assessment sheet for the students, and e) generated the final formatted lab report, and so a complete educational scenario was created. Then a pilot application of the scenario was conducted with a group of students to confirm its feasibility in reality. Subsequently, a focus group conducted a small qualitative survey with the participating students. The results retrieved from this work indicate that AI can be a feasible option in designing laboratory exercises, offering both a quality educational product while saving time for the educator. It also noted that students were more engaged and interested, and it was easier for them to understand PGT kinematics. As it turned out, the resulting lab fosters conceptual understanding, analytical thinking, and practical skills. Finally, the methodology followed for creating the educational scenario showcases an effective way of thinking with proven results that can be useful to anyone looking to use generative AI for this purpose.

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"The use of AI tools in teaching 'Motion and transport systems'"

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Keywords:AI Tools, Engineering Education, Mechanical Engineering

ABSTRACT

During the last years Artificial Intelligence (AI) has a great impact in our everyday life, however it is still under evaluation how AI teaching and learning tools can improve the theoretical understanding and practical learning. Teaching activities by using platforms such as ChatGPT, MATLAB/Simulink, Python-based AI libraries, and visual design tools like Canva or Twinmotion seems to provide a more direct communication for technical results that can better prepare the students to become part of today's growing.

These tools support various aspects of the course, including conveyor system simulations, sensor data interpretation, and modeling of transport mechanisms. AI-driven approaches not only improve student's thinking and autonomy but also align with modern engineering practices, and in any case connect the laboratory exercises with actual industry standards.The current study is addressed to the students of the course of "Motion and Transport systems" of the Mechanical Engineering Department of ASPAITE and their performance on the course by using / or not AI tools.

Students were encouraged to use ChatGPT as a study companion to clarify concepts, explore con-veyor types, and check calculations. We emphasized its role in supporting—not replacing—their learning process. We also showed them how to ask clear, technical questions and evaluate re-sponses critically. We integrated it into assignments by asking also for reflections on how it aided their understanding and promoted its use for reflection, report writing, and preparing for exams or design projects.

The course was also evaluated by the students at the end of the semester by using a questionnaire related with AI Tool Usage. When asked to evaluate the course, students reported higher engagement, improved understanding of complex topics, and greater confidence in problem-solving in comparison with courses where the use of A.I. tools was prohibited. They felt more motivated and they appreciated the on-demand help and personalized learning pace that A.I. tools provided. Final test results also showed higher performance. In conclusion, A.I. tools seem to have a large potential to assist and improve engineering education. It seems, however, that effectiveness of A.I assisted courses depends mostly on clear guidelines and purposeful integration of the tools.

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"Integrating AI systems into engineering essays. Exploring ethical and pedagogical implications in the context of a course on power transmissions"

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Keywords: Generative AI in Education, Technical Writing, Academic Integrity, Student Engagement, Mechanical Engineering Pedagogy

ABSTRACT

The adoption of large language models (LLMs), such as ChatGPT and others, is rapidly transforming engineering education. Their use in supporting students writing essays, particularly in technical domains like power transmission, offers extraordinary opportunities. This paper explores the use of Artificial Intelligence as an assistant in essay writing within mechanical engineering degree programs, with an emphasis on the pedagogical value of this approach and its relationship with academic ethics. Engineering essays are an important pedagogical tool, allowing students to develop technical communication skills, conceptual understanding, and critical reflection on complex topics such as gear drives, chain mechanisms, and torque transmission systems. The integration of AI tools into this context enables students to organize their ideas, receive real-time language and formatting support, and explore technical concepts through interactive dialogue. From an instructor's perspective, AI can serve as a co-designer, helping create essay prompts, rubrics, and formative feedback templates. However, the incorporation of AI into student writing raises pressing ethical considerations. These include concerns about academic integrity, authorship transparency, and the possible inability to develop critical thinking, if students rely too much on AI-generated text. Furthermore, the ability of students to have, or not to have, access to powerful artificial intelligence tools can contribute to creating situations that are not consistent with the principle of equal opportunities within the educational community. Pedagogically, educators must find a balance between using AI for learning support, ensuring that students retain ownership of the cognitive and creative processes, related to essay writing. This paper presents a case involving upper-level students of a mechanical engineering educators department, enrolled in a power transmission course. Students were given an assignment and were guided to use generative AI systems responsibly, citing AI contributions, reflecting on their use, and engaging in peer review sessions to distinguish between human and AI input. Rubric was developed to evaluate both the content quality and the meta-cognitive awareness of AI use. Most students reported that AI assistance helped them state their arguments more clearly. They also emphasized that instructor feedback remained vital for deeper understanding. The results suggested that AI could enhance the learning experience and writing confidence of engineering students, when ethically integrated. However, effective AI use requires clear institutional guidelines, training of the educators, and thoughtful assignments that encourage students to critically weigh their reliance on AI. This study shares practical recommendations for applying AI in engineering writing activities, outlines student perceptions, and provides suggestions for the development of a framework for ethical and pedagogically sound AI inclusion in technical education.

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"Enhancing conceptual mastery of bevel gears through a flipped classroom approach and AI-assisted course design in engineering education"

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Keywords: Flipped Classroom, AI-Assisted Course Design, Bevel Gears, Active Learning, Mechanical Engineering Education

ABSTRACT

The continuing developments in engineering education demand innovative pedagogical strategies that enhance student engagement and conceptual understanding. This work presents the design and implementation of a flipped classroom course on bevel gears in a Mechanical Educators Department. A new approach was selected to the design of this course with the use of generative artificial intelligence (AI), particularly large language models, in preparing content and activity design. AI assisted the instructors by generating learning objectives, aligned with cognitive levels of Bloom's taxonomy, proposing appropriate assessment formats, recommending supplementary material, and preparing draft worksheets and feedback questionnaires. Moreover, AI tools provided flexible support for iterative refinement based on formative feedback. This AI-supported methodology significantly reduced course preparation time while enhancing instructional quality and creativity. Instructors, on the other hand ensured the accuracy and relevance of the course material of AI-generated content with educational objectives and standards. Prior to class, students were introduced to bevel gear theory, by an instructor-created video lecture. They were also provided with supplementary textual and video resources. Out-of-class activities consisted of a reflection journal, gear geometry worksheets, and a quiz, the results of which gave instructors a good understanding of the actual effectiveness of the out-of-classroom preparatory educational material. In-class sessions prioritized active learning through collective and collaborative activities. At the end, students were asked to provide feedback via structured questionnaires, which indicated the course structure facilitated deeper exploration of bevel-gear-related geometry and kinematics. More than 90% of the students reported preference for the flipped model which, according to their opinion, stimulated increased engagement and satisfaction. The effectiveness of the flipped classroom method was highlighted, as a practical and scalable solution for teaching technical subjects like gear systems. Incorporating AI into instructional design offered a valuable opportunity to timely create engaging, high-impact learning experiences. It allowed instructors to dedicate classroom time to active learning and student interaction, while AI enhanced content development and instructional efficiency.

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"Nikola Tesla patents related to power transmission "

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Keywords: power transmissions, fountain, invention, patent

ABSTRACT

Nikola Tesla, the famous Serbian-American scientist, engineer and inventor, have a huge number of significant inventions, significant to the ingenuity of their solutions and the universality of their application, had an immeasurable impact on the technical and technological development of our civilization. Although primarily recognizable for his grandiose work in the field of electrical engineering, he also made significant contributions to other areas of science such as medicine, mechanical engineering and aeronautics. Studying the transformation of the energy of a mechanical system into a fluid and vice versa, Tesla came up with an original solution, previously unknown in practice. By using the adhesive and viscous properties of the fluid in the boundary layer, with a simple construction using rotating disks fixed close to the shaft (instead of the blades of hydraulic turbomachines), he transferred the energy of the mechanical system to the fluid and vice versa. He used the invention in a series of his patents related to fluid propulsion, turbines, but also devices for measuring speed, flow or frequency. The aim of the research is to analyze the power transmission in the mirror of the development of several different conceptual solutions of Tesla's fountain model. The changes and modifications made to their structures undoubtedly contributed to the scientist's comprehensive view of the invention and submitting a patent application to the United States Patent Office at the end of October 1913. Fountain Patent No. US 1,113,716 was granted on October 13, 1914.

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Sustainability

"Installation of an Environmentally Sustainable Ballast Water Treatment System in Existing Ocean-going Vessel Using a 3D Laser Point Scanning"

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Keywords: 3D point clouds, Autodesk Recap Scan, Ballast Water Treatment System, Marine Ecosystem, Environmental Sustainability

ABSTRACT

The 3-Dimensional scanning technology has become widespread in recent years, allowing the design of new components and devices to be introduced into existing spaces and mechanical compartments. Shipping is one of the areas where this methodology has been applied with impressive results.

Ballast water is carried by ships to maintain their stability and seaworthiness, especially when they are not transporting cargo[1]. It is a practice as old as ships themselves and helps reduce structural stress on the vessel, compensates for weight shifts as cargo changes, and improves performance when navigating in rough seas. Ballast can also be used to increase a ship's draft so that it can pass under bridges and other port structures.

A ship may carry anywhere from 30% to 50% of its total load as ballast. According to the World Health Organization, approximately 10 billion metric tons of ballast water are transported by ships around the world each year [2].

The main issue with ballast water is that its collection in ballast tanks stirs up sediments and microorganisms that are directly introduced into the tank [3]. The introduction of species across biogeographic barriers by human activities is a key component of global biodiversity loss and subsequent environmental change[4]. The human-mediated introduction of species to regions of the world they could never reach by natural means has had great impacts on the environment, the economy, and society [5]. Most of these organisms will survive the journey from the port of departure to the destination port, after which they will be discharged into the waters surrounding the destination port [6]. Most ship operators will aim to comply with the D-2 standard through onboard installation of a ballast water management system (BWMS) that typically apply a combination of physical, chemical or biological methods to reduce organism viability in ballast waters [7]

The aim of this experimental research is to highlight the use of Ballast Water Treatment System (BWTS) in the shipping sector as a route for the spread of aquatic life and chemical contaminants is ballast water for balancing the marine ecosystem.

This feasibility study presents the design and installation methodology of a ballast water treatment system under realistic conditions applied in a crude oil tanker.

The vessel has been initially inspected in the physical presence of engineers. With the help of the 3D laser scanner the point cloud was retrieved from the areas of interest. Inside the Engine Room and the Pump Room 63 and 45 scans were performed respectively and inserted in Autodesk Recap Scan software. The aim was to cover the entire area of these spaces with no unseen areas with the density of the scans varying. In critical areas such as near the pumps and the crawlspace the density was increased. In addition, successive scans have been performed in order to obtain points of overlap in the site. Consequently, the scans in each of the two sites separately were joined together using the common points as a reference. This process has determined two 3D point clouds in Autodesk ReCap Project File. With the help of Autodesk recap Pro, the existing pipes, pumps and roofs of the ship's piping network were identified. A new drawing was then created in which the 3D point clouds were imported into AutoCAD Plant 3D. The clouds were positioned along the X, Y, Z axes with the x-axis being the longitudinal, Y-axis the transverse and Z-axis the vertical. This is the final point cloud where it will be used to design the piping and also to place the equipment. The engineering study is performed after the feasibility study and presents a detailed installation study with supervision on site. This research has several implications: Using 3D point cloud scanning in shipping for a BWTS offers several advantages that streamline the installation, operation, and maintenance processes. leveraging 3D point cloud scanning for BWTS installations results in greater efficiency, accuracy, and compliance, while reducing costs and risks throughout the system's lifecycle and therefore contributing to environmental sustainability.

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"Development and Performance Evaluation of Self-Healing Flax/Glass/Carbon/Sisal Hybrid Epoxy Composites for Sustainable Industry."

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Keywords: Hybrid composite, Glass/Sisal/carbon fiber reinforcement, Polymer matrix composites (PMC), Mechanical properties.

ABSTRACT

The creation and mechanical evaluation of Flax fibers, Glass fibers, Carbon fibers, and Sisal fibers are the main objectives of the current investigation. This study examines the mechanical and thermal characteristics of hybrid composites created by hand lay-up using three layers of each Flax, Glass, Carbon, and Sisal fibers. The resins, which are 100 ml of epoxy (LY 556) and 10 ml of hardener (HY 951), were combined with 74 grams of flax, 42 grams of glass, 62 grams of carbon, and 86 grams of sisal to create the hybrid composites. A ratio of 2:1 weight percentage is used to apply a self-healing layer. Comparing the outcomes to individual fiber composites, the tensile strength, flexural strength, impact resistance, and fractured surfaces are analyzed by Scanning Electron Microscope (SEM), all show notable improvements. Furthermore, the hybrid composites demonstrate enhanced thermal stability and decreased water absorption, rendering them a viable biomaterial for sustainable applications across several industries, such as aerospace, construction, and automotive.

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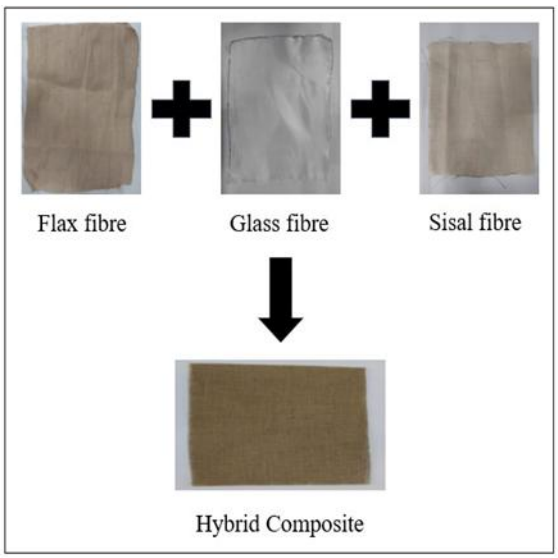

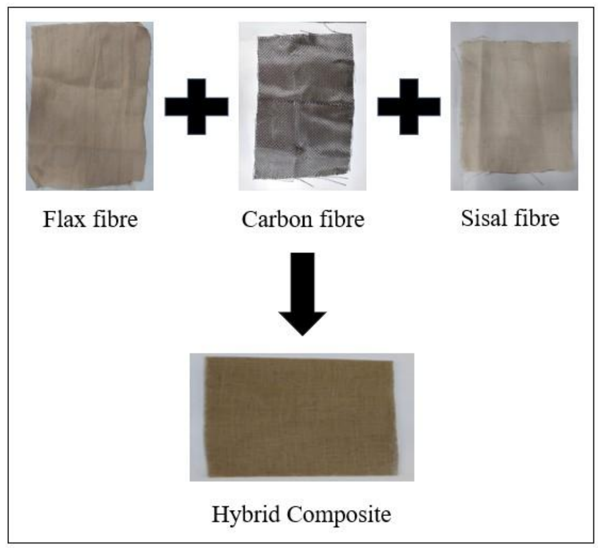

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"Fuel conversion analysis of a four-stroke marine diesel engine using combustion models"

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Keywords: Marine Engine, Combustion Model, Fuel Conversion Analysis, Hydrogen, Dual Fuel, Hydrogen Autoignition, Hydrogen Spark-Ignition, Emissions

ABSTRACT

Traditional marine diesel engines, while reliable and powerful, are significant contributors to greenhouse gas emissions and local pollutants. The maritime industry faces increasing pressure to reduce emissions while maintaining high engine performance, especially in consideration of tightening global environmental regulations. Exploring alternative fuels such as hydrogen presents a promising avenue, but requires careful simulation and analysis to ensure feasibility, efficiency, and safety. This study addresses the challenge of evaluating various hydrogen integration strategies into a conventional marine diesel engine platform.

In this study, a baseline simulation model of the MAN 32/40 marine diesel engine was developed using Ansys Forte. This model served as the foundation for investigating the effects of hydrogen integration through five additional fueling configurations. In all cases, hydrogen was introduced as a premixed fuel, while diesel was direct-injected. The configurations included one model utilizing hydrogen autoignition under preheated intake conditions, one employing spark-ignited hydrogen, and three dual-fuel models combining hydrogen and diesel. The dual-fuel models were differentiated by the proportion of each fuel: one was diesel-rich with a small fraction of hydrogen, the second featured a more balanced hydrogen-diesel ratio, and the third operated primarily on hydrogen, using diesel solely as a pilot fuel to initiate combustion. Across all simulations, the aim was to maintain the engine power output at the range of the base model. The analysis focused on in-cylinder pressure profiles and emissions characteristics, offering insights into the combustion behavior and environmental impact of each fueling strategy.

The simulation results demonstrate that hydrogen, whether used as a primary fuel or in dual-fuel configurations with diesel, can substantially reduce emissions, particularly carbon-based pollutants, while maintaining the engine's power output. However, the outcomes also reveal important complexities. Given the large displacement and high fuel demand of an engine like the one simulated, some results diverge from initial expectations. These deviations can be attributed to the engine's scale and the high volumetric flow rates required, which influence combustion dynamics and fuel-air mixing differently than in smaller engines. The findings suggest that while hydrogen shows strong potential for decarbonizing marine propulsion, the behavior of alternative fuels must be interpreted in the context of engine size and operating conditions. Overall, the study underscores the feasibility of hydrogen integration and highlights the importance of engine-specific optimization when transitioning to cleaner fuel technologies.

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