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Faculty of Mechanical Engineering
and Naval Architecture

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UNIVERSITY OF ZAGREB
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Preface

This booklet contains abstracts presented at the 10th Annual PhD Workshop, which took place on July 1, 2024. The annual PhD workshop is the integral part of PhD program of Mechanical Engineering, Naval Architecture, Aeronautical Engineering and Metallurgical Engineering, launched in academic year 2014/15. The PhD program is jointly developed by two faculties of University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture and Faculty of Metallurgy. The PhD Workshop is aimed to provide forum for exchange of ideas among PhD students, to help students to strengthen their presentation skills and to provide a platform to initiate new scientific collaborations. Additionally, the workshop should unify quality and transparency of PhD theses produced at different modules of the PhD program.

Contributions in this booklet are divided in two broad groups, abstracts of preliminary PhD topics and abstracts of final PhD topics. Former are mostly presented by the first year PhD candidates, while latter are presented by PhD students of second and higher years. Abstract are structured in a way to encourage students to write clearly and concisely purposes of their PhD theses in order to bring their research closer to the wide community and even to those who are not specialists in the field. This booklet could be a valuable and relevant reference for PhD students and their mentors as it represents kind of a milestone in the progress of their PhDs. It will also be useful for all stakeholders of PhD education to evaluate quality and progress of PhD theses. Finally, it can be useful for the industry in Croatia as it contains in one place most of the research efforts at two faculties.

23 participants on the PhD workshop presented preliminary topics of their theses, while 13 participants presented final PhD topics. Contributions collected in the booklet of abstracts are from different modules of the PhD study: Process and Energy Engineering (7 contributions), Computational Mechanics (6), Theory of Structures (4), Mechatronics and Robotics (4), Industrial Engineering and Management (1), Scientific Metrology in Mechanical Engineering (3), Aeronautical Engineering (1), Materials Engineering (4), Advanced Production Technologies (1), Naval Architecture and Ocean Engineering (3) and Metallurgical Engineering (2). Diversity of these topics clearly indicates broad and rich research interests and activities at the Faculty of Mechanical Engineering and Naval Architecture and Faculty of Metallurgy.

Editors

Contents

TOPIC NOT APPROVED

Self-Starting Characteristics of Wind Turbines with Passive Flow-Control Devices on Rotor Blades

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Introduction

In urban areas, vertical-axis wind turbines (VAWTs) proved to be more suitable for wind energy harnessing than the horizontal-axis wind turbines (HAWTs). Despite many benefits, the main drawback of VAWTs is their inability to self-start. Even a slight improvement in the self-starting characteristics may yield a substantial increase in the VAWT efficiency, Goncalves et al. (2022). Self-starting characteristics of VAWTs can be improved by using vortex generators (VGs) and Gurney flaps (GFs). Wu et al. (2021) studied the effect of VGs and indicated improved output torque. The effect of GF size on the VAWT performance proved substantial, Zhu et al. (2021).

Aims

Given a remarkable lack of information on the aerodynamic characteristics of airfoils equipped with VGs and GFs in the entire range of AoA, this topic was experimentally studied.

Methods

Experiments were performed in a closed-return wind tunnel with an open test section. A wing with a constant chord based on the NACA 0021 airfoil was placed in the test section as shown in Figure 1. The effect of VGs and GFs was studied separately. Reynolds number (Re) was set to be $Re \sim 1.8 \cdot 10^5$. The AoA for steady flow was studied in the $0^o < AoA < 360^o$ range of flow incidence angles. Pressure was recorded at 32 chordwise locations on the airfoil and integrated afterwards to calculate aerodynamic coefficients.

Expected scientific contribution

The obtained lift coefficient c_L and drag coefficient c_D are reported for various AoAs (α) in Figures 2 and 3, respectively. Solid line denotes c_L obtained for increasing α, while the scattered line is for decreasing α. It may be observed that GFs and VGs yield an increased peak $c_L \sim 1.25$, while the peak $c_L = 1.05$ in the baseline configuration, which is in accordance with Holst et al. (2019). The GF configuration has the maximal c_L, while the VG configuration exhibit minimal hysteresis in c_L. Moreover, c_D does not change significantly when GFs or VGs are added on the airfoil, while it is slightly larger when GF are installed.

By introducing VGs and GFs, the aerodynamic behavior of the airfoil was significantly improved, which is most evident in the increase of the maximum c_L and the delay of flow separation without a significant increase of c_D. Based on these results, it is clear that the application of VGs and GFs may improve the self-starting characteristics of wind turbines, which is the topic of the future work.

Acknowledgments

The support of Deutsche Forschungsgemeinschaft (DFG) Project #446073296, Deutscher Akademischer Austauschdienst (DAAD), the Erasmus+ program, COST Action CA20109 (MODENERLANDS), and the Croatian Science Foundation IP-2022-10-9434 (AHEFES) is gratefully acknowledged. Thanks are also extended to Marinos Manolesos, Marvin Jentzsch, Hrvoje Kozmar, Christian Navid Nayeri, David Holst and Felix Wegner.

Keywords

NACA0021 airfoil, Vortex generator, Gurney flap, Experimental aerodynamics, Vertical-axis wind turbine

Challenges in Measuring the Degree of Technological Humanism Within Manufacturing Companies in the Transformation Towards Industry 5.0 for Improving Their Dynamic Capabilities

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Introduction

The goal of the research is the development of a model for improving the dynamic capabilities of manufacturing companies, which is based on the implementation of digital production management and the degree of readiness for Industry 5.0. Dynamic capabilities represent a framework that record evolution over time, allowing a company to significantly improve its organisational performance and attain a competitive edge. Their effects are conditioned by digital manufacturing capabilities and are linked with digital technologies and Industry 5.0 implementation. Technological humanism, which Aims to ensure that technological progress is aimed at the well-being of people within companies in the transformation towards Industry 5.0, represents a demanding area that has not been sufficiently researched or unambiguously defined so far.

Aims

Adopting the concept of Industry 4.0 enables manufacturing companies to gain advantages from digital production management, but its problems related to human resources, management and organization have been recognized. Industry 5.0 promotes progress based on human-machine collaboration and sustainable, human-centred value creation in the concept of technological humanism. The aim is to present a framework for measurement of the degree of the technological humanism in the manufacturing company transformation towards industry 5.0. Such a framework can facilitate successful transition of companies towards industry 5.0 and can be used for the development of a model for improving the dynamic capabilities of manufacturing companies based on the implementation of smart manufacturing.

Methods

In order to analyse and measure the degree of technological humanism within manufacturing companies in the transformation towards Industry 5.0 to improve their dynamic capabilities, an empirical survey is conducted through a questionnaire. It includes questions according to the new framework with fundamental components that mark the field of Industry 5.0 with digital production management based on human-centric values and efficient cooperation between humans, machines and systems in a digital environment. Statistical methods are used to analyse the obtained data. In addition to descriptive statistics, inferential statistics methods of the multivariate type are used.

Expected scientific contribution

The scientific contribution of this work is manifested in the identification and quantification of cause-and-effect relationships and effects of internal key indicators, the degree of integration of Industry 5.0 components with included technological humanism, and the dynamic capabilities of the company. The paper creates a model for improving the dynamic capabilities of manufacturing companies based on readiness for Industry 5.0 and digital production management with the aim of improving their performance.

Keywords

Dynamic capabilities, Transformation towards Industry 5.0, Technological humanism

Strain Rate Dependent Progressive Damage Evolution in Composite Structures

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Introduction

The superior properties of fibre reinforced polymer (FRP) composites are very well known and have led to their ever-increasing utilization in major industry segments. Specifically, both unidirectional (UD) and woven carbon fibre reinforced composites (CFRP), with carbon-epoxy being the most recognized material system, are gaining a significant share of aircraft and sport automotive structures. However, some aspects of their mechanical behaviour remain unclear despite all the effort put into their examination over the last century. Strain rate sensitivity, being amongst these aspects, could be one of the most important ones to address, as high strain rate dynamic loading events and impacts are expected in the utilization of both flying and ground-based vehicles, along with other industrial composite structures and components.

Aims

The previously developed VUMAT user-defined numerical material model is to be expanded and improved. The main objective of this study is to include the strain rate effects on the response of composite structures more comprehensively, thus rendering the numerical model suitable for capturing the high strain rate loading scenarios such as impact phenomena more accurately.

Methods

The earlier version of the in-house built VUMAT user-defined model is enriched by the addition of strain rate effects on fracture energies of both longitudinal and transverse direction fracture modes. Besides that, effective failure strain element removal criterion is implemented to capture the perforation of the composite laminated plates. Validation and verification are performed by testing the simulation results obtained by utilizing the developed model with the experimental and numerical results from the reference studies.

Expected scientific contribution

By implementation of the strain rate effects on the fracture energies of the material in the present study, strain rate dependent progressive damage evolution is modelled. In combination with the already included effects of the strain rate on the ply strengths which enable the capturing of the strain rate dependent failure initiation, the current improvement thus provides a fully strain rate dependent material model. Hence, the expected scientific contribution consists primarily of the possibility to numerically investigate the mechanical behaviour and structural integrity of the laminated composite structures in a wide range of strain rates more accurately. Moreover, a more accurate assessment of the damage ex-tent of the CFRP structures after various loading scenarios is expected. Finally, more high-fidelity prediction of the remaining load bearing capabilities of the impacted CFRP structures is expected as well.

Acknowledgments

The research is fully funded by the Croatian Science Foundation (HRZZ) within the project "Computational Modelling of Composite Structures Impact Damage" (CONCORDE), grant number UIP-HRZZ-2020-02-9317.

Keywords

Composite, Failure, Damage, Impact, Strain rate

Supporting Circular Economy Strategies with Model-Based Systems Engineering

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Introduction

The methodology of Model-Based Systems Engineering (MBSE) has been developed to help systems engineers handle the complexity of the developing systems. One of the benefits discussed in the literature is that MBSE can reduce the time and effort of system/product development processes and activities that were previously done manually in document-based approaches. Along with the growing complexity of new products and systems, there is also an increasing emphasis on sustainability and the impact on the environment. This added aspect further increases the complexity of the designed product and therefore encourages the use of MBSE. Therefore, sustainability must be included in all relevant decisions and analyses. For the realization of circular strategies, targeted development decisions must be made on all system levels.

Aims

Based on the literature review, it becomes evident that MBSE and SysML (System Modelling Language) based approaches have been proposed with the goal of aiding in the development of sustainable products. The research gap we identified stems from a lack of research addressing the MBSE support for specific circular economy (CE) strategies. We have formulated an early draft for our research goal: How can MBSE support the decision-making process and mitigate uncertainties in circular economy strategies during product development? The expanded aim of our research is to determine the crucial information necessary for addressing specific CE strategies with the MBSE approach and the stage at which a model becomes sufficiently mature for practical application. Moreover, we seek to explore how MBSE can systematically support product development within the framework of CE strategies. So far, we have explored the MBSE support for the environmental analysis of system models by conducting a LCA (Life Cycle Assessment) on a system modelled with SysML. Further work shall encompass the investigation of the support for specific CE strategies. The first step for such an investigation is the research into which modelling requirements arise from CE strategies that need to be satisfied with MBSE and how to address them. Through the collaboration with TU Ilmenau, we also aim to integrate the use od data science in the later research phases for the enhanced support of the modelling process. Data science will be used for gathering and structuring the information from the system use and maintenance phases into useable knowledge in the form of knowledge graphs.

Methods

Models will be developed using the most widely used modelling language in MBSE, SysML. The MBSE model, realized with SysML, can facilitate analysis, verification, and validation activities on the design. The selected approach for developing the system model will be the MagicGRID approach. This concept for the approach stems from the best practices in systems engineering which are described in the ISO 15288 standard.

Expected scientific contribution

The main contribution of this research is in the improvement of the decision-making process during the development and lifecycle, using the MBSE method, of sustainable, complex systems. The contribution will be represented by a framework focused on the Aims mentioned earlier. The validation of the framework shall be conducted on a complex mechatronic device.

Keywords

Model-based systems engineering, Circular economy, Product development, SysML; MagicGRID

The Effect of Surface Heat Treatment on Reducing Vibration and Wear of Needle Bearing

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Introduction

Every machine is constructed out of the many parts that are connected in one larger assembly. For the reduction of the wear and friction of the moving parts, bearings are most used. Needle bearings are types of rolling bearings that use needles as rolling bodies. That type of bearing is used when the machine has fast and precise moves, and this type also produces less noise than the regular ball rolling bearing. Needle bearings are constructed of an inner ring, needles (which can be placed in a cage), and an outer ring. The inner ring is in contact with the needles, and because of the load and rotation of the bearing's inner ring, wear and other tribological processes occur. In cases of improper lubrication, the temperature, noise, and wear increase, which leads to further and faster bearing failure.

Aims

The work life of bearings can be prolonged with proper lubrication. The aim of this research is to prolong the work life in cases of improper lubrication with the different heat treatments and to record the specific phenomena that occur during the different working conditions. The temperature, noise, and wear increase can be measured to assess the changes on the surface of the bearing's inner ring. In addition to those parameters, the characteristic frequency can be monitored, which will indicate changes of the surface layer of the inner ring.

Methods

The surface layer of the needle bearing inner rings was changed using various heat treatment methods. One of the rings was left in the unmodified state, two rings were plasma nitrided with different parameters, so the surface increased wear resistance, and one ring was coated using the PACVD (plasma assisted chemical vapor deposition) method with the TiN coatings. After heat treatment, the rings were measured and photographed using the microscope. Surface roughness, hardness, and coating adhesion were also measured. The rings were driven inside the bearing housing on the rotated axel using the Proxxon drill as a drive (source of motion). The rings were tested for 5 minutes at a speed of rotation of 950 rpm. During the test, the temperature changes, displacement, velocity, acceleration, noise, and frequency were measured and compared between the different test rings. Wear was compared by comparing the microscope photographs before and after the test.

Expected scientific contribution

Bearing manufacturers have tables with life expectancies for their unmodified products, but there is very little information about the life expectancy of the modified bearings. This research will expand the methodology of testing and the wear resistance of the modified bearings. Also, in the continuation of this research, the methodology can be tested in different working conditions with different types of bearings.

Keywords

Needle bearing, plasma nitriding, PACVD, vibrations, wear

Numerical Simulation of Heat Treatment Process for Reduction of Residual Stress

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Introduction

Fusion welding is one of the cheapest and the most widespread production processes of joining steel parts, but it has some disadvantages in terms of residual stresses and distortion of welded joint. In order to achieve the highest possible mechanical properties of the welded joint, it is necessary to conduct a subsequent heat treatment of the welded joint for reduction of residual stresses. This is usually done at temperatures lower than the austenite transformation temperature of 730°C. When localized tensile residual stresses exceed the threshold value, crack initiation begins, so finding the right parameters for heat-treatment of the welded joint is of great importance in order to prevent catastrophic consequences.

Aims

In order to achieve maximum mechanical properties of the welded joint by reducing the magnitude of residual stresses, it is necessary to develop a numerical heat treatment model which can predict reduction of residual stresses with sufficient accuracy.

Methods

Although the most accurate way of obtaining data is conducting experiments, one of the alternative approaches numerical modelling. Since experimental testing is quite expensive and time consuming, numerical modeling of experiments is quite useful, but it should be verified on data obtained by experimental testing.

Numerical simulations can be computationally demanding because welding and subsequent heat treatment are highly non-linear and non-stationary processes. Sequentially coupled numerical analysis is used to address this problem. The first step is transient thermal analysis and the result is the temperature field which is used as loading in the subsequent mechanical analysis to calculate displacement and stress field.

Expected scientific contribution

The goal is to develop a numerical model for finding the most suitable parameters of heat treatment process for reduction of residual stresses in welded joints. The next step is determination of fracture parameters for heat-treated specimens machined from the welded joints.

Acknowledgments

This work has been supported and co-funded by the European Union through the European Regional De-velopment Fund, Operational Programme "Competi-tiveness and Cohesion" 2014 – 2020 of the Republic of Croatia, project "Improvement of high-efficiency welding technology" (ImproWE, KK.01.1.1.07.0076).

Keywords

welding, residual stresses, heat treatment, FEM.

Advanced Predictive Algorithms for Enhancing Electric Vehicle Integration into Smart Grids

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Introduction

Driverless electric vehicles are expected to be a disruptive technology in the transportation sector. However, there is a notable gap in research concerning the implementation of a large fleet of driverless vehicles on the local grid. Hence, developing suitable charging strategies for autonomous vehicles is greatly needed. Literature indicates certain challenges in the successful interaction between the electrical grid and vehicles, related to the stochastic nature and uncertainty of the driving schedules of electric vehicles, as well as electricity price variation. When developing a strategy for charging and discharging electric vehicles, achieving synergy among the desired goals of various participants in the intelligent mobility infrastructure (IMS) (car fleet, electric grid, energy storage system, photovoltaic system, etc.) can be very challenging. Overloading the electrical grid, unpredictable charging patterns, high energy consumption, and high costs are some of the major challenges of integrating a fleet of vehicles. Therefore, there is an increasing emphasis on developing computer algorithms for multi-objective, real-time optimization where all relevant parameters are satisfied.

Aims

The project objective is the development of an algorithm based on artificial intelligence that enables predictive management of electric vehicle charging and discharging. The algorithm will optimize the system in real-time based on the current fleet status, predictions of future fleet needs, and market conditions.

Methods

This research project begins with a literature review focused on integrating electric vehicles (EVs) into the power system and energy markets. The review Aims to identify effective methods for modeling an EV fleet and their communication with the electrical grid. Moreover, model for an EV within the fleet, incorporating details like battery capacity and driving schedules, while addressing uncertainties in these schedules will be developed. Additionally, an analysis of energy market trends will be performed to explore potential cost reductions. The core focus of the project is the development of an optimization algorithm, using Python, which will manage the charging and discharging strategies of the EV fleet based on predictive data with the primary goals to optimize operational costs and improve the flexibility of the grid.

Expected scientific contribution

The developed algorithm will significantly enhance the capability of the electric vehicle fleet to participate in the electricity market. By optimizing the charging and discharging processes of the autonomous electric vehicle fleet, there will be a considerable increase in the potential for aggregators to generate profit through participation in the electricity market. This strategy not only supports the operational efficiency of the vehicles but also contributes to a more stable and efficient energy market. By using predictive analytics and real-time data, the algorithm can dynamically adjust to market conditions, maximizing economic returns while supporting the stability of the electrical grid.

Keywords

autonomous vehicles, charging electric vehicles, predictive control

Microwave-Assisted Synthesis of TiO_2 Nanoparticles: Optimization and Characterization

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Introduction

Titanium dioxide (TiO_2) is a non-toxic, biocompatible, and inexpensive material with a very high dielectric constant and chemical stability. It occurs naturally in anatase, rutile, and occasionally brookite forms. TiO_2, a semiconductor with a band gap energy ranging from 3.0 eV to 3.2 eV, finds applications in a wide range of fields. Various methods have been developed for synthesizing TiO_2, including the sol-gel, hydrothermal, solvothermal, and new and promising microwave-assisted synthesis methods.

Sol-gel synthesis is a versatile process that produces various new materials. Unlike other methods, the sol-gel method allows for precise control over the structure and morphology of TiO_2 particles, optimization of energy costs, and the use of simple and affordable technological equipment. However, the process requires high-temperature kiln heating, thus elevating production costs.

Microwave-assisted synthesis is a technique that offers rapid and efficient material processing with greater renewability. Microwave radiation can be harnessed for nanomaterial synthesis, solid-state chemistry, nanotechnology, and organic synthesis. By choosing appropriate microwave parameters, this method accelerates organic reactions and enhances the selectivity of the resulting products. Microwave-assisted synthesis presents several advantages over conventional heating, including instantaneous and rapid heating, high-temperature homogeneity, and selective heating.

Aims

This research Aims to find the optimal parameters of sol-gel synthesis of TiO_2 nanoparticles using microwave radiation. The optimal parameters for crystalline TiO_2 nanoparticles are the highest specific surface and the lowest energy band gap.

Methods

Titanium isopropoxide was used as a precursor to prepare the sol (colloidal solution) of TiO_2, isopropanol as a solvent, acetylacetone for complexation, and nitric acid as a catalyst. Four samples of titanium dioxide were synthesized from the prepared colloidal solution in a microwave reactor at a temperature of 150 °C for 30 minutes and at a temperature of 200 °C for 10, 20, and 30 minutes. The phase composition of the prepared samples was determined by X-ray diffraction analysis (XRD) and Fourier-transform infrared spectroscopy (FTIR). Nitrogen adsorption/desorption isotherms were used to determine the specific surface area and pore size distributions using the Brunauer-Emmett-Teller (BET) method. The band gap energy values of the TiO_2 samples were determined by diffuse reflectance spectroscopy (DRS).

Expected scientific contribution

Traditional organic synthesis typically relies on conductive heating using an external source like an oil bath or heating mantle. However, this method is slow and inefficient in energy transfer due to reliance on convection currents and thermal conductivity. In contrast, microwave irradiation directly heats molecules within the reaction mixture, providing efficient internal heating. Microwave-transparent reaction vessels allow uniform temperature distribution, resulting in faster and more efficient reactions compared to conventional methods.

Acknowledgments

This work was funded by the Croatian Science Foundation under the project [IP-2022-10-4400]: Development of molecularly imprinted polymers for use in the analysis of pharmaceuticals and during advanced water treatment processes (Maehara).

Keywords

Titanium dioxide, microwave-assisted synthesis, characterization

Sensitivity Setting of the Ultrasonic Testing System Using Additively Manufactured Reference Blocks with Embedded Disc Reflectors

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Introduction

Ultrasonic testing (UT) is used for flaw detection and evaluation against pre-set acceptance criteria. To successfully detect flaws and accurately estimate their sizes, it is crucial to properly adjust an ultrasonic testing system. The Distance Gain Size (DGS) technique is commonly used for this purpose. It involves comparing the echo from a detected indication with the echo from a theoretical disc-shaped reflector at the same distance. DGS technique is primarily developed for normal probes, but later was applied to angle beam probes as well. However, the DGS technique when using angle beam probes is not as accurate as when using normal probes.

Aims

The research Aims to investigate the possibility of using Additive Manufacturing (AM) to produce reference blocks with embedded disc reflectors. The development process takes into account technological factors affecting the characteristics of the produced disc reflectors, respecting the quality of ultrasonic response at the same time. The developed reference block with embedded reflectors will be used to improve the use of the DGS technique for angle beam probe sensitivity setting, thus achieving more accurate sizing of detected flaws.

Methods

The literature review will identify factors that influence the quality of disc reflector production. A Design of Experiments (DOE) will be established to assess the significance of these factors. For this DOE, reference blocks containing disc-shaped reflectors with varying parameters will be manufactured. Initially, computed tomography (CT) will be used to characterise the reflectors' dimensions due to higher accuracy compared to UT. By comparing the actual (CT-measured) and designed dimensions, the accuracy of the produced disc reflectors will be evaluated. Following the CT measurements, experimental measurements will be performed using the pulse-echo technique. The sizing of the disc reflectors will be conducted using DGS diagrams integrated into the ultrasonic device, and results will be expressed as an Equivalent Reflector Size (ERS). These ERS values will then be used for the DOE analysis of the selected parameters from the identified influencing factors. This analysis will help determine the significance of these factors and identify which parameter combinations give the highest quality of disc reflectors. Based on the results from the DOE analysis, an innovative reference block for sensitivity setting will be designed and manufactured. The sensitivity will be set by using the embedded disc reflector to create a DGS curve.

Expected scientific contribution

The Expected scientific contribution involves developing the additively manufactured reference block with embedded disc-shaped reflectors with a particular geometry. This block is designed for the sensitivity setting of UT systems that use angle beam probes for detecting and sizing flaws. Disc reflectors with various geometry enable more accurate DGS measurements with angle beam probes, getting closer to the theoretical principle of flaw sizing using the DGS technique. This approach reduces the inaccuracy in estimation ERS that typically results from converting the rectangular transducer shape into an equivalent circular shape and neglecting the non-symmetric sound field. The developed reference block will meet the requirements for UT while considering the limitations of AM techniques.

Keywords

ultrasonic testing, sensitivity setting, disc-shaped reflector, angle beam probe, additive manufacturing

Data-Driven State-Feedback Controller Synthesis for Dissipativity: a Dualization-Based Approach

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Introduction

In recent years, there have been significant developments in the field of data-driven control. Relatively large set of the proposed data-driven analysis/synthesis methods is based on the so-called Willems' fundamental lemma as an underlying theoretical foundation. Another central theoretical foundation, nowadays also in focus of some data-based approaches, is the dissipativity theory, which is also attributed to Jan Willems. For example, some related results are: necessary and sufficient conditions for dissipativity of a linear time-invariant (LTI) system based on noisy data; data-driven state-feedback controller synthesis methods which include design of a controller that enables filter-based loop-shaping; non-conservative design methods for quadratic stabilization, H2 and H-infinity control based on noisy state-input data; sufficient conditions for stabilizing, H2 and H-infinity controller based on noisy input-output data. In this work, we assume that model of a discrete-time LTI system is partially unknown, what is compensated for by the knowledge of noisy state-input measurement data.

Aims

The goal is to obtain a non-conservative static state-feedback controller synthesis method for discrete-time LTI systems, which makes the closed-loop system dissipative with respect to a given quadratic supply rate.

Methods

In order to derive proposed controller synthesis method, we used the results for transformation of matrix inequalities such as dualization lemma, matrix s-lemma, congruence transformation, Schur's complement rule, etc.

Expected scientific contribution

While the same problem has already been considered in the literature, the main novelty is the solution approach which is based on the dualization lemma to obtain solvable linear matrix inequalities for controller synthesis.

Acknowledgments

This result will be presented at American Control Conference 2024.

Keywords

Linear systems, LMIs, H-infinity control

Development of Innovative Microalloyed Copper-Aluminum-Manganese Shape Memory Alloys

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Introduction

Shape memory alloys (SMA) are a group of intelligent materials that return to a predefined state or shape during appropriate processing. The change in shape of these alloys is a consequence of phase transformations that can be achieved by mechanical or thermal treatment (heating and cooling). The shape memory effect of SMA is a consequence of the reversible martensitic phase transformation from austenite to martensite. Copper-based shape memory alloys are sensitive to various factors such as chemical composition, grain size, manufacturing, heat treatment, plastic deformation, etc. The addition of certain alloying elements can significantly improve the properties of copper-based SMA and expand their application possibilities. During quenching and heat treatment (austenitization), large grains can form in the alloy structure, which hinders martensite formation and consequently leads to increased brittleness and susceptibility to cracking at the grain boundaries. To improve the properties of copper-based shape memory alloys (such as hardness, corrosion resistance, wear resistance, shape memory properties), certain alloying elements such as titanium, vanadium, silver, niobium, cerium, etc. are added. In this research the focus will be on monitoring the influence of microalloying elements (titanium and/or silver) on the functional, mechanical, thermal and corrosive properties of CuAlMnX (X=Ti, Ag) shape memory alloys.

Aims

The aim of this paper is to produce CuAlMn and CuAlMnX (X=Ti, Ag) shape memory alloys with improved properties and to investigate the influence of heat treatment on their microstructure and thermal properties. Furthermore, a model to determine the optimal microalloying parameters and the subsequent heat treatment to improve the microstructure of microalloyed CuAlMnX (X=Ti, Ag) shape memory alloys will be developed and validated.

Methods

In this research, the samples will be prepared by casting and melting in a vacuum induction furnace. The actual chemical composition of the CuAlMnX alloys will be determined using the spectrometer LECO GDS 900. The heat treatment is carried out in laboratory resistance furnaces for austenitization and tempering. The thermal analysis will be determined by differential scanning calorimetry and dilatometry (DIL 805 A/D) methods. The microstructural analysis will be performed by light microscopy (LM) and scanning electron microscopy (SEM). The mechanical properties will be determined using microhardness and Vickers microhardness testers. Corrosion behavior will be monitored by electrochemical methods (open circuit potential measurement) and polarization methods (linear, potentiodynamic and cyclic polarization measurements).

Expected scientific contribution

The scientific contribution of this research is the development of innovative microalloyed CuAlMnX (X=Ti, Ag) shape memory alloys with improved properties and the identification of optimal microalloying conditions to achieve the desired mechanical and corrosive properties. In addition, a model for optimal production parameters of copper-based shape memory alloys will be developed.

Acknowledgments

This research will be conducted within the framework of the research project IP-124-MG University of Zagreb Faculty of Metallurgy and Centre for Foundry Technology (SIMET), KK.01.1.1.02.0020.

Keywords

Shape memory alloys, CuAlMn, heat treatment, phase transformation, microalloying

Mechanical Characterization and Numerical Modelling of Shape Memory Polymers

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Introduction

Cardiovascular diseases stand as the prime cause of mortality worldwide, with atherosclerosis being the most prevalent. Atherosclerotic plaque accumulation induces stenosis in the carotid arteries, posing a risk of stroke. Stent implantation emerges as a viable surgical intervention option. Predominantly, commercial stents are deployed utilizing balloons, facilitating stent expansion to an elastoplastic state. Consequently, elastic recoil may excessively dilate the vessel wall, resulting in post-implantation damage and complications. Conversely, employing a shape memory polymer (SMP) stent offers a distinct advantage. Throughout stent deployment, the stent diameter progressively increases to its maximum extent, reducing the risk of high stresses that could cause vascular injury or stent damage.

Aims

The main aim of this study is the mechanical characterization of a selected hemocompatible SMP for stent manufacturing. It is imperative to evaluate elastic properties (both in tension and compression), the viscoelastic properties of the material (e.g., creep) and the dynamic properties (at heart frequency of 1 Hz). Utilizing experimental data, an optimal constitutive model will be identified, and its corresponding material parameters will be determined. The chosen model and calculated material parameters will be validated by comparison of numerically and experimentally obtained data on a more complex stent geometry.

Methods

Mechanical testing will be conducted on square and cylindrical samples for the chosen hemocompatible SMP for stent and silicone material for artery. Square samples will be used for biaxial testing at various deformation rates and dynamic testing, while creep testing will also be conducted for SMP material. Cylindrical samples for both materials will undergo pressure-extension testing at different loading rates and dynamic testing, with additional creep testing for SMP. All the experiments will be conducted at the body temperature of 37°C. Moreover, the time needed for shape recovery depending on programming temperature and maximal strain will be studied. Based on the results of experimental testing constitutive models will be selected, and corresponding material parameters will be determined. Additionally, the initial evaluation of SMP stent medical efficacy and durability will be verified by implanting 3D-printed stents into stenosed silicone arteries and monitoring the long-term wall diameter changes. Suitable constitutive model will be implemented into the finite element software and will be used to numerically model uniaxial tension of the stent and stenting procedure into silicone artery. The numerically obtained results will be compared with corresponding experimental data for constitutive model validation.

Expected scientific contribution

The main contribution of this study is identification and validation of optimal visco-hyperelastic constitutive model and appropriate material parameters for hemocompatible SMP. Herein developed experimental procedure can be used for mechanical characterization of other polymers and SMPs.

Furthermore, within this work, an initial experimental investigation of the medical efficacy, i.e. suitability of such materials to be used for stents, will be performed.

Acknowledgments

This work is supported by grant from the Croatian Science Foundation (project IP-2022-10-1497, principal investigator I. Karšaj).

Keywords

Experimental testing, shape memory polymer, ather-osclerosis, silicone artery, stent

Mathematical Model of Needle Bearing Tribocorrosive Wear

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Introduction

Roller bearings represent critical elements for the transmission of power and motion in mechanical constructions, which are subjected to increasingly demanding structural, technological and operational conditions. Bearing constructions require a reduction in mass while increasing resistance to contact pressures and mechanical loading. High accuracy, precision and reproducibility of measurements and achieved properties are required in manufacturing. In the exploitation of roller bearings, good reliability in operation, minimal maintenance, as well as the possibility of predicting the state of wear of the bearing using non-destructive testing methods and extending the service life of the bearing are required. These requirements can be partly realized by special construction solutions and the choice of better bearing material, selection of the appropriate lubricant, the application of procedures for modifying and coating the bearings surfaces and the implementation of periodic inspections and maintenance of the bearing according to the condition of the rolling bodies surfaces.

Aims

In the proposed research, it is planned to examine the influence of nitriding and coating of bearing ring surfaces with tribological coatings on wear and corrosion processes and on the occurrence of vibrations, noise and heating of needle bearings under laboratory conditions of loading and exposure to a corrosive aggressive medium. Based on the results of wear and corrosion tests of needle bearings carried out according to the statistical test plan, a mathematical model will be set up to predict the impact of wear, corrosion and surface condition (uncoated, nitrided, surface with tribological coatings) of the bearing bodies on the parameters of vibration, noise and increase in bearing working temperature. The model will be validated on selected examples of the operating conditions of roller bearings with and without the application of functional layers on the roller rings.

Methods

The proposed research is planned to be carried out in the following four main stages: review and systematization of rolling bearings operating conditions and wearing, implementation of selected procedures for coating the needle bearing rings according to the statistical test plan, laboratory testing of needle bearings with the tribological coatings and mathematical modeling of the coated bearings behaviour under working load conditions.

Expected scientific contribution

The proposed research will establish a mathematical model on influence of the tribocorrosive wear on vibration, noise and heating of coated roller bearings. A tribometer will be created for the simultaneous testing of tribocorrosion, vibration, noise and heating of roller bearings under the given conditions of operation and load. An additional contribution of the planned research will be in the evaluation of the impact of specially developed surface coatings on the wear and corrosion reduction of the roller bearings.

Acknowledgments

These research will be conducted within the framework of the Croatian-Canadian scientific Support Project „Development and evaluation of functional surface layers for military vehicles needle bearings, 2024.-2026.“ , financed in the scientific cooperation program of NATO member countries by the NATO STO AVT panel.

Keywords

Rolling bearing, tribological coatings, nitriding, PVD, PACVD

Tooth Root Load Capacity of Asymmetric Spur Gears

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Introduction

A striving towards implementing smaller, lighter, and more efficient gear transmissions is observed. One of the possible approaches to fulfilling these requirements is optimizing the gear tooth geometry. Pedersen [1] studied the effect of tooth asymmetry and direct root shape optimization on tooth root stress. Tooth root fatigue life can be increased with the suitable modification of the gear's pressure angle and rim thickness [2]. Kapelevich [3] proposed a model for generating the geometry and possible design solutions of asymmetric gears. Demet [4] has demonstrated that the asymmetric tooth profile can increase gears' root load capacity. One of the main issues preventing the wider use of asymmetric gear tooth geometry is the difficulty of manufacturing and inspecting such gears [5]. The calculations of tooth root load capacity of asymmetric gears are mostly based on FE analyses or experimental measurements [6] although certain analytical calculation models were proposed. Wen et al. [6] devised an analytical model to determine the critical location and the maximum tooth root stress. Similarly, Dogan et al. [7] modified the DIN 3990 standard to determine the tooth root stress in asymmetric gears. Langheinrich [8] proposed an analytical model for the determination of geometry, tooth root stress, and deformation for asymmetric gears. None of the authors [6, 7, 8] conducted experimental investigations to validate their proposed models.

Aims

The aim of the research is to develop a computational model utilizing the S-N (stress-life) method to predict the critical location and tooth root load capacity of asymmetric spur gears.

Methods

The first step in the research will be the definition of a few gear geometries upon which the following phases will be based. Afterwards, the root stresses in selected geometries will be determined utilizing FE analysis. It is planned to perform the analyses on 2D gear models. Subsequently, the number of cycles to failure for each tooth root surface node will be determined using the S-N method. The safety factor in each node will be determined as a quotient of its fatigue strength and the corresponding value of maximum principal stress. The critical location will be defined by the location of a node with the lowest safety factor while the number of cycles to failure will be determined from the corresponding fatigue strength curve. The tooth root load capacity for a given number of cycles to failure will be determined from a curve that defines the dependence of maximum principal stress on the imposed load. Finally, the proposed computational model will be experimentally validated. The test results will be compared to initial predictions to assess the suitability of proposed calculation model.

Expected scientific contribution

The Expected scientific contribution of this research is computational model for the determination of critical location and tooth root load capacity of asymmetric spur gears.

Acknowledgments

I would like to thank my mentor, professor Krešimir Vučković PhD for guidance and support throughout my doctoral study.

Keywords

Asymmetric tooth profile, stress life method, fatigue, tooth root load capacity

The Influence of Flax, Cotton, and Safflower Fibers' Preparation on the Properties of Polypropylene Composites

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Introduction

Composite materials are versatile materials composed of a combination of two or more substances with distinct properties. They comprise two components: reinforcement and matrix and offer exceptional strength-to-weight ratios, making them advantageous for various applications. Bio-composite materials utilize natural reinforcements or matrices, or both. These eco-friendly materials have gained significance due to their lower environmental impact and production costs compared to conventional composites.

In recent years, bio-composites reinforced with natural fibers have found applications in many industries, especially transportation, where their lower mass contributes to fuel savings. Sustaining the life cycle of bio-composites involves utilizing raw materials from renewable sources and incorporating reuse or recycling. The most used reinforcements are those from plants such as flax, hemp, banana, agave, coconut and bamboo.

Aims

This work focuses on cotton, safflower, and flax fibers as reinforcements for the polypropylene matrix. By utilizing fibers, which require chemical treatment for enhanced compatibility, an analysis can be conducted to evaluate the influence of input parameters (chemical treatment duration, fiber proportions, size, manufacturing process etc.) on the mechanical properties of the composite. The results guide the selection of optimal parameters to achieve desired composite properties.

Methods

The process of separating natural fibers from the rest of the plant affects their quality. Chemical treatments, such as alkaline treatment, silane treatment, acetylation, maleic acid treatment, or enzyme treatment, can enhance fiber properties and improve their compatibility with the polypropylene matrix. In this work, a solution of NaHCO3 and water is used because it is the most environmentally friendly option.

Selecting the appropriate production process is crucial for composite manufacturing. Considering the hydrophilic nature and sensitivity of natural fibers to high temperatures is essential when choosing the production process. In this specific case, the injection molding process has been chosen, following thorough research and exploration that pinpointed the ideal production temperature for the fibers at 200 degrees Celsius.

Expected scientific contribution

Replacing conventional composites with natural ones to preserve the environment, lower carbon emissions and contribute to a more sustainable future, also minimal impact on ecosystems when disposed of at the end of their lifecycle and reducing the reliance on fossil fuels. The main contribution is achieving a more sustainable, eco-friendly, and socially responsible approach to materials and manufacturing.

Keywords

injection moulding, , bio-composites, flax, safflower, cotton, polypropylene

Planning of Integrated Energy Systems with High Shares of Variable Renewable Energy Sources and Decarbonized Transport

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Introduction

The research explores the role of decarbonized transport in planning and managing integrated enegy systems efficiently. In light of the European Union's climate neutrality goals by 2050, integrating decarbonized transport stands as a pivotal element of the low-carbon energy transition. Electric vehicles and other forms of decarbonized transport increase eletricity consumption, potentially shifting the supply-demand dynamics of the energy system. The study emphasizes incorporating variable renewable energy sources into integrated energy systems. Besides reducing greenhouse gas emissions, electric vehicles serve as energy storage units, contributing to grid balancing, which is crucial given the variable nature of renewable energy production.

Aims

The research Aims to identify effective strategies for integrating decarbonized transport into existing energy systems while accounting for increased electricity consumption. It also focuses on optimizing the incorporation of variable renewable energy sources, ensuring that electric vehicles contribute to balancing the grid through energy storage.

Methods

The research will utilize computational tools for energy planning and system management. Initially, the methodology will involve a comprehensive review of existing policies, future energy consumption forecasts, and analysis of available technologies, such as battery storage and power-to-x systems, with a particular focus on the role of electric vehicle fleets in the energy grid. Advanced modeling software, such as H2RES, will be used to simulate and optimize integrated energy systems. This approach will enable detailed scenario analysis to assess the long-term performance of various system configurations. Electric vehicles will be modeled both as flexible consumers and energy storage units to simulate vehicle-to-grid systems. A scenario-based approach will evaluate different decarbonization pathways and their effects on energy supply and demand balancing, while techno-economic analysis will identify the most viable solutions.

Expected scientific contribution

The research is expected to provide valuable insights into the effective integration of decarbonized transport within integrated energy systems, emphasizing the role of electric vehicles in grid balancing and energy storage. It will offer strategies for incorporating variable renewable energy sources efficiently while minimizing costs.

Keywords

Decarbonized transport, variable renewable energy sources, energy planning, integrated energy sys-tems, demand response.

Digital Transformation in Nose Surgery

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Introduction

A significant part of contemporary research in the field of technology and production is focued at the development of automated devices and systems for smaller production volumes. For their realisation, besides process phyics, a detailed understanding of the manual work involved is needed. The availability of advanced sensorics and virtual reality (VR) provides great potential for the analysis of manual processes, as a basis for their better understanding and optimization as well as standardization of manual processes. One such still unobserved area is ENT (ear, nose, throat) surgery.

Aims

The aim of the work is to facilitate digital integration of the whole nose surgery process, from the diagnosis and state of a specific patient, through surgery itself till wider health-care and social context.

Methods

The attention was given to surgeries related to inferior turbinate and rhinoplasty. Based on key data collected from the real-world surgical procedures, the inferior turbinate surgery was designed and simulated in CAD software, while rhinoplasty surgery was modelled and performed by using HTC Vive virtual reality headset system.

Expected scientific contribution

The research gives basis for future work, that may include digital encompassing of further details of the observed surgical procedures, recording of the surgeon's actual movements during the procedures and their transfer to a digital model. The collected data and subsequent results can form the basis for comparing the work of several surgeons, thus giving the possibility to standardise the procedures. Finally, together with the Introduction of virtual reality into the training of surgeons this can give an excellent basis to learn one, standard procedure.

Acknowledgments

The work is the result of the research in which the PhD candidate and his mentor have cooperated with doc. dr.sc. Gorazd Poje (KBC Rebro, University of Zagreb School of Medicine) and FAMENA students Mario Knežević and Bartol Antunović.

Keywords

ENT surgery, process planning, modelling, CAD, virtual reality

Near Real-Time Calculation of Road Traffic Emissions

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Introduction

Emissions from internal combustion engines of road vehicles are considered as a significant problem of the modern era. The primary reason for monitoring, analyzing, and reducing emissions is the various negative effects of individual emissions on human health, the environment, and climate. With the continuous increase in demands and restrictions on certain exhaust gases, new technologies for exhaust gas treatment have been introduced. However, new i.e. current regulations apply only to newly manufactured vehicles, while various older vehicles that emit significantly higher amounts of harmful substances than newer vehicles are still in use. An additional problem is posed by vehicles with malfunctioning or intentionally manipulated exhaust gas treatment systems. While older vehicles can still freely participate in traffic (except in some cities that have restricted the use of such vehicles in the city centers or so called Low Emission Zones), vehicles with malfunctioning exhaust gas treatment systems are not technically sound and should not be registered or allowed to be used in traffic. Since the emissions of a particular vehicle depend on the vehicle's equipped after-treatment system (evident through the Euro standard of each vehicle), vehicle speed and acceleration, and technical condition, detailed analysis requires insight into the composition of vehicles and actual condition of the fleet used in a specific area.

Aims

The aim of the research is to investigate the impact of the composition of the vehicle fleet and vehicle speed on emissions from road traffic in a specific area and time frame, and then correlate this data with the state of air quality in the surrounding area.

Methods

The research will be conducted using an experimental setup consisting of traffic surveillance cameras capable of reading vehicle license plates (using OCR method) and vehicle speed, an anonymized database of vehicles, and programs and scripts that integrate all collected data and calculate emissions. With the determined vehicle emissions based on the analyzed sample, possibilities for extrapolating data to a larger area and longer time periods will be explored using available traffic intensity data.

Expected scientific contribution

This research will facilitate the advancement of methods for the rapid, near real-time calculation of road traffic emissions. Through continuous measurements across a network of locations, road traffic emissions for specific road sections and areas within the city will be estimated, allowing for further analysis and mitigation efforts.

Acknowledgments

This research was conducted by video camera and accompanying software provided by Dahua Technology Hungary Kft. and emission measurement equipment of IC Engine and Motor Vehicle Laboratory of Faculty of Mechanical Engineering and Naval Architecture.

Keywords

road traffic emissions, traffic emission model, Internet of Things

Modelling the Elastoplastic Behaviour of Materials Using Feed Forward Neural Networks

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Introduction

With the increasing use of new materials with heterogeneous microstructures and the exploitation of known materials, there is a need for more precise and comprehensive characterization of material constitutive behaviour. While the multiscale approach, typically employed for this purpose is effective, it is computationally demanding and time consuming. For this reason, reduced homogenization methods have been developed that seek to find the optimum between the result accuracy and the calculation complexity. These new multiscale methods have proven to be incredibly effective in generating a large database that will be utilized to develop neural network-based material models.

Aims

The research Aims to develop a constitutive model using neural networks based on input data obtained by numerical simulations of microstructure behaviour.

Methods

Large databases, obtained from validated finite element numerical simulations under various loading conditions and using self-clustering multiscale method, will replace traditional experimental measurements. This data is used for neural network training and learning. Strains are used as input data for neural networks, to predict homogenized stress precisely. Once trained, the neural network model can be enhanced with additional data. Training uses a backpropagation algorithm to minimize the difference between known and predicted stress values. Neural networks come in various architectures tailored to input and output data; initially, this research focuses on feed-forward neural networks. The efficiency of neural networks can be optimized through hyperparameters such as the number of layers, their type, and the number of neurons. Neural networks are built using the open-source software PyTorch, based on the Python programming language.

Expected scientific contribution

The developed neural network-based model should adequately replace the classical multiscale analysis of heterogeneous materials. This could result in significant reductions in time and resource expenses. Furthermore, neural networks allow to describe the mechanical behaviour of materials without the use of classical constitutive models or a priori assumptions about the constitutive model.

Keywords

Neural networks, heterogeneous materials, machine learning, elastoplastic behaviour, feed-forward neural networks

Numerical Study of Arterial Remodeling After Stent Deployment

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Introduction

The most common cardiovascular disease is atherosclerosis, a plaque build-up on the inner layer of an arterial wall, and its treatment involves the deployment of a meshed tube known as a stent. This medical procedure serves to expand the arterial lumen, but it also concurrently increases stresses within the arterial wall. The most commonly used types of stents are made from self-expanding metals, while shape memory polymers have recently gained popularity among researchers. Numerical analysis is a powerful tool that can be used to investigate the effect of stent implantation within the artery. Soft tissues can be numerically modeled with the growth and remodeling (G&R) model. Over the years, this modeling approach has significantly contributed to understanding the biochemical and biomechanical processes and prediction of disease progression.

Aims

The aim of this study is to numerically model the adaptation of a carotid artery following the insertion of a stent. The stent expands the artery continuously for up to three years after deployment. Elevated wall stresses induced by the stent prompt growth and remodeling mechanisms within the arterial wall. This process may result in in-stent restenosis (ISR), characterized by a gradual re-narrowing of the stented area, typically occurring between 3 to 12 months post-stent placement. This restenosis is likely caused by an increased production of arterial wall constituents due to increased wall stresses. This study investigates the mechanical impact of stent implantation on the artery, pinpointing regions of peak stresses and the production of arterial wall components, which are associated with potential sites of neointima formation.

Methods

The growth and remodeling (G&R) model is a 3D-constrained mixture model that describes the artery as a mixture of different constituents–elastin, four types of collagen fibers, and smooth muscle cells–each with distinct mechanical and structural attributes. This model has demonstrated its efficacy in accurately depicting changes in mass and remodeling within intricate structures like blood vessels, along with their responses to diverse mechanical and chemical stimuli. The G&R model, already implanted in a finite element analysis program (FEAP) and applied to abdominal aortic aneurysms, in this study is adapted for the carotid artery. The stent and the plaque are modeled as Neo-Hookean materials.

The stent deployment, which rapidly expands the artery, and the continuous changes in the artery structure and shape for the next 1000 days are simulated, and various parameters are varied and compared. These parameters include plaque types and various model parameters that influence the artery expansion and constituent's production. The locations of the highest stresses and production of arterial wall constituents are studied, as they are key factors in ISR occurrence.

Expected scientific contribution

Expected scientific contribution includes the use of the growth and remodeling model for modeling artery adaptation to stent implantation, and the analysis of the stent and artery contact.

Keywords

Finite element method, growth and remodeling, carotid artery, stent, in-stent restenosis

Utilization of the Available Offshore Wind Generation Potential in the North Adriatic Area

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Introduction

The European Commission determined the targets of reducing greenhouse gas emissions by at least 55% by 2030, with the aim of achieving a climate-neutral economy by 2050. It is therefore the drive toward climate neutrality that imposes the priority of the reorganization of the existing energy sector towards completely renewable energy systems. The power generation systems play a crucial role in the energy transition by meeting the energy requirements for decarbonizing various sectors. These systems provide clean and reliable energy to support technologies such as electrical heating, industrial applications, and transportation. Additionally, the power system must supply the energy needed to produce feedstocks and fuels for other sectors. However, those future systems based on renewable energy sources are characterized by intermittency, leading to challenges in generating energy or feedstocks due to disparities between the generation and consumption locations. The existing electricity transmission grids are inadequate to handle the demands, especially when it comes to highly concentrated sources of generation and demand. Therefore, additional investments into energy transmission infrastructure are required.

Aims

North Adriatic is one of the most promising offshore wind sites in Mediterranean Sea suitable for fixed turbines. The focus of the research is to determine the most economically viable way to evacuate electricity produced from offshore wind farms by applying long-term energy planning strategies with the criteria of system decarbonization in order to achieve climate neutrality. Findings can indicate the most viable option for utilizing offshore wind potential for production of needed feedstock and fuels for different industrial demands, therefore providing energy transition pathway to achieve the goals of carbon neutrality.

Methods

The implementation is evaluated alongside national energy modeling and is carried out in the H2RES energy modelling and optimization tool. Various infrastructure investments and utilization methods for the available energy are examined, including high voltage direct current lines, hydrogen, and ammonia pipelines, as well as other forms of transportation. Additionally, different combinations of storage and feedstock generation arrangements are considered.

Expected scientific contribution

The research will provide insight into the optimal way of evacuating the generated energy from offshore windfarms, directly via transmission lines or energy vectors, and will investigate the role of offshore wind energy potential in the decarbonization of the energy system. The developed research will fill the gap in the long-term energy planning of the integration of offshore wind farms through the optimal mix of energy vectors.

Keywords

Energy planning, Renewable energy sources, Off-shore wind, H2RES

Calibration and Localization of a Four-Wheel Mobile Robot with Independent Steering and Drive

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Introduction

This study presents a methodology for localization of a mobile robot with four steerable and four independently driven wheels (4WIS4WID). The odometry of a 4WIS4WID robot can be estimated using a nonlinear kinematic model that includes the robot's dimensions, steering angle and the radius of each wheel. Due to imperfections in the wheels radii and their positions, as well as errors from numerical integration and robot slippage, it is necessary to use information from other sensors for better robot localization. Tracking camera and an inertial measurement unit (IMU) together with odometry can be used to estimate the position and orientation of the robot using an extended Kalman filter for nonlinear models. In this study, the calibration of the robot's kinematic parameters were first conducted using four optimization methods, two gradient-based and two stochastic. The objective function chosen to minimize was the squared error between the actual and estimated position of the robot, with the actual position measured by an external OptiTrack system that has a declared accuracy of 0.2mm. After parameter estimation, the newly obtained parameters were used for verification, showing an improvement of around 60 percent. As numerical integration also affects robot localization error, use of odometry is not sufficient for sufficient localization accuracy. Fusion of multimodal measurements from multiple different sensors enables better robot localization, thus the application of the extended Kalman filter can achieve additional improvements in localization. The results presented in this research show that the calibrated robot, together with the fusion and position estimation, demonstrate significant improvements in robot localization.

Aims

The main aim of this study is to present possible solution for calibration of the 4WIS4WID mobile robot structure, as well as how extended Kalman filter can improve accuracy of the mobile robot odometry when it is used with other sensor measurements.

Methods

In this study four optimization algorithms will be used for mobile robot calibration, two gradient optimization – constrained nonlinear optimization and Levenberg-Marquardt optimization algorithm. Despite two gradient method, two stohastic methods will be also used – genetic algorithm and particle swarm filter. In addition, extended Kalman filter will be used to improve localization.

Expected scientific contribution

Expected contribution are comparison and framework for 4WIS4WID mobile robot calibration as well as how sensor fusion can improve localization of the mobile robot.

Keywords

our-wheel steered and drive mobile robot, parameter estimation, odometry calibration, extended Kalman filter, localization

Changing the Perception of the Laboratory's Competence in Hardness Measurement by Applying General Systems Theory

PhD candidate: Branimir Buntak
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Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

This PhD thesis proposes a novel approach to redefine laboratory competence in hardness measurement by applying General Systems Theory (GST) to the organizational competence model. Traditional competence assessments often overlook broader systemic interactions that significantly impact laboratory effectiveness. The organizational competence model, which encompasses four domains—competence of human resources, technical competence, technological competence, and structural competence—is integrated using GST to provide a more holistic evaluation of laboratory operations.

Aims

There are several goals that this research Aims to achieve. Firstly it is to adapt and apply the organizational competence model to laboratories, using GST to integrate and assess all domains of competence. Secondly, to assess the current state of organizational competence maturity in Croatian laboratories, focusing on the implementation of sustainable and holistic practices. The last aim of this research is to demonstrate the applicability of the GST-based model in improving the perception and reality of laboratory competence in the field of hardness measurement.

Methods

The research methodology encompasses three phases:

- Primary research: Conducting a primary research study to assess the current state of organizational competence maturity across Croatian laboratories, using surveys and interviews to gather data.
- Model development: Developing a GST-based framework that encapsulates the four domains of organizational competence, tailored specifically for laboratory environments.
- Empirical testing: Implementing the developed model in selected laboratories to validate its effectiveness, using both qualitative and quantitative data analysis techniques.
- Comparative analysis: Comparing the pre- and post-implementation states of competence to evaluate improvements and gather insights.

Expected scientific contribution

The research Aims to make significant contributions to the added knowledge in this research area that also has a practical application. Theoretically, it advances the understanding of laboratory competence by framing it within a comprehensive organizational context using GST. Practically, it introduces a new standard for assessing laboratory competence that emphasizes sustainability and a holistic approach, potentially influencing future standards and practices in scientific measurements and beyond. This research will offer actionable insights into enhancing laboratory operations, promoting a culture of comprehensive quality and sustainability.

Acknowledgments

This work is conducted with the support of the Faculty of Mechanical Engineering and Naval Architecture at the University of Zagreb and under the guidance of Professor Željko Alar. Appreciation is extended to all participating laboratories for their cooperation and to both academic and professional communities for their valuable contributions.

Keywords

Organizational Competence, Laboratory Competence, General Systems Theory, Hardness Measurement

APPROVED TOPIC

Numerical Modelling of Rolled Plug Installation Process Inside the Steam Generator Tube

PhD candidate: Luka Šarlija
Mentor/s: Tomislav Lesičar
Affiliation: INETEC, Croatia

Introduction

Rolled plugs present a corrective action once the steam generator tubes have been damaged, in order to prevent radioactive water leakage into environment during the whole tube lifespan. The rolled plugs are installed inside the steam generator tube using roll expansion method, which is typically used for the installation of the tubes inside the heat exchangers. Rollers consist of a roller shell, 3 rolls and conical mandrel. The roller is connected onto rotating pneumatic tool which causes rotation of the roller and axial movement of conical mandrel which results in radial expansion of the rollers. The roll expansion causes rolled plug shell to plastically deform and causes radial expansion, which results in formation of leak-tight seal with the tube and prevents water flow.

Methods

Nonlinear numerical modelling of roll expansion process using axisymmetric model is presented. The numerical modelling is separated into 2 steps, where the first step shows tube roll expansion for the purpose of tube installation inside the prototypical steam generator tube sheet. The second step presents installation of the rolled plug inside the expanded tube. Roll expansion process is simplified herein due to the high complexity of the method. Numerical model shows material models used within the simulation, contact formulations and boundary conditions. The axisymmetric model is used as reference for 3D modelling planned in the future investigation.

Preliminary results

Results of the numerical analysis are compared to the experimental measurements of the plastic deformation of the rolled plug. They show good correlation for the purpose of validating prescribed contact formulations, boundary conditions as well as impact of roll expansion process simplification on the results accuracy.

Discussion

The results require further detailed 3D modelling, which will be used for finding of the correlation between the roll expansion torque and rolled plug shell plastic deformation in numerical model and experimental data.

Acknowledgments

I would like to express gratitude to INETEC for providing financial support for the development of this product

Keywords

rolled plug, roll expansion, steam generator, numerical modelling

The Influence of Hydrogen on the Mechanical Properties of Natural Gas Pipeline Materials

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Introduction

To support the decarbonization of the natural gas distribution network, hydrogen plays a significant role. The biggest challenges lie in the development of infrastructure for the transport of a mixture of hydrogen and natural gas, and the safe conversion of existing pipelines for higher concentrations of hydrogen. The possibilities of repurposing existing gas infrastructure for higher concentrations of hydrogen, its impact on natural gas pipeline materials and the extent to which the harmful effects of hydrogen can be reduced by commercially available coatings to protect pipeline materials are investigated. The study highlights the importance of coatings and evaluates their potential and effectiveness through various laboratory tests. In conclusion, future directions of research are highlighted, including the improvement of existing experimental methods, and solving the technical challenges of protecting existing materials in the transport of hydrogen through gas infrastructure.

Methods

The research methodology will consist of:

- review of the existing scientific and professional literature in the field of research,
- procurement of samples (substrates) of steel pipelines for the transport and distribution of natural gas, commercially available coatings for laboratory research,
- making a model and preparing an experimental track for the beginning of laboratory research,
- implementation of laboratory research (method of measurement, method of samples, (laboratory work, testing, method of proof and refutation, method of analysis and synthesis, inductive and deductive method),
- monitoring the research process and
- presentation of research results.

Preliminary results

Surface treatment by applying a protective coating to the pipeline material can prevent or limit the penetration of hydrogen into the pipeline walls.

Discussion

Research by the impact of different hydrogen concentrations on the mechanical features of pipeline materials will result in the recommendation of the use of certain commercially available coatings, their efficiency in protecting the basic pipeline material in different conditions, estimates of long -term material behavior in work, and the use of new technologies in creating a protective barrier between the working pipeline and the media in pipe containing hydrogen.

Acknowledgments

1. A method for evaluating the behavior of pipeline materials, processing data and reporting limitations arising from technical conversion of existing pipelines of the gas system.
2. Guidelines for predicting the influence of hydrogen on the mechanical characteristics of the materials of existing pipelines and the functionality of the protective coating.

Keywords

hydrogen in the natural gas pipeline; hydrogen embrittlement; internal coatings; steel pipeline

Demand Response in Buildings: a Comprehensive Overview of Current Trends, Approaches, and Strategies

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Affiliation: Energy Institute Hrvoje Požar, Croatia

Introduction

The 21st century grapples with major challenges like pollution, climate change, and dwindling fossil fuel reserves. Identifying alternatives to fossil fuels is imperative, with renewable energy sources offering promise despite their intermittent nature. Demand response (DR) emerges as a vital strategy, involving adjusting energy consumption in response to price changes or incentives. Buildings, accounting for 43% of final consumption in the EU, play a crucial role in this by adapting energy usage. The paper provides insights into assessing DR solutions, addressing the growing interest in DR in buildings and its importance in ensuring power grid reliability and resilience.

Methods

This literature review employs a systematic approach to analyze existing research on DR in buildings. Steps include literature search, inclusion criteria, data extraction, analysis, synthesis, and acknowledging potential biases and gaps in selected papers.

Preliminary results

A statistical analysis of 50 recent scientific research papers reveals diverse approaches to DR in buildings. The majority focus on specific building types, suggesting a need for broader investigations. Grey-box modeling prevails, especially in smaller-scale buildings. Load shifting is the most common DR strategy, followed by load modulation and shedding. Combining strategies shows promise, emphasizing the importance of a multifaceted approach to DR management.

Discussion

The analysis of recent research papers highlights trends and practices in DR for buildings. Most papers focus on specific building types, indicating a research gap in comprehensiveness. Grey-box modeling is prevalent, aligning with the scale of buildings studied. Load shifting dominates as the most prevalent DR strategy, but there's an increase in load modulation adoption. Combining strategies proves beneficial, emphasizing the need for a comprehensive approach to demand-side management.

Keywords

smart grid; smart buildings; demand response; demand response modeling; demand response management strategies

A Model of Cognitive Load for Computer-Aided Design Performance

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Introduction

The engineering designer's performance in computer-aided design (CAD) activities affects the quality, cost, and timelines of the contemporary engineering design process. Despite the significant influence of the engineering designer's performance on the process' success, its key elements, their relations, and influencing factors are yet to be defined. This research seeks to enhance understanding and support the assessment of engineering designers' performance in CAD activities by investigating the underlying cognition. Since CAD primarily involves cognitive processes, understanding the allocation of engineering designers' information-processing resources and the cognitive load imposed on their cognitive system is essential for ensuring effective and efficient performance. Therefore, the proposed research Aims to develop and validate a theoretical model of cognitive load in CAD activities, a theoretical model of the engineering designer's CAD activity performance, and a method for measuring and analysing cognitive load in CAD activities.

Methods

Literature reviews and experimental studies serve as the primary methods in this research. Two empirical studies conducted to date have utilised three main data gathering methods: subjective assessment (e.g. self-rated scales), psychophysiological measurement (e.g. electroencephalography; EEG), and performance measurement (e.g. accuracy and task completion time). The analysis of experimental data involves a combination of task analysis, cognitive modelling, as well as the statistical analysis of EEG and CAD performance data.

Preliminary results

The Preliminary results indicate that EEG can be used to investigate design cognition. Additionally, the studies revealed the impact of two factors on participants' EEG readings: the type of projection used to present design information and the difficulty level of CAD tasks. Moreover, participants reported varying levels of cognitive load experienced when engaged in CAD modelling tasks under the tested conditions. These findings are supported by significant differences observed in both task completion time and accuracy.

Discussion

The experimental and literature review findings collected thus far have highlighted the need to define EEG features that signify changes in cognitive load during CAD modelling tasks. Consequently, our efforts have focused on identifying such indicators by incorporating machine learning algorithms into our EEG data analysis protocol. Moving forward, we will strive to establish relationships between cognitive load and measurable aspects of CAD performance. If successful, we may then proceed to validate and elucidate the effects of experimental factors on cognitive load and performance throughout the CAD modelling process.

Acknowledgments

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Keywords

cognitive load, computer-aided design, performance

Optimization of Charging Station Placement and Scheduling of Electric City Buses

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Introduction

The electrification of urban bus transport is recognized as a key solution to reduce emissions of harmful gases and greenhouse gases, as well as noise levels. However, it faces challenges such as increased investment costs for electric buses and charging infrastructure, and operational limitations related to reduced range and longer charging times compared to conventional buses. Thus, optimizing the planning process for electrification becomes crucial from the perspective of minimizing investment and operational costs, ultimately aiming to achieve a sustainable and economically viable transportation system.

Methods

Virtual computer simulations are a crucial tool for planning the electrification of transportation systems, relying on accurate electric bus models and recorded driving cycles of conventional fleets. The research will focus on numerical approaches, including computer modeling, optimization, and simulation. Analytical efforts will center on formulating optimization problems. Work will be performed on a multi-processor workstation using Python and SQL for modeling and data analysis, along with Matlab, modeFRONTIER, and Gurobi for advanced optimization.

Preliminary results

A novel data-driven regression model for predicting battery energy consumption in electric city buses was developed, using data from an experimentally validated physical simulation. The model, which includes powertrain and HVAC system submodels, utilizes trip-related data such as travel distance, mean velocity, and passenger count, offering advantages over physical models that require high-frequency driving data. Furthermore, data-driven model operates significantly faster, making it suitable for large-scale electrification planning and real-time applications. Additionally, an optimization strategy for bus scheduling was implemented to minimize fleet numbers and travel distances, using mixed integer linear programming for small fleets and a genetic algorithm for larger fleets, demonstrating effectiveness on real-world transport data.

Discussion

Despite extensive recent research efforts in this field, opportunities for improvement have been identified towards a) a numerically efficient data-driven model that takes into account a wide set of influential features of driving cycles and has a high level of generalization, and b) a comprehensive algorithm for optimizing the planning of charging infrastructure and scheduling electric buses across lines, considering practical options and requirements such as partial charging, variable number of chargers and charging power per station, and the sustainability of the state of charge at the end of the operational day.

Acknowledgments

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Keywords

City buses, battery electric vehicles, data-driven modeling, bus scheduling, optimization

Investigation of the Energy Efficiency of Fishing Vessels

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Introduction

Global warming, triggered by the high level of Greenhouse Gases (GHGs) in the atmosphere, poses a significant environmental threat. Efforts by the International Maritime Organization, such as the MARPOL Annex VI, focus on reducing maritime emissions. Mandatory principles, the Energy Efficiency Design Index and the Ship Energy Efficiency Management Plan, analyze the ships' design and promote the use of more energy-efficient and environmentally friendlier technologies. Recent amendments, like the Energy Efficiency Existing Ship Index and annual operational carbon intensity indicator, require ships to minimize their GHG emissions by increasing their energy efficiency in the short term. However, smaller fleets, i.e. fishing vessels, remain underregulated, despite recognition of the importance of their decarbonization. This study Aims to evaluate the energy efficiency of fishing vessels in the Adriatic Sea, while considering the lack of environmental regulations in this sector and the predominance of obsolete diesel-powered vessels.

Methods

The assessment is carried out in line with the new decarbonization targets and Aims to identify opportunities for vessel improvements. A novel aspect of the analysis is the integration of the vessels' environmental impact relative to their benefit for society, considering specific operational characteristics and catch quality. A comprehensive analysis of the emission index calculation for the Croatian fishing fleet, focusing on 163 purse seiners and 82, is conducted. The results are validated using data from 12 vessels equipped with monitoring systems. To address the different values of fish species, the emission index is calculated relative to realized income and compared across two types of fishing vessels.

Preliminary results

The results show that purse seiners exhibit emission indices ranging from 0.32 to 2.01 $CO_{2\text{-eq}}$ per kg catch, with a predominant range of 0.48 to 0.91 $CO_{2\text{-eq}}$ per kg catch. Trawlers show emission indices spanning from 2.08 to 14.11 $CO_{2\text{-eq}}$ per kg catch, with values typically 13–15% higher than purse seiners. Factors like engine power, gross tonnage, and vessel age significantly influence emission index values. Market prices play a notable role – smaller catches don't necessarily result in lower profits, affecting emission index outcomes.

Discussion

Previous studies highlighted the pivotal role of Fuel Use Intensity in assessing vessel energy efficiency in trawl fisheries. Studies examining fuel consumption and emission indices in fishing fleets revealed that varying vessel sizes and gear types significantly influence fuel usage, with consumption rates ranging from 2.9 to 3.3 liters per kilogram of fish and emission indices varying from 922 to 10,784 kg CO_2 per ton of fish. Comparisons with other studies showed differences in energy inputs among vessels targeting similar species and utilizing similar gear. Developing an efficiency index tailored to fishing vessels' power systems and catch characteristics could enhance energy efficiency evaluations, emphasizing the importance of analyzing market dynamics in assessing the environmental impact of fishing activities.

Acknowledgments

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Keywords

Fishing vessels, decarbonization, energy efficiency, environmental footprint.

A Coupled Computational Model of Hydrodynamic and Aerodynamic Loads and Response of Offshore Floating Wind Turbines

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Introduction

The analysis of the mooring system of offshore floating wind turbines has been commonly carried out in accordance with the recommendations provided in relevant international standards and norms, where the environmental loads on structures are provided regarding the action of wind, waves and sea currents. Reliable methods previously developed for the offshore oil and gas industry are available to determine waves and sea current loads. However, the wind effect is determined somewhat simplified based on the average wind velocity with a correction factor to account for turbulence effects. These conditions do not correspond to the wind characteristics in nature, where the standard deviation of the wind velocity fluctuations due to turbulence can be up to 40% of the average wind velocity. At the same time, the aerodynamic loads on structures may be up to 70% of the total environmental loads. Therefore, the goal of this research is a coupled computational model of hydrodynamic and aerodynamic loads and responses of offshore floating wind turbines subjected to realistic environmental conditions characteristic of the lower atmosphere with exhibited turbulent airflows.

Methods

The hydrodynamic loads of sea currents and waves will be calculated for floating wind turbines with traditional and synthetic mooring lines using Hydrostar and Ariane software. The software packages are based on coupled models for the analysis of moored objects by taking into account the hydrodynamics of the floating object and the dynamics of mooring lines. Calculations of aerodynamic loads on the structural portion above the sea surface will be carried out using the approaches recommended in relevant international naval architecture standards and by directly employing experimental results.

Preliminary results

Three different standards were revised, Det Norske Veritas, the American Bureau of Shipping and Bureau Veritas. Loads caused by waves, sea currents and earthquakes are very well physically described in the aforementioned standards, and no shortcomings have been identified. However, all three standards are deficient in terms of wind load, especially concerning non-synoptic winds such as hurricanes, storms, downbursts, tornadoes and bora wind, which could occur in real offshore conditions. Therefore, a synoptic winds-only assumption could lead to the collapse of the floating wind turbine, causing significant economic harm, which is multiplied in the case of a collapsed wind farm.

Discussion

Shortcomings of the observed standards and recommendations for their improvement are to be taken into account in the future: realistic wind flow data, non-synoptic wind profile, non-synoptic winds such as a tornado, hurricane/typhoon, tropical cyclones, bora, downburst, integral turbulence length scales and Reynolds shear stress.

Acknowledgments

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Keywords

Hydrodynamic loads, Aerodynamic loads, Non-synoptyc winds.

Influence of Laser Beam Focus on the Microstructure and Properties of the Welded Joint of Dissimilar Materials in Battery Systems of Electric Vehicles

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Introduction

Laser welding is increasingly used when welding parts of electric vehicle battery systems due to significant advantages such as simple automation, small width of the heat-affected zone, the possibility of welding dissimilar materials, high accuracy and high welding speed. During laser welding of dissimilar materials with different physical, chemical and thermal properties, hard and brittle intermetallic compounds are formed in the weld metal and the heat-affected zone, pores may appear, and cracks may occur due to high residual stresses. These irregularities and defects in the welded joint do not significantly affect the electrical properties, but they impair the mechanical properties and quality of the welded joint. In this research, the influence of the focus of the laser beam, as one of the parameters of laser welding, on the microstructure and mechanical properties of the welded joint of dissimilar materials in battery systems of electric vehicles will be examined.

Methods

The test samples were made by laser welding Al-alloy and electro-nickel plated steel (Hilumin). The weld was made with a disc laser, as a lap joint, with Al-alloy on top. During welding, the focus of the laser beam was varied, while the other welding parameters were constant. In order to identify the intermetallic compounds formed by welding, an analysis of the microstructure in the polished state was performed using an optical microscope and a scanning electron microscope. Also, the microhardness HV0.01 was measured in the base materials, the heat-affected zone and the weld metal.

Preliminary results

Analysis of the microstructure in the polished state using an optical microscope and a scanning electron microscope, in the weld metal showed numerous cracks and pores, which can make the quality of the weld very poor. By measuring the microhardness HV0.01, in the heat-affected zone and the weld metal, very large scattering results were obtained, which indicates that different intermetallic compounds were formed during welding.

Discussion

Based on the results of microhardness measurements and microstructure analysis on an optical and scanning electron microscope, it is possible to identify the formed intermetallic compounds. Preliminary research has shown that by changing certain process parameters of laser welding, the formation and growth of intermetallic compounds can be controlled, which consequently affects the microstructure and mechanical properties of the welded joint. Further tests will contribute to the optimization of laser welding parameters for application in battery systems of electric vehicles.

Keywords

Laser welding parameters, dissimilar materials, characterization, microstructure, microhardness

Improvement of Numerical Spray Modelling for Industrial Applications with Heat Transfer

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Introduction

Experimental investigation of spray and spray/wall interaction phenomena are often very demanding, require sophisticated equipment and data processing procedures, and provide limited insight into the actual spray behavior. Therefore, numerical models are employed to describe and investigate spray behavior. By conducting Computational Fluid Dynamics (CFD) simulations, spray shape evolution, wall film formation and heat transfer can be calculated. The models used to describe spray-related phenomena are usually empirical and should be carefully selected depending on the applications for which simulations are performed. In industrial processes such as metal quenching, coupling between hydrodynamic and thermodynamic phenomena is crucial. The aim of this study is to develop a new modelling framework for description of such processes by combining the existing knowledge on the subject and results of performed experimental tests.

Methods

Spray shape evolution, spray radius and primary spray angle will be investigated using Mie-scattering technique. Shadowgraphy imaging will be used to determine droplet size distributions, which will be used for model validation. The computational work will be performed using CFD software based on Finite Volume Method, where Eulerian formulation is used for solving the continuous phase dynamics and Lagrangian formulation is used for tracking of spray droplets. Experimental data from literature will be used to formulate an improved spray/wall interaction model, while correlations for different boiling regimes will be implemented to account for droplet/wall heat transfer. CFD calculations will be coupled with heat conduction calculation based on the Finite Element (FE) approach. Temperature histories at each FE cell will be used to calculate microstructure using CCT diagrams, allowing for simulation of spray quenching.

Preliminary results

A spray/wall interaction model from literature was implemented into AVL Fire CFD code. The model is extended to account for wall temperature effects and calculate spray/wall heat transfer using general heat transfer model. Spray cloud evolution was successfully captured, but the results showed that specific heat transfer correlations should be implemented for each boiling regime. Based on experimental cooling curves from the literature, FE simulations using Autodesk Inventor Nastran solver were performed to acquire temperature histories within the quenched samples. The model available from literature was used to evaluate resulting steel microstructure based on temperature histories and showed satisfactory results.

Discussion

Although models for spray quenching simulation already exist, none of them consider full spray simulation and coupling with heat transfer. This novel approach allows for more robust and accurate models allowing for more accessible virtual prototyping, which essentially leads to reduced production costs. The acquired Preliminary results are promising, but refinement of the heat transfer model is necessary. The performance of the model will only be assessed after the full coupling procedure has been implemented.

Acknowledgments

This work has been supported by the Croatian Science Foundation.

Keywords

CFD, spray/wall interaction, heat transfer, quenching

Towards Polynomial Smoothing Using Chebyshev Polynomials

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Introduction

The efficient solution of large sparse linear systems is essential in computational fluid dynamics (CFD) applications, where it serves as a foundation for computing numerical solutions of partial differential equations (PDEs). These numerical solutions are required for simulating fluid flows, heat transfer and combustion in real-world scenarios.

Methods

In CFD applications, the accurate model of physical phenomena relies on the discretization of continuous PDEs into algebraic systems, typically in the form of large sparse linear systems. The size of these systems is derived from the spatial discretization in which the number of finite volumes is the same as the dimension of the coefficient matrix. As the computational domain becomes more detailed and has more elements, the resulting linear systems of equations show sparsness patterns that can significantly impact the efficiency of iterative linear solvers [1]. The algebraic multigrid (AMG) method [2] has proven to be an efficient scalable parallel solver [3], but recent high-performance computers present new challenges for its parallel usage.

Discussion

This study presents an algorithm which uses polynomial smoothing as an easy and effi- cient way to improve the efficiency and scalability of the AMG solver. As the literature suggests, there is no single ”best” polynomial; the proper choice depends on the eigen- value distribution, which is rarely known a priori [4]. Specifically, we demonstrate how the Chebyshev polynomial is attractive for usage on parallel architectures, due to the lack of memory-intensive inner product calculations [5]. The newly implemented algorithm will be tested for single-phase, incompressible, laminar and turbulent flows. The proposed algorithm's expected outcome is a faster solution phase. We expect that our findings will help address the challenges that arise when using recent high-performance computers and that the proposed algorithm can serve as an effective solution procedure for solving large sparse linear systems in CFD applications.

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Validation of Finite Volume Fsi Solver on Patient-Specific Type-B Aortic Dissection

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Introduction

Aortic dissection is a life-threatening cardiovascular disease caused by a tear in the innermost aortic wall layer. This leads to the formation of a secondary blood flow channel in the media layer of the aortic vessel wall known as the false lumen. Treatment can be medical, endovascular, or surgical. Survivors of the acute phase undergo lifelong monitoring to prevent fatal events such as dissection rupture. Patient-specific fluid-structure interaction (FSI) models could potentially aid in disease management by providing insight into the complex hemodynamics of dissections. However, such models are rarely validated, their reliability is questionable and their clinical application is limited.

Methods

In this work, the validation of the finite-volume partitioned FSI solver on a patient-specific aortic dissection type B geometry is described. The aortic geometry used for the simulations is derived from a computed tomography angiography (CTA) scan of a patient with TBAD. This geometry is 3D printed into a physical phantom using a material with known mechanical properties. Fluid flow through the phantom is acquired with 4D-flow magnetic resonance imaging (MRI). The FSI solver is based on a monolithic computational framework where both fluid and solid models are spatially discretized using a cell-centered finite volume method and temporal discretization is performed by a second-order accurate implicit scheme. The FSI problem is solved using the added-mass partitioned scheme, where the fluid sub-problem is solved with Dirichlet boundary conditions (BC) for velocity (structure velocity) and Robin BC for pressure at the FSI interface, while the solid subproblem is solved with a Neumann BC (fluid stress) at the interface.

Preliminary results

The FSI solver results were compared to benchmark test cases, including wave propagation test case and balloon-type problem. The results showed good agreement with analytical results, thus validating the solver.

Discussion

The solver has been tested on wave propagation in an elastic tube test case characterized by a low solid-to-fluid density ratio. Temporal stability was also shown in this test case, proving second-order temporal stability for the backward temporal scheme, and first-order stability for the Euler temporal scheme. The stability of the method is shown for strongly, as well as for loosely coupled solution procedures. This means that the solver converges in a small number of FSI iterations (1 or 2) thus making it less computationally demanding. Also, the balloon-type problem, which is hard to solve because of the incompressibility dilemma is successfully solved which proves solvers' ability to deal with problems in which the fluid domain is completely enclosed with Dirichlet boundary conditions.

Acknowledgments

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Keywords

Fluid – structure interaction, computational fluid dynamics, finite volume method, aorta

Autonomous Underwater Vehicle Subjected to Underwater Explosion

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Introduction

Autonomous underwater vehicles (AUVs) are primarily used for tasks such as underwater surveys and data collection, while also finding extensive applications in military operations. The usage of AUVs in military operations is expanding, particularly in the areas of defense and security. AUVs employed in military applications are susceptible to shock loadings from underwater explosions (UNDEX), requiring a robust design that can withstand such occurrences. Understanding the mechanisms of underwater shock damage is essential for developing a rational design. Interaction between UNDEX and AUV structure can be simulated with fluid-structure interaction (FSI). This simulation can be used to investigate this phenomenon and how different explosion and structural parameters influence the structural integrity of AUVs.

Methods

The research will first focus on a state-of-the-art investigation of AUVs, UNDEX, UNDEX structural interaction, and numerical modeling of FSI. Afterward, the research will proceed with the development of a structural AUV model based on the technology and requirements identified in the state-of-the-art investigation. Secondly, a simulation model of UNDEX will be developed in the software LS-Dyna, at which point the UNDEX and AUV models will be coupled. After the FSI of UNDEX and AUV is fully developed and validated, a set of simulations will be conducted based on different scenarios of UNDEX and AUV structural arrangements. Based on this data, a new numerical model for the fast estimation of damage parameters using a surrogate modeling approach will be developed.

Preliminary results

So far, an initial state-of-the-art investigation has been conducted on the UNDEX phenomenon, UNDEX structural interaction, and modeling of FSI. It has been identified that while UNDEX has been extensively researched as a solitary event, there is limited research on UNDEX and underwater structure interaction, and even less on the structural response of submarines and AUVs to UNDEX. Regarding the research and development of numerical modeling, it is possible to develop an FSI simulation of UNDEX and AUV using multiple software programs, with LS-Dyna being the most commonly used due to its capabilities for simulating explosion events.

Discussion

The research is investigating how various parameters of UNDEX, as well as structural parameters, affect the damage sustained by AUVs. Based on the conducted FSI numerical simulations and their results, a surrogate model can be developed. Additionally, the research Aims to identify improvements in structural design that can be implemented to enhance the survivability of AUVs in the event of underwater explosions.

Keywords

Autonomous underwater vehicles, underwater explosion, Fluid-Structure Interaction, Surrogate model

Enhancing Nano Positioning Efficiency Through Optimized Perforated Hinge Designs in Compliant Mechanisms

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Introduction

The advancement in nano positioning has sparked considerable research interest due to its critical role in modern industries requiring precise manipulation, adjustment, and positioning. Compliant mechanisms, known for their superior friction, noise, maintenance, and backlash performance, are increasingly utilized in these applications. Unlike rigid mechanisms, compliant mechanisms transmit force and motion through elastic deformation, which allows them to be produced as a single piece, eliminating the need for assembly. This study explores the potential of enhancing the efficiency of compliant linear stages by utilizing perforated hinge designs, with a focus on optimizing their performance using additive manufacturing technologies.

Methods

The study involved both preliminary laboratory testing and simulations to evaluate the performance of different perforated hinge designs. Initially, we examined the horizontal and vertical displacements of the linear stage under specific forces. Various hinge geometries were tested, each with configurations of one, two, or three perforations, maintaining a total perforation area of 10 mm^2. These configurations were analyzed using the Static Stress simulation module in Autodesk Fusion 360, with ABS plastic as the material of choice. The simulations aimed to mimic the conditions under which the mechanisms would operate, and the results were compared to identify the most efficient designs.

Preliminary Results

The simulation results revealed that perforated hinge designs significantly improve the horizontal displacement of compliant linear stages compared to solid hinges. Among the tested shapes, the triangular and diamond perforations exhibited the highest efficiency, particularly when three holes were used per hinge. The horizontal displacement was notably higher in these configurations, while the vertical displacement, though increased, remained within acceptable limits. These findings suggest that incorporating perforations can enhance the performance of compliant mechanisms without compromising structural integrity.

Discussion

The results underscore the potential of using complex hinge geometries to enhance the efficiency of compliant linear stages. The increased horizontal displacement achieved with perforated designs suggests that these mechanisms can be made more compact and efficient, making them suitable for a wider range of applications. Future research should focus on experimenting with a greater number of perforations and varying their shapes and sizes to further optimize performance. Additionally, validating these simulation results with experimental data will be crucial for practical implementation.

Keywords

Interferometer, Nanometer, Compliant mechanism, Linear stage