University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture

SVEUČILIŠTE U ZAGREBU
METALURŠKI FAKULTET

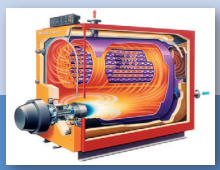
UNIVERSITY OF ZAGREB
FACULTY OF METALLURGY

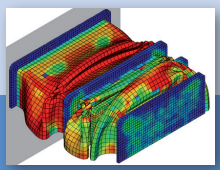
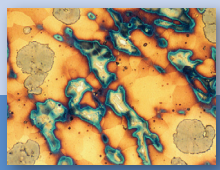
Ninth Annual PhD Workshop

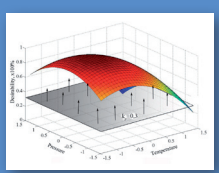
PhD Study of Mechanical Engineering, Naval Architecture,
Aeronautical Engineering and Metallurgical Engineering

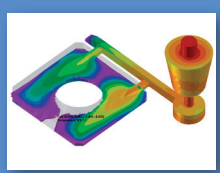
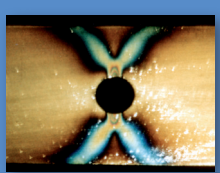
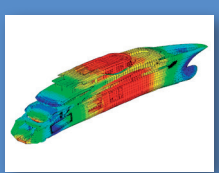
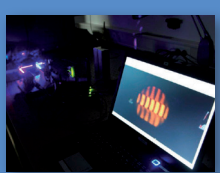
Book of Abstracts

September 22, 2023



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Preface

This booklet contains abstracts presented at the 9th Annual PhD Workshop, which took place on September 22, 2023. 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.

35 participants on the PhD workshop presented preliminary topics of their theses, while 16 participants presented final PhD topics. Contributions collected in the booklet of abstracts are from different modules of the PhD study: Process and Energy Engineering (14 contributions), Computational Mechanics (5), Theory of Structures (6), Mechatronics and Robotics (6), Industrial Engineering and Management (3), Scientific Metrology in Mechanical Engineering (3), Aeronautical Engineering (1), Materials Engineering (4), Advanced Production Technologies (4), Naval Architecture and Ocean Engineering (2) and Metallurgical Engineering (3). 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

Numerical Modelling of Strain Rate Dependent Impact Damage Initiation and Propagation in Composite Structures

PhD candidate: Jakov Ratković
Mentor/s: Darko Ivančević
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Due to their anisotropy, interconnection of different constituents, production imperfections and other factors, fiber reinforced polymer (plastic) materials exhibit highly complex and yet not fully understood behaviour under various loading conditions, which is even more pronounced in high strain rate conditions. As investigated in a wide range of references, during events that induce high strain rates in composite materials, the failure modes are different compared to the failure modes in quasi-static loading conditions. Furthermore, stiffness moduli and strengths of a ply increase in high strain rate conditions.

Aims

A numerical material model containing constitutive behaviour, including strain rate effects is to be developed. Strain rate effects will be considered when evaluating strengths, stiffness moduli and fracture energies in all material directions. Four failure criteria, describing fiber and matrix tensile and compressive failure modes, along with a delamination criterium are to be implemented. Damage evolution will be incorporated according to bilinear traction-separation law, based on the fracture energy values corresponding to different failure modes. The goal is to create a material model suitable for both composite layups comprised of unidirectional and those comprised of woven plies.

Methods

The numerical model is to be written as a FORTRAN subroutine code, prepared to be incorporated in commercial FEM software (e.g. Abaqus or LS_DYNA) as VUMAT (user-defined material) subroutine. For debugging purposes, an in-house built VUMAT standalone testing program that is simulating the commercial software input was created in order to simplify the process by avoiding the need for UI FEM software. In subsequent stages, testing of the produced material model is to be performed on one finite element tests, to fully understand the behaviour of the written code. Finally, significantly more complex simulations of ballistic impacts are to be performed to validate the obtained results against the available data.

Expected scientific contribution

More detailed and accurate modelling of composite material behaviour may lead to improved structural integrity prediction, including the most severe loading conditions – impact events. Thus, less highly expensive physical testing on experimental setups is to be performed, reducing the time and financial expenses in major industries utilizing composite materials, such as military, aeronautical and automotive.

Acknowledgments

The scholarship is funded by the project Development of innovative systems for the use of geothermal energy sources and energy from biological waste – RazInoGeoBio (Project code: KK.01.2.1.02.0314) financed from the European Fund for Regional Development. The research is fully financed by the project Numerical modelling of impact damage in composite structuresfunded by Croatian Science Foundation (Project code: UIP-2020-029317 CONCORDE).

Keywords

composite, failure, damage, impact, strain rate

Life-Cycle Assessment and Life-Cycle Cost Assessment of the Lithium-Ion Power Battery for Fully Electric Ro-Ro Passenger Ships for Short-Sea Shipping

PhD candidate: Lovro Frković
Mentor/s: Tomislav Pukšec, Nikola Vladimir
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Introduction

Shipping is the backbone of the global economy and global trade. Unfortunately, this mode of transport still depends on the consumption of fossil fuel and consequently pollutes the marine eco-systems. The International Maritime Organization (IMO) reported that greenhouse gas (GHG) emissions of the total shipping industry exceeded one billion tons in 2018. To prevent further increase, the maritime regulation is cutting down permitted limits of harmful emission from shipping and pushing the energy transition of the shipping industry. Among various alternative technologies, the lithium-ion batteries can ensure full conformity with strictering maritime regulation. Moreover, the research and development of the lithium-ion batteries improved their characteristics such as energy density, power density, light-weight and lifespan. Therefore, the lithium-ion battery received considerable attention in terms of replacing diesel engines on ships for short sea shipping.

Aims

The aim of this study is to compare diesel engine power system with a lithium-ion battery power system considering the environmental and economic indicators. Moreover, this paper discusses technological readiness and gaps of lithium-ion battery technology to replace traditional diesel-powered solutions and decrease emissions released from maritime transport.

Methods

The life-cycle assessment (LCA) and Life-Cycle Cost Assessment (LCCA) are performed to analyze environmental and economic performance of the ship with lithium-ion battery power system and diesel engine power system. The analysis included ro-ro passenger ships from the Croatian short-sea shipping, highlighting the lithium-ion battery as a superior technology compared to the diesel engine according to environmental and economic indicators.

Expected scientific contribution

Findings of the study demonstrate that, although the investment costs of the lithium-ion battery is higher than of diesel engine, the total cost of lithium-ion battery powering option can be lower due to significantly lower operating costs. Additionally, the study indicated that a ship with lithium-ion batteries significantly decreases the emissions and improves the air quality compared to a ship with diesel engines. However, the study concluded that lithium-ion batteries can achieve sustainable energy transition of the short sea shipping only if such baterries are charged with the electricity supplied from the power sector with 100 % renewable energy sources (RES).

Keywords

Decarbonization, All-electric ship, Lithium-ion technology, LCA, LCCA

Active Metamaterial Cell Concept for Nonreciprocal Vibroacoustic Transmission Using Dislocated Position Feedback

PhD candidate: Srećko Arandia-Krešić
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Introduction

This work examines absolute position feedback using dislocated sensor-actuator pairs to design an active metamaterial cell concept for non-reciprocal vibration transmission. It is of interest to consider pure absolute position feedback because, in contrast to velocity feedback, strong quasi-static and low-frequency error signals could potentially induce a large nonreciprocity at low frequencies.

Aims

A proposed concept suggests a 4-degree-of-freedom (4DOF) mechanical model activated with two decentralised position feedback loops. Specifically, each of the two identical feedback loops is composed of a sensor-actuator pair which is said to be „dislocated". A sensor and an actuator are collocated, if the actuator exerts a force on a degree of freedom whose kinematic variables are measured by the sensor. Note that collocated sensor-actuator configuration is normally preferred for its beneficial stability properties. In particular, the phase of the open-loop sensor-actuator Frequency Response Function (FRF) in a collocated control arrangement is confined in a 180 degrees range. This indicates that the closed-loop control system stability using non-collocated transducer pairs requires additional attention. Furthermore, because the two feedback loops operate concurrently, they effectively form a decentralised Multi-Input-Multi-Output control system. This may cause further stability and performance problems due to the cross-talk between distant transducers. Therefore, in this study comprehensive stability and performance analyses of the position feedback using dislocated sensor-actuator pairs are carried out. In addition, the effect of transducer dynamics on stability of the system is investigated.

Methods

The influence of collocation of sensors and actuators on the system's response is investigated by considering the mass, damping, or stiffness matrices of the system. The collocation of sensor-actuator pairs is of importance because the reciprocal behaviour of linear-time-invariant systems is tied to their transfer function matrices. Specifically, by introducing non-collocated position feedback control, stiffness matrix of the system becomes diagonally asymmetric, and the symmetry of the system's transfer function matrix is lost as well. In continuation, the Routh-Hurwitz stability criterion is used to investigate stability conditions. By carefully introducing specific dimensionless variables, the 8^{th} order characteristic polynomial is factorized to two 4^{th} order polynomials, which are easily analysed using the mentioned approach. Additionally, the sensor-actuator Nyquist plot of the open-loop transfer function is used to analyse the impact of transducers on the stability of the system. In order to quantify the reciprocity loss, two mobility functions for two opposite directions of propagation are compared by the means of their FRF amplitudes. The loss is further quantized using the H_2 norm of the transfer functions.

Expected scientific contribution

This work showcases a vibroacoustic metamaterial cell concept that, in contrast to other metamaterial cell concepts, provides an efficient method for achieving non-reciprocal response at wide frequency bands, with emphasis on low frequencies, without compromising the stability of active structure.

Acknowledgments

The Croatian Science Foundation HRZZ-IP-2019-04-5402 (DARS) support is gratefully acknowledged.

Keywords

dynamic reciprocity, active metamaterials, stability of active control systems, performance of active control systems, absolute position feedback

Investigation on the Occurrence of Plastic Instabilities During Plastic Processing of Almg Alloy

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Affiliation: University of Zagreb, Faculty of Metallurgy, Croatia

Introduction

During the plastic deformation of most metallic materials, the normal material flow takes place in the deformation zone. There are some exceptions in certain alloys where process of plastic deformation is unstable and there is inhomogeneous plastic flow under certain deformation conditions. The proposed research will primarily include issues of occurrence of plastic instabilities during plastic processing of AlMg alloys, which are associated with the phenomenon Portevin Le Chatelier effect (PLC effect). The PLC effect manifests itself as deformation localization in the form of deformation lines that lead to repetitive serrations on the stress-strain curve during tensile tests. Instabilities like PLC effect cause problems during metal processing into final products. In this research, the focus will be on the appearance of the Portevin-Le Chatelier effect, which occurs during plastic processing of aluminum alloys.

Aims

The aim of this paper is to investigate the Portevin-Le Chatelier effect that occurs during the deformation of AlMg alloys, and also to study the influence of different deformation parameters on the occurrence of the Portevin-Le Chatelier effect and the possibilities and parameters to avoid the occurrence of the PLC effect in production.

Methods

In this research, samples will be prepared by machining on a CNC machine from samples taken at different stages of production and processing. The mechanical properties will be determined by a static tensile test. The deformation zone will be observed by the method of thermography (IR) and the changes within the zone during plastic deformation will be analyzed. Visualization of material flow, measurement of displacement and deformation during the experiment will be performed by Digital Image Correlation (DIC) technique, and analysis in correlation program will determine the amount of deformation and record deformation maps.

Expected scientific contribution

Model of the deformation mechanism by which the PLC effect takes place. Proposal of parameters that would avoid the occurrence of the PLC effect in production.

Acknowledgments

This research was conducted within the framework of the research project IP-124 IJ University of Zagreb Faculty of Metallurgy, Centre for Foundry Technology-SIMET, KK.01.1.1.02.0020 and VIRTULAB-Integrated laboratory for primary and secondary raw materials, KK.01.1.1.02.0022

Keywords

Portevin Le Chatelier effect; AlMg alloy; Digital Image Correlation; Thermography, Microstructure

Coupled Numerical Model of Ship Manoeuvrability, Collision, and Flooding for Assessment of Ship Collision Consequences

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Introduction

Ship collision has been studied for several decades, but most often they include the dynamics of ships immediately before the collision and structural damage during the collision. The goal of the research is to look at all aspects of ship collisions, that is, the dynamics of the causes and consequences of ship collisions. The research is divided into three parts: in the first part, manoeuvrability equations will be implemented in the program package LS-DYNA. In the second part, both internal mechanics as well as external dynamics of ship collision will be studied. In the third part, the consequences of the collision will be analyzed with an emphasis on the flooding of the ship. Finally, the developed numerical model will be applied in the analysis of ship collisions. The result of the research is the development of a coupled model of ship manoeuvrability, collision and grounding for a detailed analysis of ship collisions with application in the forensics of maritime accidents.

Aims

The objective of the research is to develop a holistic and efficient method for ship collision analysis by coupling hydrodynamic and contact forces as well as forces due to flooding, using the Nonlinear Finite Element Method (NFEM). This will reduce simulation time and will provide a better understanding of ship collision events including events prior to collision, the collision itself and the consequence of the collision.

Methods

The research will be divided into three consecutive and connected phases, manoeuvrability equations implementation into the NFEM code, ship collision with implemented damage model under different manoeuvres and angles of attack, and finally, implementation of flooding equations in the NFEM code.

The first phase will consist of implementing the Abkowitz model into the LS-DYNA using subroutine and FORTRAN programming. Already known hydrodynamic derivatives will be used for specific ship. This will be further tested and compared with the experimental results of ship manoeuvres.

The second phase will focus on the accurate modelling of ship collision with focus on both internal mechanics and external dynamics of ship collision. Implementation of complex physical phenomena such as plasticity and damage will be done and verified by experimental results.

The third phase will consist of the implementation of flooding forces into the LS-DYNA based on Bernoulli's equation. The rupture hole and distance from the free surface will be based on damage estimated during ship collision.

Expected scientific contribution

1. A novel method for numerically efficient calculation of hydrodynamic forces before, during and after ship collision, based on NFEM simulation and explicit time integration in LS-Dyna is developed.
2. Algorithm for the prediction of damage size and position in transient simulation is developed for accurate and numerically efficient flooding calculation.

Acknowledgments

The work has been supported by the Croatian Science Foundation within the projects HRZZ IP-2020-02-3420.

Keywords

Hydrodynamic derivatives, maneuverability, collision, NFEM, flooding

Improvement of the Air to Water Heat Pump Performance Based on a Parameter-Driven Evaporator Defrosting System

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Introduction

One of the main disadvantages of air-water heat pumps is the reduced capacity in conditions of high relative humidity and low temperature, where ice forms on the surface of the evaporator. The formed frost layer reduces the airflow and acts as an additional resistance to heat exchange, reducing the device's efficiency. Traditional defrosting techniques consist of timer-driven cycles that stop the heating process for too long or use excessive energy. This thesis will examine a parameter-driven defrost strategy to increase the system's energy efficiency.

Aims

- Establishing an experimental set-up for testing the efficiency of the heat pump under different environmental conditions
- Determine the influence of the temperature and humidity of the outside air on the cooling rate of the heat pump air evaporator;
- Development of a parametric control model for the defrosting process.

Methods

The first step of the research is defining the test conditions and developing the test station where the whole study will be conducted. The psychrometric chamber is the central part of the test station, which simulates the environmental conditions in which the heat pump with the air evaporator works.

The second step is to determine the measurement uncertainty of the experimental setup.

The third step is experimental testing divided into several parts:

- Testing the freezing time at different environmental temperatures and humidities. Freezing rates at constant temperature will be tested for different relative humidities ranging from 60 to 90 %. This will determine the critical temperatures where freezing is the most intense;
- Defining the moments of starting and stopping the process for specific environmental conditions;
- Examination of changes during operation in partial load.

Expected scientific contribution

- Model of the parametrically driven evaporator defrosting process based on the current operating characteristics of the heat pump;
- Improving the efficiency of the air-to-water heat pump in frosting conditions.

Acknowledgments

The measuring and testing equipment was acquired through IRI 2 – KK.01.2.1.02.0132. Research and development of air-to-water heat pump with natural refrigerant and advanced evaporator defrost system project funded by the European structural and investment funds together with Frigo Plus, to whom we sincerely thank.

Keywords

Heat pump, Evaporator frosting, Energy efficiency, Defrosting

Development of Rolled Plug for Defected Steam Generator Tubes Plugging

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Introduction

Steam generator tubes are critical component inside the nuclear power plant, as they form barrier between the primary and secondary circuit. Primary circuit consist of the reactor pressure vessel in which nuclear fission reaction occurs, pressurizer and steam generator which transfers heat from the primary circuit to secondary. Secondary circuit consists of turbine, condenser and generator which generates electricity due to the rotation of the turbine blades. Degradation of the tubes inside steam generator due to the high pressure, hot temperature, stress corrosion cracking and feedwater vibrations can cause tube rupture and leakage of radioactive water from primary circuit to secondary and into the environment. In order to prevent this from happening, corrective action such as plugging of the steam generator tubes is required. Plugging is installation of plug which forms leak tight seal with the tube and prevents flow of the radioactive water through the damaged tube. The rolled plug is fast and reliable solution for plugging of the steam generator tubes while also reducing the exposure of the personnel to the radiation and reducing the cost of the inspection, while forming leak tight seal with the tube for 60-year lifespan.

Aims

The aim of the research is to optimize existing rolled plug geometry and to develop the procedure for installation, as well as the removal of the rolled plug during inspection of the steam generator tubes.

Methods

Development of the optimized rolled plugs will be divided into several phases. First phase is based on the literature review and acquiring data for establishment of the working conditions inside steam generator. Second phase is development of the numerical model based on the acquired data, in order to optimize rolled plug design. In numerical simulations, maximum pressure load which plug can withstand without leakage will be determined. In addition, simulation of whole plugging procedure inside tube sheet block will be conducted in order to determine stress distribution and simulation of the material fatigue due to the transient conditions. Lastly, the rolled plug removal simulation will be conducted. Also, the validation of the numerical analysis through extensive experimental testing for each simulation will be conducted.

Expected scientific contribution

Optimization of rolled plug design in order to reduce harmful radiation exposure of personnel. Comprehensive numerical model of the rolled plug behaviour inside steam generator tube, including influence of the temperature, material nonlinearity and fatigue. Validation of the numerical results by comparison to the experimental testing.

Keywords

rolled plug, steam generator, numerical analysis

City Bus Fleet Planning and Optimal Routing

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Introduction

The electrification of public bus transportation has a strong impact on reducing harmful and greenhouse gas emissions. In addition, the introduction of electric vehicles enhances the comfort of the ride in terms of mechanical aspects and thermal aspects. All of these factors, including significantly increased energy efficiency, ultimately lead to greater passenger satisfaction. However, the transition to electrified transportation is not a simple process as it requires adapting the entire transport-energy infrastructure. To achieve this with minimal investment and operational costs, detailed transportation-energy analyses will be conducted based on an advanced virtual computer simulation model and methods for optimal configuration of the transport-energy system and charging system management.

Aims

The main objective of the project is the development of innovative sustainable measures to reduce harmful emissions at airports, both in the air and on the ground, while improving energy efficiency, air quality, biodiversity, and waste management. As a contribution to the project, this research will focus on the development and implementation of procedures for electrification planning, optimal routing, and charging of a fleet of city buses to connect the airport and its surrounding area and/or to connect terminals within the airport. The overall computer tool will consist of five modules: (i) processing a large amount of recorded telemetry data and extracting driving cycles, (ii) creating a simulation data model for a battery electric bus, (iii) modeling the fleet of electric buses and charging systems for virtual simulation purposes, (iv) determining optimal schedules, charging locations, and charging algorithms, and (v) conducting techno-economic analysis of the entire transport-energy system.

Methods

For the research purposes, a multi-processor workstation with appropriate software support for modeling and optimization (Python, SQL, Matlab, modeFRONTIER) will be utilized. The research will primarily have a numerical nature, involving data processing, machine learning, system optimization, and simulations.

Expected scientific contribution

1. Electrification Planning and Optimization: The study focuses on developing procedures for planning the electrification of city bus fleets and optimizing their routing and charging. The research could provide valuable insights into efficient integration of electric buses into transportation systems, leading to reduced emissions and improved energy efficiency.
2. Numerical Data Processing and Machine Learning: The research involves processing large amounts of telemetry data and utilizing machine learning techniques. The findings may contribute to advancements in data processing methodologies, particularly in the context of transportation and energy systems.

Keywords

Electric vehicles, fleets, charging, driving cycles, data processing, machine learning, modeling, optimization.

Advanced Oxidation Processes for the Removal of Organic Micropollutants in Water

PhD candidate: Debora Briševac

Mentor/s: Davor Ljubas

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Introduction

The scarcity of freshwater resources necessitates exploring alternative water sources like seawater and wastewater. However, these sources require extensive processing due to micropollutants before they can be used as drinking water. Conventional methods often fail to remove these contaminants adequately, prompting the need for advanced solutions. Advanced oxidation processes (AOPs), including heterogeneous photocatalysis, are promising methods for eliminating organic and inorganic micropollutants. This study focuses on removing organic micropollutants like pharmaceuticals, personal care products, disinfection byproducts, and pesticides. Despite their toxicity, current regulations lack comprehensive guidelines for permissible levels of these substances in discharged waters. Moreover, these pollutants tend to bioaccumulate over time, requiring more efficient purification methods.

Aims

To address these challenges, advanced oxidation processes, specifically heterogeneous photocatalysis, offer potential solutions. Photocatalysts activated by UV or visible radiation can decompose and degrade harmful micropollutants, rendering them harmless. Titanium dioxide (TiO_2) is a well-studied and effective photocatalyst commonly used. However, its limited activation under UV radiation is a drawback. This study proposes modifying TiO_2 with other compounds to enhance photocatalytic activity and enable it to function under natural solar radiation.

Methods

The proposed photocatalyst can be easily synthesized using the sol-gel process, involving a sol added to polluted water. Microwave-assisted synthesis offers advantages such as accelerated reaction rates, energy efficiency, and environmental compatibility. Immobilization on substrates like borosilicate glasses or ceramic foams is necessary for practical application and stability. Borosilicate glasses are known for their inertness and compatibility, while ceramic foams offer a larger active surface area and improved performance.

The research methodology involves selecting an organic micropollutant, synthesizing the photocatalyst using microwave-assisted sol-gel synthesis, immobilizing it on substrates, and conducting adsorption and photocatalysis tests using water samples. Photolysis tests will also be performed, followed by an investigation under real conditions and solar radiation.

The study includes various characterization techniques like X-ray diffraction, thermal analysis, atomic force microscopy, and evaluation of pollutant degradation.

Expected scientific contribution

The outcomes aim to enhance the efficiency and effectiveness of heterogeneous photocatalysis for removing organic micropollutants, contributing to advancing water treatment technologies and addressing the urgent need for clean and safe water resources.

Keywords

photocatalysis, titanium dioxide, organic micropollutants, water treatment

Prediction and Modelling of Pedestrian Crossing Behavior at Uncontrolled Crosswalks

PhD candidate: Mate Ćorić
Mentor/s: Tomislav Stipančić
Affiliation: AVL, Croatia

Introduction

One of the key safety aspects of autonomous vehicles is to have robust prediction and representation of vulnerable road users.

Pedestrian safety is a critical issue in urban areas, and uncontrolled crosswalks present a significant risk to pedestrian safety due to the interaction with vehicles. This PhD research aims to develop reliable methods for predicting and modeling pedestrian crossing behavior at uncontrolled crosswalks while interacting with vehicles.

Aims

The main goal is to propose a prediction model for pedestrian crossing behavior and pedestrian crossing behavior model. Special attention is given to validation of pedestrian crossing model on real-world datasets. The aim of the pedestrian crossing model is to take into account factors such as pedestrian perception error and kinematic properties of different types of pedestrians (conservative, average, aggressive).

Methods

The research validates the prediction models and modeling methodology using real-world datasets from uncontrolled crosswalks and large-scale single-vehicle single-pedestrian simulation datasets. The results demonstrate the potential use of prediction models for safe vehicle control strategies in autonomous vehicle systems. Prediction models are based on well known feed-forward and recurrent neural network architectures for time series data processing.

Expected scientific contribution

The first contribution of this research is the development of a prediction model for pedestrian crossing behavior. The prediction models take into account time dependent pedestrian and vehicle kinematic data such as distance from crosswalk, speed and acceleration. The methodology uses two machine learning models to predict pedestrian intention (crossing prior or after the vehicle) and the probability of a pedestrian crossing the road at a particular instant, given situational factors.

The second contribution of this research is the development of a pedestrian crossing behavior model.

The behavior model uses a combination of reinforcement learning algorithms to model the decision-making process of pedestrians at uncontrolled crosswalks taking into account vehicle behavior. Pedestrians learn a specific type of behavior that is incorporated into the learning process through design of optimization objective (reward function) using known pedestrian behavior statistics from real-world dataset.

Keywords

autonomous vehicles, pedestrian behavior, machine learning, deep learning, safety

Assessment of Required Energy for Heating of University North Building: a Comparative Analysis of Measured Data, Norm Calculations, and Neural Networks

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Mentor/s: Marino Grozdek
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

University North is the only higher education institution in the Republic of Croatia that participated in the "Program energetske obnove zgrada javne namjene". The financing of the energy renovation was carried out through the ESCO (Energy Service Company) model, where the initial investment is repaid through the achieved savings after the energy renovation. The ESCO model requires only the repayment of the energy service, which the user pays before the renovation, while the energy service provider repays the initial investment through the difference in savings. Before building renovation, the energy service provider defines the guaranteed savings, which are calculated based on standardized microclimate parameters for indoor environmental quality and standardized parameters for the external environment. After the building renovation and commencement of use, the delivered energy will mostly differ from the predicted consumption. There can be various reasons for these differences, which often include the building's usage patterns after the renovation, influenced by user behavior and the state of the external environment, such as higher indoor air temperatures, increased ventilation, lower outdoor air temperatures, reduced solar heat gains, and lower internal heat gains.

Aims

The utilization of the Artificial Neural Network (ANN) and the norm HRN EN ISO 52016-1 provided valuable insights into energy consumption patterns and the influence of user behavior. Comparing measured data from the building and the results obtained from the ANN analysis and norm contributed to the enhancement of energy efficiency strategies and decision-making processes in building management. By incorporating the ANN and norm, University North aims to optimize energy consumption, improve occupant comfort, and contribute to sustainable practices in the public sector building sector.

Methods

The ANN was trained and tested on the measured parameters including temperature, relative humidity, concentration of Volatile Organic Compounds (VOC), and CO_2 concentration in occupied building spaces. The ANN serves as a mathematical model, devoid of explicit knowledge of underlying physics, functioning as a "black-box" model for predicting energy consumption. In parallel, a norm-based model grounded in physics principles is utilized for comparison against the results obtained from the ANN and the measured data.

Expected scientific contribution

This research will result in a model that will serve as a simulation for continuous management and optimization of operating parameters of HVAC systems in buildings to further increase energy efficiency and therefore savings.

Acknowledgments

The research and measured data presented in this study were conducted as part of the project "Razvoj sustava za automatizirano mjerenje parametara udobnosti (ugode) i verificiranje smanjenja potrošnje energije zgrada nakon provedene energetske obnove", funded by the Agencija za pravni promet i posredovanje nekretninama.

Keywords

Energy-efficient building renovation, HRN EN ISO 52016-1, user impact on energy consumption, measurement of indoor comfort parameters, Artificial Neural Network

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. Motivated by the potential benefits of bridging the recognised gap, the herein-presented research seeks to improve the understanding and support the assessment of engineering designers' performance in CAD activities by investigating the underlying cognition. It is assumed that the execution of CAD activities, due to their cognitive complexity, imposes high demands (i.e. cognitive load) on the engineering designers' cognitive system. The cognitive complexity of CAD activities arises from the characteristics of design tasks as well as from the use of CAD systems. Since engineering designers' information-processing cognitive resources are limited, understanding their allocation in CAD activities is important to ensure effective and efficient performance. Thus, the necessary further research steps include defining the model of cognitive load as well as the means to measure and analyse it in the CAD context.

Aims

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 the cognitive load in CAD activities.

Methods

The research activities are organised in four main stages: research clarification, descriptive study I (that embraces literature review and preliminary empirical studies), prescriptive study (that proposes theoretical models and method) and descriptive study II (that validates the developed theoretical models and method). The empirical studies will incorporate three types of methods: the subjective assessment (e.g. self-rated scales), the psychophysiological measurement (e.g. electroencephalography), and the performance measurement (e.g. the number of errors, task completion time, analysis of CAD log files, etc.).

Expected scientific contribution

The scientific contribution of the proposed research is manifested through the theoretical models and the method. The developed theoretical model of cognitive load (the first scientific contribution) and engineering designers' performance (the second scientific contribution) will ground a basis for developing the method for measuring and analysing the cognitive load in CAD activities (the third scientific contribution).

Acknowledgments

The proposed research is funded by the Croatian Science Foundation project IP-2018-01-7269: Team Adaptability for Innovation-Oriented Product Development – TAIDE and the Erasmus+ project 2021-1-SI01-KA220-HED-000027506: Product Hackathons for Innovative Development – PRO HACKIN'.

Keywords

cognitive load, computer-aided design, performance

Determination of the Solidification Mechanism of Ductile Iron

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Introduction

Cast iron as a type of metal alloys (especially ductile iron) is very important and popular material since the development of iron smelting and casting technologies. Ductile cast iron has a very important role as an engineering material. It is constantly developing and has progressed to a complicated material. Although they have been replaced, their constant development and progress in foundry has fueled a resurgence in the use of iron castings as construction materials. The microstructure of ductile cast iron is significantly influenced by different parameters like chemical composition, melt processing, cooling rate, size, and distribution of excrete graphite but also the development of metal base as a mixture of ferrite and pearlite. Microstructure represents an important area of study of the physical metallurgy of iron alloys and the interrelationship of chemical composition, production process, microstructure, and mechanical properties. Although numerous studies have been carried out on the topic of the growth mechanism and solidification course of graphite in ductile iron casting, they have not been fully elucidated. Hypothesis is that the chemical composition and nucleation at different speeds will have a certain influence on the mechanical properties of ductile iron.

Aims

The aim of this paper is to determine the solidification mechanism of ductile cast iron of certain quality and the influence of the melt on the development of the microstructure and mechanical properties. Casting into Y – samples will be carried out. After the preparation of the samples mechanical tests and metallographic analysis will be performed.

Methods

The methods consist of determining the chemical composition of ductile cast iron, thermodynamic parameters as well as of determining microstructure and mechanical properties. Creation of mathematical model that would link chemical, thermodynamic and microstructural parameters and enable the prediction of solidification mechanisms and the mechanical properties themselves.

Expected scientific contribution

The scientific contribution of the research will be reflected in the creation of a mathematical model that would be based on the correlation of input parameters such as chemical composition, selection and proportion of nodulator and output parameters such as achieved mechanical properties – tensile strength, impact energy, elongation. If such a mathematical model were to be applied in industry, it would contribute to the production of thick-walled casting with high mechanical properties based on the "right for the first time" principle.

Keywords

Ductile iron, solidification, microstructure, mechanical properties, mathematical model.

Generalization of the Kalman–Yakubovich–Popov Lemma

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Introduction

In this Phd Workshop, a generalization of the Kalman-Yakubovich-Popov (KYP) lemma will be presented. KYP lemma, also known as the Positive Real Lemma, has been recognized as one of the most important tools in modern systems theory. In particular, the KYP lemma shows equivalence between frequency dependent matrix inequalities and an algebraic feasibility property of a linear matrix inequality. KYP Lemma originates from Popov's frequency condition for the stability of a feedback system with memoryless nonlinearity, and Yakubovich and Kalman proved that the Popov's condition is equivalent to the existence of Lyapunov function in a specific form. Another concept with an important role in systems theory is dissipativity, which was introduced by Jan Willems to describe input-output properties of a system, as a natural extension of the Lyapunov stability theory for non-autonomous systems. For a linear time-invariant (LTI) system, a time-domain matrix inequality of KYP lemma can be used to formulate a dissipativity condition, with respect to quadratic storage and supply function. This relation is used in a large number of system analysis and synthesis methods, for example in optimal feedback control, robust control, etc.

This novel generalized KYP lemma provides time-domain matrix inequality which can be interpreted as generalization of dissipativity condition which depends on state, input and output vectors, and their time derivatives. The reason for the generalization of the KYP lemma is to find new tools for system analysis and controller synthesis.

Aims

The goal is to generalize the KYP lemma, which can be used to bound a gain of LTI systems with a frequency-dependent rational function.

Methods

This novel result is based on results from linear algebra and convex analysis. Frequency-domain inequality of the KYP lemma depends on state and input vector, and this generalization of the KYP lemma was derived by introducing additional variables, next to state and input vector. In particular, these additional variables are input time derivatives. Using similar arguments as in Anders Rantzer's proof of the KYP lemma, this extended frequency-domain inequality of KYP lemma is transformed into an equivalent time-domain matrix inequality. Furthermore, quadratic supply function of this generalized dissipativity condition was structured as a function of input, output and its time derivatives, so that gain of the LTI system can be bounded by a frequency dependent rational function.

Expected scientific contribution

This generalization of KYP lemma can be used for analysis of LTI systems. Frequency dependent gain bound of a system in form of frequency dependent rational function could be useful for shaping the gain function of a closed-loop systems. Derivation of a non-conservative controller synthesis method based on this result is still an open problem.

Keywords

KYP lemma, dissipativity, convex analysis

Numerical Analysis of the Carotid Artery Adaptation to Stent Implantation

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Introduction

Carotid arteries secure the blood flow to the brain. The condition when plaque (cholesterol deposit) builds up on the inner lining of an artery is called atherosclerosis, and when it is affecting the carotid arteries, it is called carotid artery disease. Atherosclerosis causes the carotid arteries to narrow, thus reducing the blood flow to the brain, which can lead to stroke. Carotid angioplasty and stenting are procedures where a mesh tube called a stent is placed in a narrowed, atherosclerotic carotid artery to restore the blood flow to the brain. The finite elements method (FEM) has lately been frequently used to broaden our current understanding of biochemical and biomechanical processes and predict disease progression.

Aims

The aim of this study is to numerically investigate the adaptation of a carotid artery to the implantation of a stent. Stents are usually constructed from longitudinal segments called struts that can be arranged to form various shapes that have different influences on the arterial wall. Stent-induced increase in wall stresses triggers the growth and remodeling processes in the arterial wall. The most known risks and complications after the stenting procedure are stent thrombosis (ST) and in-stent restenosis (ISR). ST is mostly linked to changes in hemodynamic factors, such as wall shear stress and oscillatory shear index. On the other hand, ISR, a gradual re-narrowing of the stented segment that occurs mostly between 3 to 12 months after stent placement, is likely caused, at least partially, by increased production of wall constituents due to increased wall stresses. In this study, the mechanical impact of the stent implantation on the artery is studied, such as the locations of the highest stresses and arterial wall constituents' production, related to probable locations 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 families of collagen fibers, and smooth muscle cells) that possess different mechanical and structural properties. The model has been proven to successfully describe the changes in mass and remodeling of complex structures, such as blood vessels, and their response to different 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. To simplify the analysis, the stent is modeled as a thin cylinder.

Expected scientific contribution

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

Carotid artery disease, stent, finite element analysis, growth and remodeling

Sensitivity Setting of the Ultrasonic Testing System on the Designed and Additively Manufactured Reference Block

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Introduction

The essential purpose of non-destructive testing (NDT) is to detect and evaluate defects in mechanical components. To detect defects the sensitivity for ultrasonic testing has to be set. The sensitivity setting may be performed by several techniques, which include a flat-bottomed hole (FBH), a side-drilled hole (SDH), and a rectangular notch, as reference reflectors. When using an angle beam probe, usually sensitivity is set by generating DAC curves with SDH or by using a Distance Gain Size (DGS) diagram, according to which acceptance criteria are determined. Generally, defect sizing is performed by comparison of the echo amplitude of the detected defect to the amplitude generated by a reference reflector at the same path. Since the size of defects is one of the most crucial information for quality assurance decisions it is compared with the acceptance criteria that is set as equivalent reflector size (ERS) when ultrasonic sensitivity is set. Furthermore, for detected defects, ERS is estimated using the DGS diagram by comparing the reflecting echo of the detected defect with that of a theoretical disk-shaped reflector (that is FBH).

Aims

The sensitivity setting and the defect evaluation should be performed with the same type of reference reflector and not rely on transfer calculations from one reflector to another, which introduces an error. The main goal of this research is to enable the ultrasonic sensitivity setting, when testing with angle beam probes, using the disk-shaped reference reflector. That reduces the influence of the reflector's geometric shape on the ultrasonic energy response.

Methods

The development of the reference block includes determining the optimal geometry, shape, and position of the reference reflectors in the reference block. Making the reference block using additive technology enables the production of internal disk reflectors at different angles, ensuring the responses of ultrasonic energy generated by angle beam probes from the flat surfaces of the reference reflectors. Onto the designed and produced reference block will be conducted experimental measurements using the pulse-echo technique. Evaluation of reference reflector size will be performed using the DGS diagram and the DGS mode integrated into the ultrasonic device. To determine the accuracy of the obtained results, they will be compared with each other, with the designed values (CAD model) and actual values as well. The actual position and shape of the reflectors will be determined by computed tomography (CT), which will perform dimensional measurements of the reference reflector.

Expected scientific contribution

The development of the additively manufactured reference block, with disk-shaped reference reflectors, for the sensitivity setting of the ultrasonic testing system will approach the theoretical method of the sensitivity setting (by FBH) when testing with angle beam probes.

Keywords

Ultrasonic testing, sensitivity setting, additive manufacturing, reference block

Localization and Navigation of a Verticaly Driving Mobile Robot

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Introduction

The utilization of mobile autonomous systems capable of vertical locomotion has gained significant importance due to their applicability in environments where human presence poses inherent risks. Prominent applications of such systems include the inspection of concrete walls, cleaning of vertical glass facades, and the transportation of materials to elevated locations. This doctoral workshop focuses on the control of a mobile robot, encompassing both navigation and localization. A primary challenge in controlling a mobile robot on vertical surfaces is the occurrence of slippage, which adversely affects the robot's odometry and consequently its localization accuracy. Poorly localized robots face significant limitations in efficient navigation and task execution. To optimize control and enhance the robot's understanding of the surface friction and other perturbations encountered during vertical movement, a comprehensive dynamic model has been devised. This model encompasses the dynamics of critical components such as drive motors, adhesion motors, robot mass, inertia, and gravitational influences. The proposed model has been validated using an actual robot, establishing a solid foundation for subsequent research and development of advanced control, localization, and navigation algorithms. Localization of the mobile robot is achieved by employing motor encoders, which calculate the robot's precise position through a direct kinematic model. Slippage, a pervasive and critical phenomenon during vertical robot motion, cannot be solely detected by encoders. Therefore, it is imperative to explore methodologies for slippage detection, including model-based estimation, fusion of additional sensor data, or integration with an external positioning system.

Aims

The primary objectives of the research are to find the optimal way to control the robot regarding energy consumption, but with the emphasis that the localization and navigation of the robot remains good enough. Adequately finding the friction model or its detection by other methods will be crucial in the research, and subsequently the strategy will be determined whether the slip will be compensated at the control or navigation level.

Methods

The methods used in this research will be model-based control and fusion of multiple sensor systems. The method for validating the research itself is measurement with an external system (mocap system – OptiTrack) which has a declared accuracy of 0.2 mm, which is more than enough for system validation.

Expected scientific contribution

The expected contributions are a new dynamic model of a mobile robot for vertical surfaces, a new slip detection method using multiple sensor systems and a navigation algorithm for navigating with slip compensation.

Acknowledgments

I would like to thank the Regional Center of Excellence for Robotic Technologies (CRTA), which provided equipment to work with, including a mobile robot, a test setup and the OptiTrack validation system.

Keywords

mobile robot for verticl surface, dynamic modeling, sensor fusion, friction, slippage detection

Comparison of the Fsi Simulations with 4D-Flow Mri Data

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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, 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 computational fluid dynamics models could potentially aid in disease management by providing insight into the complex hemodynamics of dissections. However, such models were rarely validated, and their reliability is questionable as well as their clinical application. In this work, we use a partitioned fluid-structure interaction (FSI) solver that is based on finite volume (FV) discretization to compare patient-specific aortic dissection geometry with the gold-standard 4D-flow MRI in patients with Stanford type B aortic dissections (TBAD).

Aims

The aim of this work is to compare the FV-based FSI simulation results with the current gold-standard of 4D-flow MRI and thus validating the FSI solver.

Methods

The aortic geometry used for the simulations is derived from a computed tomography angiography (CTA) scan of patients 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). For the simulation, we use a partitioned FV-based FSI solver for the interaction between the fluid and solid domain as well as the complex flow of the two blood flow channels. Blood is modelled as Newtonian and incompressible fluid, while the vessel wall is modelled as incompressible and nonlinear material. The time-dependent variable flow is imposed on the inlet (aortic root) and Windkessel boundary conditions are used on the outlets.

Expected scientific contribution

Seamless comparison of multimodal heterogeneous data: unstructured FV-based FSI simulation data (tetrahedral and polyhedral mesh) with structured 4D flow MRI data (3D volumetric grid over time).

Acknowledgments

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Keywords

CFD, FSI, aortic dissection, validation

Analyzing Cryogenic Waste Heat Recovery Systems for LNG-Powered Ships

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Introduction

Greenhouse gas emissions from shipping industries come from carbon dioxide emissions which are result of burning petroleum-based fuels in a conventional propulsion system which is still dominant prime mower in the seaborn transportation. To limit the negative impact on the environment, IMO presented several regulations and measures to stimulate ship owners and shipbuilders to improve energy efficiency of ships, thus reducing harmful emissions. The technical measure recognized with the most potential in carbon reduction is replacement of conventional fossil fuels with alternative cleaner fuels with lower or zero carbon content. Until zero emission fuels and technologies become more approachable fuels with lower carbon content like LNG will have major contribution on market. When LNG powered ships are used, cryogenic waste energy from LNG can be used to increase the efficiency of ship energy system by using it as a heat sink for refrigeration purposes or for improving the energy efficiency of ship power systems. The development of cryogenic waste energy utilization could decrease energy consumption on ships which will lead to more environmentally friendly seaborn transport.

Aims

The aim of this research is to develop a method for analyzing the potential of the integration of cryogenic waste energy recovery systems on LNG-powered ships. The method will consider satisfying power and refrigeration demand of the ship, the fuel prices, technical aspects of integration waste heat recovery systems and energy and exergy calculations. Secondly, the aim is to define the LNG price range at which certain cryogenic recovery systems will have higher energy and exergy efficiency and a lower environmental impact than traditional power systems, while at the same time being economically feasible.

Methods

The first step in this research includes detailed energy and exergy analysis of ship refrigeration systems and analysis of LNG cryogenic waste heat potential. Next is modeling of possible cryogenic waste heat recovery technologies that can be used on the ship. The third step is to simulate different cryogenic waste heat recovery technologies on LNG-powered ships to assess the impact of utilizing waste heat on energy efficiency of the ship. The final step is to develop a method for comparing different cryogenic waste heat recovery technologies based on energy consumption, environmental impact and economic feasibility.

Expected scientific contribution

This research will result with a method for choosing a cryogenic waste heat recovery system which will meet LNG-powered ship power and cooling demands while considering economic feasibility, ecological impact and efficiency of a ship energy system.

Acknowledgments

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Keywords

Refrigeration, waste heat, LNG, shipping

Experimental Determination of Residual Stresses in Mig Welding of Butt Welds on Al-Mg Alloys

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Introduction

Residual stress is a type of stress that remains in a material after the load that caused it has been removed. During welding, residual stresses can occur due to thermal expansion and contraction of the welded material. Over time, these residual stresses can cause deformation, cracking, and even failure of the welded structures. Residual stresses in welding are an important factor to consider in the design and welding of structures. Several methods are available to measure and quantify residual stresses in welded structures. These include destructive and non-destructive testing methods, such as X-ray diffraction, neutron diffraction, and hole-drilling methods. By accurately measuring and analysing residual stresses distributions, engineers can better understand the behaviour of welded structures and develop strategies to reduce the negative effects of residual stresses on performance. X-ray stress measurement is a commonly used non-destructive method for measuring residual stresses in polycrystalline solids. The advantage of the method is that the required equipment is relatively cheap compared to other diffraction techniques, the lateral resolution is relatively high and radiation protection can be achieved very easily due to the low energy level.

Aims

In this study, we aim to quantify the effectiveness of X-ray diffraction as a method for studying residual stresses. We will also attempt to determine the longitudinal stress distribution in a butt joint. In addition, we will investigate the influence of the modified MIG welding process with alternating current on the residual stress values. By combining these objectives, we hope to gain a comprehensive understanding of residual stress analysis and its application in welding processes.

Methods

Two pairs of plates with a thickness of 8 mm were butt welded using MIG welding technology with different set of parameters. The dimensions of the plates were 300x100 mm. Aluminium alloy 5083 was used as the base material. A 1.2 mm thick wire of aluminium alloy 5356 was used as filler metal, and argon 5.0 was used as shielding gas. The plates were welded in one pass without any joint preparation before welding. The first sample was welded using the DC pulse MIG welding method, and the second sample was welded using the AC MIG WAVE PULSE welding method. The welding power source was Daihen Varstroj WB -W400. Residual stresses were measured using the non-destructive X-ray diffraction method based on the cosα method. For this purpose, a portable Pulstec μ-X360 instrument was used. Before starting the measurement, the measurement points were electropolished for 60 seconds. The measurement was performed after removing the surface layer of the metal at a depth of 30 μm below the surface. Electropolishing was performed to remove aluminium oxides that could affect the residual stress measurement results. The device EP -3 was used to perform electropolishing.

Expected scientific contribution

By studying the influence of the modified MIG welding process with alternating current on the values of residual stresses, we aim to improve the understanding of welding techniques and their effects on residual stress levels. The results of this research will not only increase our knowledge of residual stress analysis, but also have practical implications for optimizing welding processes and minimizing residual stresses in various applications.

Keywords

AC MIG, Butt joint, XRD, Residual stresses, cosα method.

The Influence of Natural Fibers on the Mechanical Properties of Composite Materials

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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. Except plant origin, reinforcements can also be of animal origin, for example wool or feathers.

Aims

In this work, the focus is on safflower as a reinforcement for the polymer matrix. By utilizing safflower 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 polymer matrix. Selecting the appropriate production process is crucial for composite manufacturing. Hand lay-up, injection moulding, and extrusion are commonly employed techniques. Considering the hydrophilic nature and sensitivity of natural fibers to high temperatures is essential when choosing the production process.

Expected scientific contribution

Replacing conventional composites with natural ones to preserve the environment, lower carbon emissions and contribute to a more sustainable future, also has 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

bio-composites, natural fibers, polymer matrix

Improvement of Numerical Spray Modelling for Industrial Applications with Heat Transfer

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Introduction

Experimental investigations on spray and spray/wall interaction phenomena are often very demanding, require sophisticated equipment and data processing procedures, and only 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 based on the Finite Volume Method in the Euler-Lagrange formulation, spray shape evolution, along with wall film formation and heat transfer can be calculated. The models used to describe spray-related phenomena are usually empirical or semi-empirical in nature and should therefore be carefully selected depending on the applications for which the simulations are performed. In industrial processes such as metal alloy quenching, coupling between hydrodynamic and thermodynamic phenomena is crucial. The aim of this study is to develop a new modelling framework for the description of such processes by combining the existing knowledge on the subject and the results of the experimental tests carried out in this research.

Aims

The aim of this research is to improve numerical modelling capabilities of CFD tools for more physically accurate predictions of industrial processes involving spray impact onto heated surfaces with strong emphasis on quenching. This will be achieved by developing a comprehensive modelling framework which can be implemented into CFD code to describe spray/wall interaction, spray/wall heat transfer and heat conduction within the quenched sample to obtain cooling curves at each computational cell in the sample. The temperature curves can then be used to assess the microstructure of the quenched sample and residual thermal stresses.

Methods

For experimental spray investigations several methods will be employed. Spray shape evolution, which is usually described with primary and secondary spray penetration, spray radius, primary spray angle, will be investigated using Mie-scattering technique, where spray cloud is illuminated with monochromatic laser sheet and recorded with high-speed camera. A heated inox plate will be used as impact target for spray/wall interaction investigations. Temperature of the plate will also be monitored to characterize the heat transfer upon spray impact. Microscopic shadowgraphy imaging will be used to determine droplet size distributions in spray pre- and post-impingement. Single droplet impact on structured surface shadowgraphy experiments will also be performed to investigate more fundamental phenomena, mainly influence of sample temperature, impact velocity and sample structure in impact properties. Experimentally gathered data will be used calibrate and improve existing numerical models and validate the developed coupled model. Numerical simulations will be performed using Finite Volume Method for spray simulation and Finite Element Method for heat conduction within the sample.

Expected scientific contribution

The expected scientific contribution of this research is a comprehensive numerical modelling framework for simulation of spray quenching which includes spray/wall interaction, heat transfer, heat conduction within the sample and evolution of microstructure and residual thermal stresses. The model will be validated against experimental results from literature as well as from this research.

Acknowledgments

This work has been supported by the Croatian Science Foundation (DOK-2021-02-7875).

Keywords

CFD, spray/wall interaction, heat transfer, quenching, modelling

Modeling of Plasma-Assisted Chemical Vapor Deposition for Additively Manufactured Metal Materials

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Introduction

Additive manufacturing of metal materials using selective laser sintering (SLS) and electron beam melting (EBM) represents modern processes for obtaining industrial and biomedical products manufactured with an approximately final shape, minimal material consumption, and subsequent machining. Within the group of additively manufactured metal materials, titanium alloys stand out due to their favorable mechanical and physical properties, corrosion resistance, and biocompatibility. However, along with these favorable properties, certain irregularities may arise, such as porosities, microstructural inhomogeneities, residual tensile stresses, and increased surface roughness. These mentioned shortcomings can be mitigated through post-processing techniques such as deformation processing, fine surface machining, and heat treatments. By applying the plasma-assisted chemical vapor deposition (PACVD) process, it is possible to increase hardness and wear resistance by depositing coatings such as TiN, TiCN, and TiBN. This study will investigate the influential factors on the surface quality and properties of monolayer, multilayer, and gradient PACVD coatings on additively manufactured Ti6Al4V alloy. Based on the results of statistically planned sample preparation and testing of mechanical, tribological, and corrosion properties, a mathematical model will be proposed and validated for predicting and optimizing the properties of PACVD coatings on additively manufactured Ti6Al4V alloy.

Aims

Aim of the research is to develop statistical models to predict coating properties dependent on substrate chemical composition, surface topography, and coating parameters. These models will aid in selecting optimal parameters for the PACVD process, considering the given application of the additive manufacturing substrate and the desired hard coating.

Methods

The proposed experimental investigation is planned to be conducted in three consecutive phases. The first phase involves the production of test specimens from titanium alloy using the electron beam melting (EBM) process, followed by the deposition of an appropriate combination of hard coatings (TiN, TiCN, and TiBN) using plasma-assisted chemical vapor deposition (PACVD) based on a statistically designed experimental plan. In the second phase, the characterization of the base material and coatings will be performed using various methods such as scanning electron microscopy (SEM) and glow discharge optical emission spectroscopy (GDOES) analysis of chemical composition. The final phase includes the development and validation of a mathematical model for predicting and optimizing the properties of PACVD coatings, considering the type of additively manufactured material and the parameters of heat treatment and PACVD deposition processes.

Expected scientific contribution

The main scientific contribution is the proposal of a model that would identify optimal parameters for the pre-treatment of additive manufacturing (AM) alloys in order to achieve the best possible properties of hard coatings on AM alloys.

Keywords

Ti6Al4V alloy, additive manufacturing, PACVD, hard coatings

Safe Human-Robot Collaboration Using Information on Human Activity and Intention

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Introduction

Enabling robotic manipulators to work along side humans shows great potential when taking into consideration requirements regarding technological operations such as assembly or welding. In such environments it is possible to create production teams comprised of human workers and robots where the fences are removed. Along with the benefits, such workplace adaptations pose numerous challenges and safety risks. With advancements in machine learning (ML) and computer vison (CV) it is possible to analyze humans in real time while operating in collaborative environments. The use of human pose detection algorithms can provide the information on human location over time and be used to classify activities. In this research authors propose a safety mechanism that mitigates potential health hazards by developing a model based on human activity and intention recognition. Such information is used to add context to detected human poses and in term use it to predict the future ones. The poses will be used to limit or enable robot for safe and efficient path planning.

Aims

The aim of this research is to develop an effective human pose prediction model based on human activity and intention information. The predictions will be used to dynamically generate safety zones for safe Human-Robot Collaboration (HRC).

Methods

In order to classify activities and intentions authors use the Long Short Term Memory (LSTM) network model and train it with Industrial Action Recognition Dataset (InHARD). The information selected for action recognition are keypoints representing human joints while intention recognition is trained using the head pose information. The model is then deployed to the OAK-D camera system for online classification. For experimental purposes authors propose to use four different actions that appear generalized and can be identifies in all environments (Picking left, picking in front etc.). The results from these networks are used to actively switch the pose prediction regression models. The classification and prediction models are verified statistically based on accuracy, recall and F1 score. The performance of pose prediction will be verified experimentally based on a test pass/fail criteria.

Expected scientific contribution

The expected contribution is a robust trainable model for human pose prediction in industrial environment along with the safety zone generation for robot action and path planning.

Acknowledgments

This work was supported in part by the Croatian Science Foundation under the 423 project ”Affective Multimodal Interaction based on Constructed Robot Cognition—AMICORC 424 (UIP-2020-02-7184)“ and Visage Technologies AB.

Keywords

HRC, Action recognition, intention recognition, LSTM

The Inflluence of Stacking Sequence of Polymer Composites on Resin Infusion Time

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Introduction

Today's engineering challenges related to sustainability, light weighting and efficiency goals are often met by glass fiber reinforced polymer composites. Composite materials offer great advantages over conventional materials due to the ability to tailor their properties during manufacturing. Resin infusion is one of the liquid composites manufacturing processes with which structures of a substantial variety in complexity and size can be produced. The permeability of the composite laminate is a crucial part of the resin infusion process since it determines all the other factors needed for a successful filling of the mould cavity.

Aims

Filling the mould cavity before the polymerization of the resin is paramount for product quality. Large composite structures such as ship hulls are often produced via trial-and-error method. Resin infusion is determined by Darcy's law which connects process parameters with the permeability of the laminate. Stacking sequence is mostly considered in terms of mechanical properties of the material but as it has an effect on the flow of the resin during the infusion a better understanding of the parameters influencing related behavior is the topic of this research.

Methods

Four different stacking sequences are used to create rectangular stacks to infuse with epoxy resin. Six layers of glass fiber rowing and mats of different weights are used. Optical measurement method is a way to monitor resin flow front and capture its position on the parts of the laminate. A vacuum pump and resin infusion set up is used to carry out the experiment.

Expected scientific contribution

A better understanding of the correlation between stacking sequence and the permeability of the composites is the focus of this research. The author strongly believes that tailoring the material in a way to add to the efficiency of the manufacturing via resin infusion is a better strategy than formulating a stacking sequence solely on the requirement of the mechanical response of the composite structure. Thus, the ability to connect various types of fibers and their combinations with the process parameters would be beneficial for a wider composite application.

Acknowledgments

The author wishes to express gratitude to the Chair for polymer processing by Faculty of mechanical engineering and naval architecture for financial support and usage of the lab equipment to carry out this research.

Keywords

Permeability, stacking sequence, resin infusion, opti-cal measurements.

Data-Driven Modelling of Dry Clutch Lining Coefficient of Friction

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Introduction

Dry friction clutches are used for motor vehicle powertrains because of their simplicity, efficiency and low cost. Although electric vehicles mostly do not have a clutch, there is still large proportion of conventional and hybrid vehicles that will need efficient clutch system for years to come. Dry clutches are mostly used in manual transmissions, but with the introduction of automated manual transmissions in a higher share of total vehicles, understanding of friction behaviour of sliding contact for different operating conditions becomes important. As dry friction linings are mostly made of polymer composite materials, their coefficient of friction is highly influenced by the temperature of friction contact, but there can also be other influencing parameters such as slip speed or normal force.

Aims

The aim of this research is to analyse the coefficient of friction behaviour of dry clutch friction lining material and its dependence on influencing parameters such as temperature, normal force and slip speed. Also, a coefficient of friction prediction model will be proposed with expected value and variability calculations included.

Methods

The experiments for coefficient of friction characterization will be made on a disc-on-disc tribometer. They will be done simultaneously with wear characterization experiments, but data will be recorded with a „controller area network" (CAN) logger for instantaneous coefficient of friction calculations. Data recorded on 2 ms basis will first be processed and only relevant phase of the clutch closing cycle will be considered. The datasets will be divided into modelling and validation sets. The prediction model will be made using three input polynomial approximation but with only the most significant terms selected using some of feature selection methods, like least-absolute shrinkage and selection operator to reduce model overfitting the data. The model for predicting confidence of the expected coefficient of friction value will be made using the maximum likelihood method. The full coefficient of friction expectation model will be validated using a validation dataset.

Expected scientific contribution

The results of the research will contribute to sliding contact understanding in dry clutch systems. It will present the method for instantaneous coefficient of friction expected value and variability modelling and its dependence on normal force, temperature and slip speed. The models will be useful for transmission control strategy development and optimization of dry friction clutch systems.

Keywords

clutch, modelling, coefficient of friction, dry contact

Resilience of Energy System with a High Share of Offshore Wind Energy Regarding Different Weather Conditions

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Introduction

The signing of the Paris Agreement represents a consensus on limiting the increase of the average global temperature compared to the pre-industrial period and led the European Union to set the goal of achieving climate neutrality by 2050. Consequently, future energy systems will be based on renewable energy resources characterized by production variability. Production depends on current availability, i.e., meteorological conditions, and can vary significantly on an annual basis, but also under the influence of long-term changes caused by climate change, representing new challenges in energy system planning. Such systems require diverse energy resources as well as storage technologies that would enable system flexibility. Wind, together with solar energy, will be one of the base resources of energy systems. Offshore wind farms are expected to attract increasing investment in near future due to their more even distribution of wind energy, higher speeds, lower environmental impact and exploitation of useful space in comparison with onshore wind farms.

Aims

This work aims to demonstrate the resilience of energy systems with a high share of offshore renewable energy resources as meteorological parameters and extreme conditions vary due to climate conditions. This would provide better understanding of different energy system configurations and influence of weather conditions on installed capacities, curtailment of renewable energy, emission levels and system cost.

Methods

The analysis will be carried out on a case study for Croatia. First, a scenario analysis through energy planning software H2RES will show the possibility of implementing a 100 % renewable system and then its resilience to the availability of energy resources and their impact on import, export, and the critical excess of electricity production, as well as the role of energy storage, flexibility technologies, and electrification of transport in the integration of renewable energy resources.

Expected scientific contribution

Energy systems based on renewable energy sources, especially with a high share of offshore wind, are still not widely used, but will undoubtedly spread in the upcoming years given the climate neutrality goals. This work expects to contribute to the modeling and planning of future systems, demonstrating that high share of renewable energy sources allows safe and sufficient supply in various weather conditions with the help of flexibilization technologies.

Keywords

Energy planning, Renewables energy sources, Offshore wind, Energy transition

Data-Driven Cad

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Introduction

Strong competition in today's market demands high product functionality, quality, and shorter development time, leading to complex design processes requiring adaptation. Design automation (DA) is a current research endeavour that transforms design-related data to support decision-making and generate new design solutions. Data mining techniques, AI tools, and machine learning algorithms are widely applied in DA. The success of the design process depends on more than just having design skills and design abilities; it also depends on the user proficiency with the supporting design tools. Computer-Aided Design (CAD) systems are no exception here as one of the essential supporting tools in the design process. CAD systems are used to create precise geometric representations of their designs and facilitate the iteration and modification of designs. Hence, among many, researchers have increasingly acknowledged DA as an approach toward reducing the repetitiveness of mundane design tasks in CAD systems, constantly aiming to improve the efficacy and precision of user interaction with the tool. Information that is valuable to describe the design process and that can be extracted from the CAD systems are (a) design actions via CAD event logs and (b) CAD modelling history regarding operations used to create the CAD model, seen as the CAD feature tree within CAD systems. Contrary to research efforts and despite the advancements in research on the use of CAD data, very few studies have focused on both the CAD modelling sequences and user interaction with the CAD. Furthermore, none of the research focuses on linking user behaviour to feature trees or CAD modelling data to investigate or comprehend how designers employ CAD to create geometric representations of their solutions.

Aims

The proposed research aims to bridge the design process and the usage of data-driven approaches to improve the CAD model construction process from both the CAD modelling process and the user behaviour perspective.

Methods

The Design Research Methodology (DRM) will be used as the main research framework. The framework consists of four key phases:

1. Research clarification is the step that involves establishing the motivation for the proposed research based on an initial literature review.
2. Descriptive study I includes a literature review and preliminary empirical studies.
3. The prescriptive study involves proposing theoretical models and methods based on the findings of descriptive and experimental studies.
4. Descriptive study II serves to validate the generated theoretical models and methods.

Expected scientific contribution

The theoretical model of the geometric representations creation process within the design process for a data-driven approach.

Keywords

Data-Driven Design, Computer-Aided Design (CAD), CAD Modelling Process, CAD Feature Tree,

Changing the Perception of the Organization's Competence Using the General System Theory

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Introduction

According to the Croatian state metrology institute, scientific metrology is part of metrology that deals with problems common to all metrology issues. It covers general theoretical and practical problems concerning measurement units, including their realisation and transmission by scientific methods, problems of measurement errors and uncertainties, and problems of the measurement properties of measurements. The importance of laboratory competence is also reflected in the requirements of standards related to laboratory management systems, but often competence is viewed through the prism of human potential. Considering the laboratory is a business system – an organisation, – and that the standards are related to management systems, it is necessary to consider all the features that define the system, as well as the key elements of the system theory. This means the laboratory must be seen as a system (in which competence is characteristic), a whole within which human potential is one of the subsystems. Taking this fact into account, laboratories must be competent as organisations as a whole, and it is necessary to apply the theory of organisational competence. The theory of organisational competence defines four competence domains: human potential competence, technical competence, technological competence and structural competence.

Aims

Expansion of the perception of laboratory competence to other domains of organisational competence, investigation and definition of key factors within each domain, and analysis of the actual state of, as well as a possible management model for the laboratory's organisational competence.

Methods

To confirm the defined hypothesis, an analysis of previous research related to the application of general system theory in testing the application of different models will be carried out. Based on this, the obtained results will be synthesized to establish a model of organizational competence. which will define domains of organizational competence, which consist of indicators investigated using the survey method. Based on a planned representative sample of business organisations, in which the key parameters that define the relevant parameters for the assessment and management of organizational competence will be investigated and used in a simulation.

Expected scientific contribution

This scientific paper aims to broaden the perception of laboratory competence beyond human resources potential, and to analyse the actual state of laboratory organizational competence by investigating key factors within each of the four areas of organizational competence. The results of this study will also suggest a possible model of laboratory organisational competence management that has not been developed so far. The paper will help understand laboratory competence and its role within the metrology system, as well as provide practical insights into laboratory management.

Keywords

laboratory, competence, organisational competence

Stochastic Model Predictive Control of an Autonomous Vehicle While Approaching Unsignalized Crosswalks

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Introduction

Autonomous vehicles have emerged as a transformative technology with the potential to revolutionize transportation systems worldwide. As self-driving technology advances, ensuring the safety and efficiency of their interactions with pedestrians has become a critical concern as pedestrians represent one of the most vulnerable groups of traffic participants. To overcome this, it is crucial to develop a control strategy that can be employed by autonomous vehicles near high-risk traffic areas, such as unsignalized crosswalks where neither pedestrians nor vehicles have a clear right of way. Since pedestrian behavior involves inherent uncertainty, employing stochastic optimal control methods is suitable for the autonomous vehicle's control strategy. During the design of this strategy and optimization algorithm, considerable attention will be given to ensure the computational efficiency of the final algorithm.

Aims

The main objective of this research is to propose a probabilistic state machine-based model of pedestrian behavior near an unsignalized crosswalk, which is validated on experimental data and used to develop a chance constraint-based stochastic model predictive control strategy for an autonomous vehicle. The control strategy will ensure the safety of all traffic participants as well as the minimum traveling time, drive efficiency, and comfort.

Methods

The research will be predominantly numeric (i.e., computer analysis, data processing, simulations) and it will include designing and calibrating the probabilistic state machine pedestrian behavior model and designing the autonomous vehicle control system based on stochastic model predictive control. The whole control strategy will be tested and validated through detailed simulation-based experiments.

Expected scientific contribution

It is expected that the developed probabilistic state machine-based pedestrian behavior model will accurately reproduce real-world vehicle-pedestrian interactions. Additionally, the developed autonomous vehicle stochastic model predictive control strategy, which considers uncertain pedestrian behavior and vehicle-pedestrian interactions on the prediction horizon, will be beneficial for autonomous vehicles in terms of providing a safe, comfortable, and efficient drive. It is also expected that the control strategy will benefit pedestrians in terms of increasing total traffic safety and minimizing the risk of traffic accidents.

Acknowledgments

It is gratefully acknowledged that the research work of the author is supported by the Croatian Science Foundation through the „Young researchers' career development project – training of new doctoral students".

Keywords

autonomous driving, pedestrians, modelling, stochastic model predictive control

Thermal Conductivity Improvement by Addition of Expanded Graphite and Boron Nitride to Hdpe

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Introduction

Addition of nano- and micro-constituents in composites generally leads to increase of thermal properties compared to matrix material. Since their high value of thermal conductivity (l) compared to polymers, carbon-based fillers increase thermal conductivity of composite containing them. Superior thermal properties of graphite are correlated to hexagonal structure of this material. Expanded graphite (EG) is one of many alterations of graphite produced by intercalation. Worm-alike structure of EG is a base for achieving better l of composite including this filler. Similar to EG, boron nitride (BN) shows good l because of its hexagonal structure. Polyethylenne, especially high-density polyethilenne (HDPE), is used in wide variety of products because of its low price, reciclability, non-toxicitiy, good resistance to chamicals and processasbility. Properties of composites with HDPE matrix are based interface compatibility of polymer and fillers, polarity of filler surface polymer chains etc. Better compatibility between matix and fillers can be achieved with compatibilizer, such as maleic anhydride acid (MAH), which leeds to increase of thermal and mechanical properties of compound.

Aims

Aim of this research is to investigate l of composite based on HDPE matrix with EG and BN fillers. Hypothesis is that by increase of filler content l will increase too. Expected l of new compound is 2 W/mK, where mass ratio of both fillers is 22 %.

Methods

Lab mixer will be used for composite blending, where fillers, both EG and BN, will be added as well as compatibilizer, polyethylene-grafted maleic anhidride (PE-g-MAH). Product of blending will be milled in mechanical mill in particles up to 5 mm large. Composite is than hot pressed in moulds. Samples are tested on l by transient hot bridge method.

Expected scientific contribution

Research will provide insight to contribution of fillers in composite leading to increase of thermal conductivity. Therefore, results can be foundation of further research investigating properties of HDPE/EG/BN composite.

Acknowledgments

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Keywords

polyethylene/graphite/boron nitride composite, thermal conductivity, composite blending

The Impact of Tampering on Fulfillment Required Pollutant Emission Limits of Diesel Engines Installed in Non-Road Mobile Machinery

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Introduction

Tampering (i.e., illegal manipulation) is described as inactivation, adjustment or modification of the internal combustion engines (ICE) emission control system which cause, intended or not, lowering efficiency or even disabling the control of pollutant emissions. It is evident that human activities, especially controlled combustion processes with carbon based fuels, contributes significant to accelerated climate changes, air quality deterioration and environmental contamination. As enforced by EU legislation through a series of directives and/or regulations, emission standards named "Stage (No.)" are introduced to limit selected exhaust emissions emitted from ICEs installed in non-road mobile machinery (NRMM).

Aims

Since there are numerous usage patterns of ICEs within NRMM regarding planned purpose, ignition principle, speed operation and power range, the focus of this research will be on quantities of nitrogen oxides (NO_x) and particulate matter (PM) derived as consequence of tampering. Two quoted pollutants have harmful effects on human health, particularly in zones with high traffic volume (urban areas, highways), where EU urban population is often exposed to concentrations beyond certain EU standards and WHO guidelines. Main pollutant emissions of Diesel engines exhaust are NO_x and PM, thus corresponding above explained.

Methods

The most research activities would be conducted as practical laboratory and/or field emission measurements. All needed measurement equipment, ECU reprogramming software and hardware, emulators, test facilities, laboratory experts and testing/measuring object are granted for usage from the Laboratory of IC Engines and Motor Vehicles of the Faculty of Mechanical Engineering and Naval Architecture. If there is a shortage of some equipment or testing capability, the same will be procured. Tampering approach – ECU remapping or ECU performance chip or sensor emulators – together with emission test cycle will compile matching test protocol.

Expected scientific contribution

Acquired NOx and PM tampered emission values, after validation, should present their impact on accomplishing default emission standard constraints. Directly connected to this are negative environmental effects of tampering, indicating policy makers and nationals authorities how to act as pursuing persons who sell, install and use such products.

Keywords

tampering, environmental pollution, non-road mobile machinery, NOx and PM emissions

The Role of Connectivity in Increasing the Efficiency of Smart Factory Processes

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The digitization of industries with the use of new technologies of Industry 4.0 ensures a wide range of improvements in various areas:

greater flexibility in business.

CO2 footprint reduction

- focusing human resources on processes that are based on creativity
- increasing safety in the work of employees
- greater utilization of available data (analytics), resulting in faster and more competent management decisions
- increase the efficiency of supporting functions of production

The positive impact of the application of new digital technologies can be seen within the companies themselves, but each individual company also by choosing its path of digital transformation / transition can ensure both global impact and position in the international market. 5G technology of mobile networks enables application in different industries due to its characteristics: low latency, management of a large number of different devices, and high data bandwidth. 5G technology ensures connectivity in networks of different business branches. Connectivity must respond to the set requirements that are the result of strategic decisions of the management of the company, which depend on the internal and external environment, and on the specific problem, or specific case, of the companies themselves. The research will be focused on improving the speed of decision-making with the aim of better efficiency, proposing modalities for transforming classic factories into smart factories, and shaping a portfolio of 5G services that are suitable for use in industries. The methods that will be used in this research are: collection and analysis of the use of 5G technology in industries, selection of acceptable application of solutions from the portfolio of 5G services and products, and verification of application. As a result of the research, a proposal for a model of introducing 5G connectivity as a basis for successfultransformation and digitalization in communication networks of industries is expected.

Keywords
5G, Connectivity, Verticals, Digitalisation, Private network, Smart factory

Shortening the Learning Curve in a Learning Factory Environment Using Gamification

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Introduction

The fourth industrial revolution, coined Industry 4.0 by Acatech, brings a generation well-versed in gaming into the business world. Gamification is thus recognized as an effective tool for increasing efficiency and motivation.

Aims

This research seeks to design and verify a model that utilizes gamification to expedite the learning process in smart factory environments, focusing on productivity, motivation, and job satisfaction

HYPOTHESIS Using gamification can accelerate productivity attainment, augment motivation and job satisfaction in the smart factory learning process.

Methods

The study proceeds in five phases:

1. Initial research will yield a theoretical understanding of gamification, the current general gamification models across industries, and frequently used performance indicators. This phase involves extensive literature review and analysis.
2. The second phase explores technologies of Industry 4.0 and selects the optimal process for digital technology learning through expert interviews.
3. Phase three involves developing two learning process variants: a conventional one and a gamified one, using the literature synthesis from phase one. The gamification elements are created using "no-code" tools. KPIs for result comparison are defined.
4. The fourth phase tests the model via an experiment with two groups following single-blind study rules. The experiment's repetitions and structure will be determined based on experimental analysis and planning knowledge.
5. The final phase involves suggestions for future research improvements, usage guidelines for the model, and proposals for upcoming studies based on obtained results.

Expected scientific contribution

a) A novel model for hastening learning via gamification in smart factories.
b) Defined performance indicators in the developed model.
c) Empirical verification of the proposed model.

Keywords

Industry 4.0., gamification, learning curve

APPROVED TOPIC

Investigation of the Long-Range Interpolation for Algebraic Multigrid

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The efficient solution of large sparse linear systems is crucial in computational fluid dynamics (CFD) applications for computing numerical solutions of partial differential equations. The coefficient matrix's dimension, which is equal to the number of finite volumes in the spatial discretization, determines the sparseness pattern of the matrix, which can affect the performance of iterative linear solvers. The algebraic multigrid (AMG) method has proven to be an efficient scalable parallel solver, but recent high-performance computers present new challenges for its parallel usage. This study presents an algorithm that investigates long-range interpolation between coarse and fine members on the first level of the multigrid coarsening cycle, to improve the efficiency of AMG. Specifically, we demonstrate how the weighting factor is interpolated and test the proposed algorithm for single-phase, incompressible, laminar and turbulent flows using the selective AMG solver. We focus our comparison on the pressure coefficient matrices. The proposed algorithm's expected outcome is a faster solution phase, albeit with a prolonged setup 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 for solving large sparse linear systems in CFD applications.

Keywords
algebraic multigrid, aggressive coarsening, iterative linear algorithms, long-range interpolation

Data-Driven Reduced Order Models for HVAC Energy Efficiency and Occupant's Thermal Comfort Estimation

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Introduction

Although the usage of computational fluid dynamics (CFD) for HVAC efficiency and thermal comfort estimation offers numerous advantages compared to conventional methods, the computational requirements of this method are still substantial, which is especially evident when combining optimization algorithms with a numerical model. Within this research, the opportunities of data-driven reduced order models (DD-ROMs) as a possible solution for reducing the time required to conduct building CFD simulations by an order of magnitude were investigated. Two approaches to combining DD-ROMs with CFD simulations are proposed.

Methods

An incompressible, non-isothermal, multispecies numerical model was developed as a basis for DD-ROM training. Firstly, feedforward neural networks were used to develop a simplified boundary condition for individual components of the air distribution system. The architecture of the neural network consists of one input layer, 5 deep layers of 20 neurons each, and an output layer equal to the number of polyhedral numerical mesh elements on the face zone of the boundary condition. Secondly, encoder-decoder NN is implemented as part of the optimization procedure, where the data generated by the optimization algorithm is used to train the neural network, while the results of the neural network are used to initialize the solution of the remaining simulations in the optimization procedure. The NN consists of an input layer with air velocity and temperature per individual air diffuser, 10 deep layers of 20 neurons each, and the output layer with the velocity, temperature, turbulence intensity, and CO_2 field.

Preliminary results

Data-driven ROMs have proven to be a suitable method for modeling individual components of the HVAC system. With just a few simulations, it is possible to generate a surrogate model that reproduces CFD results with 99.9 % accuracy (on training and testing data) in milliseconds, without any computational burden, regardless of the number of elements of the numerical mesh. Using this surrogate model in OpenFOAM as a simplified boundary condition for more complex building simulations, it is possible to reduce the numerical mesh several times, given that certain components of the HVAC system with complex geometry (which are replaced with a surrogate model) required extremely fine numerical mesh. In the second case of implementing neural networks as part of the optimization procedure, significant time savings were also achieved, which is especially evident as the optimization procedure progresses from the beginning to the end.

Discussion

Although the number of simulations required to generate a surrogate model increases proportionally with the number of design variables, with the implementation of DD-ROMs to individual components of the HVAC system or as part of the optimization procedure, as well as by selecting design variables that influence airflow the most, it is possible to achieve significant time-savings while conducting CFD simulations. Regardless of the number of design variables, if enough simulations are provided for ROM training, it is possible to achieve surrogate model accuracy better than 99 % compared to experimental and CFD results, and simultaneously decrease processor performance requirements up to 1000 times compared to solving 3D Navier Stokes equations.

Keywords

Data-driven ROMs, CFD, HVAC efficiency estimation

The Method of Determining the Radius of Techno-Economic Feasibility of Waste Heat for the Planning of the District Heating System

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The heating sector is one of the most energy-intensive sectors, accounting for almost 50 % of final energy consumption at the level of the European Union. Looking at where that energy comes from, it is noticeable that almost 70 % of that energy comes from fossil fuels. In this context, the question arises as to how this dependence on fossil fuels can be reduced, and one of the answers to that question is the utilization of waste heat, not only from industry but also from urban heat sources. Urban heat sources such as the refrigeration system of supermarkets, cooling systems of supermarkets and shopping malls, data centres, and power substations are well known and recognized as systems that can be a reliable source of heat for the district heating system, but what represents a difficulty is their spatial dispersion and therefore spatial planning a district heating system is more demanding and requires considering many factors. In this paper, a methodology is offered that systematically helps in planning the integration of urban heat sources in district heating systems, considering several criteria. The criteria can be divided into criteria characteristic of heat sources: heat source temperature, waste heat potential, and criteria characteristic of the district heating system: temperature regime of the heat network, heat demand, and plot ratio. The main outcome of the paper is to determine the radius of techno-economic feasibility of waste heat, at different temperature regimes of the district heating network (high-, medium-, low-, and neutral-temperature regimes), different heat demands (environments with the low and high demand), and different plot ratios (high and low population environments). The method has been implemented and tested in the case of the City of Zagreb.

Keywords
district heating, urban heat sources, waste heat potential, techno-economic feasibility, district heating planning

Modelling of Shipbuilding Projects Realisation Process Through Application of Digital Lean Management

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Introduction

Improving the competitiveness of European shipyards, especially in relation to state supported Far Eastern, which after the global economic crisis of 2008 are increasingly penetrating market niches of high added value products, such as cruise ships and special purpose vessels, the ones in which European shipbuilding solely retains world primacy, primarily depends on measures of continuous business processes improvement. The doctoral thesis analyzes the implementation significance of certain digital technologies in the project realization process in terms of the business system productivity, i.e., profitability improvement, along with prior detection and reduction of losses in shipbuilding processes by applying selected lean tools.

Methods

In the dissertation, mostly qualitative research is conducted, namely, theoretical conclusions and recommendations are drawn based on explanatory type of case studies, mostly in the single-case model and with regard to the observed shipbuilding system processes or functional units; studies are based on statistical or archival data comparison and processing and the empirical data analysis.

Preliminary results

Previous studies, presented at conferences and/or published, present the improvements achievable through lean shipbuilding sales sector management, as well as the ship outfitting process improvements achieved through 3D modeling in the Digital Twin content. Hence, the Value Stream Mapping lean tool implementation results in a sales process costs reduction by approximately 38 % and sales employee productivity increase by as much as 93 %, with a 30 % sales volume increase and a 20 % shipyard's income theoretical increase. Furthermore, the application of Digital Twin technology enables the ship outfitting in more favorable, earlier stages of construction, up to the level of 70 % of outfitting, which results in a production process productivity increase of 20 % with a near equal percentage saving of electricity in the construction of a highly complex ship.

Discussion

The previous studies on the contribution of the shipbuilding system dual transformation to the competitiveness of the project realization process already confirm the hypothesis of the dissertation about productivity increase by at least 10 % compared to a traditional factory, but also indicate further process improvements through the implementation of new digital technologies. Thus, the publication of two studies is in preparation – on the possibility of outfitting process further improvement by applying augmented reality technology upgraded to a ship digital prototype, and generally on the project realization using blockchain technology, namely, the smart contracts application in the ship building and purchase financing process. However, a precondition for the shipyard's transition to smart or ultimately green, is the implementation of lean process management, which, given the shipyard system complexity, requires a separate research – currently underway – in order to define a model for introducing lean tools in the shortest possible time and at a lowest possible cost.

Keywords

shipbuilding, lean management, dual transition, competitiveness

Influence of Alternating Current Parameters on Weld Joint Properties at Tig Welding of P91 Steel

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Introduction

Environmental awareness and aspiration for higher efficiency has led to development of existing and new process plants, especially thermal power plants which require application of creep resistant steels. However, with increasing operating temperatures and pressures double benefit has been achieved, plants became more efficient and the emission of harmful gases is reduced, but modern creep resistant steels are much more difficult to weld and technology requires precise determination of heat input. This research investigates possibility and new approach for welding P91 steel with use of alternating current (AC) for improving overall weld joint properties and residual stresses decrease.

Methods

The influence of shielding gases for welding, frequency and polarity balance of the TIG welding process will be observed through the analysis of macroscopic specimens and dimensional quantification of the welded joints, including the heat affected zones (HAZ). The hardness test of the welded joints will be performed by the Vickers method HV10. The microstructures of welded joints with different heat input will be checked by analysis of polished microscopic specimens, while specific phases, precipitates and grain sizes will be analysed by electron microscopy. Due to mostly harmful effects of residual stresses on welded joints of steel P91, residual stresses will be tested by non-destructive X-ray diffraction method. Analysis of results, statistical processing and formation of a mathematical model will be carried out.

Preliminary results

First part of the experiment has been done with automatic TIG welding without filler metal with three values of frequency and balance polarity, two values of welding current and use of one shielding gas. Two samples for comparison were welded within standard use of direct current (DC). All the other welding parameters were constant. Preheat temperature and post weld heat treatment (PWHT) are excluded in this research. On the welded samples geometrical evaluation, hardness testing and microstructure analysis have been performed. Second part of experiment was measuring residual stresses with diffraction method.

Discussion

Different balance polarities and frequencies show their influence on welding process stability, depth and width of weld metal and heat affected zones. Performed visual examinations showed that finest welding process, lowest heat input and electric arc stability is given with -20 % balance polarity regardless used frequency. Macro specimens analyze indicate that with AC TIG welding is possible to achieve same or even better weld penetration in comparison with DC TIG welding with the narrower width of HAZ. Micro specimens and hardness testing analyzes confirmed necessity of using PWHT. AC TIG welding of P91 steel allows heat input increase, larger weld puddle and increased penetration rate with possibility of providing tempering of the previously weld layers. Influence of certain parameters on residual stresses results still needs to be developed.

Keywords

P91 steel, TIG welding, alternating current, weld joint properties, residual stresses.

An Overview of the Latest Research in the Field of Demand Response in Buildings

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The defended topic of the doctoral thesis includes developing a method for assessing the demand response potential in buildings that will be applicable to all buildings, and its application will additionally evaluate and prioritize building types according to the highest technical and economic potential. Namely, building flexibility is the ability to change the heat and electricity consumption, as well as the production of the building, considering the preferences of the end users. It includes all flexible building resources: building energy system, the building itself (envelope, HVACs, equipment, electric vehicles) and behaviour of occupants. For this purpose, it is necessary to analyze in detail the already existing scientific findings and contributions. More specifically, a detailed review of the literature over the past 3 years was conducted to identify the latest research in the field of demand response potential in buildings. Special emphasis is placed primarily on the results of the conducted research, the scope of the research, the applied techniques, and the applied strategies of demand reponse. Through literature review, various techniques for establishing flexible building load models were identified, which were categorized into three types: white box (physics-based), black box (data-driven) and grey box (combination of physics-based and data-driven). In addition, the literature review identified various demand management strategies such as load shedding, load shifting and modulation. In conclusion, the literature review provided the latest results in the field of demand response in buildings, but also identified all relevant concepts related to this field. The results of the literature review provide quantitative data on the used techniques, methods and scope of the research.

Keywords
demand response in buildings, demand response strategies, demand response techniques

Comparison of Numerical Methods in Electromagnetics on Team Problem 20

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Introduction

This work deals with the comparison of two numerical methods used for the calculation of electromagnetic phenomena inside real materials. For that purpose, several magnetostatic simulation are carried out, where A-phi formulation is used to describe the magnetic and electric fields. Both methods are tested on a TEAM problem 20, for 4 different current excitations, with available expermental results for a magnetostatic force and the magnetic flux density at specific locations. The choice methods are the finite element method and finite volume method, which are employed through commercial software. Finite element simulations are ran in Ansys Maxwell and Comsol Multiphysics, which showed good match with all experimental results. Finite volume simulations are ran in Fire M which showed some discrepancies from the experimental values, both in force and magnetic flux density results. The discrepancies are higher in the cases with the lower currents which produced the highest permeability jumps between the air and the center piece. The cases with higher currents showed better results for the magnetic flux density albeit the force results are slightly overshooting the experimental values. Adding more boundary layers on the multimaterial interface has shown better results for the magnetic flux density, but slightly alters the the results of force. This is probably due to the current method of force calculation, which relies on the surface, rather than volume integral due to numerical efficiency.

Keywords

Magnetostatic, Finite volume, Finite element, TEAM 20, Multimaterial interface

Experimental Study of Combustion Characteristics and Emissions of Pre-Chamber Induced HCCI Combustion

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Introduction

It is a well-known fact that HCCI combustion offers the possibility of achieving high efficiency with low emissions, but with the challenges in combustion control and ability to adjust to changing environmental conditions. To resolve the aforementioned challenges, a pre-chamber induced homogeneous charge compression ignition (PC-HCCI) combustion mode was experimentally tested with aim of providing initial boundaries of combustion stability and obtaining initial performance results.

Methods

The single cylinder engine equipped with active prechamber and compression ratio of 17.5 was fueled by gasoline. The engine speed was fixed to 1600 rpm with intake air temperatures varied from 33°C to 95°C. The initial experiments were performed to verify the possibility of PC-HCCI combustion mode. Parameters that were varied were pre-chamber fuel mass and spark timing at different air excess ratios in the main chamber. After initial experiments, an additional set of measurements have been conducted to analyze performance and controllability of PC-HCCI combustion mode at 3.5 bar indicated mean effective pressure (IMEP) while maintaining coefficient of variation of indicated mean effective pressure (CoV IMEP) under the proposed limit of 5 %. Additional numerical analysis was conducted to compare experimental results with PCSI combustion mode and to define the share of total engine-out emissions that originated from pre-chamber combustion.

Preliminary results

The results showed that PC-HCCI combustion mode ensures higher efficiency for the similar engine load compared to PCSI combustion mode, but lower efficiency when compared to HCCI combustion, possibly only due to non-optimized operating parameters. Its efficiency and combustion stability largely depend on the excess air ratio in the main chamber, amount of fuel in the pre-chamber and intake air temperatures. PC-HCCI combustion allows lower emissions of total hydrocarbons (THC) compared to PCSI combustion mode while obtaining very low amounts of nitrogen oxides (NO_X) because of low combustion temperatures. The analysis showed that pre-chamber fuel mass has a major impact not only on ignition and combustion stability, but also on total emissions of NO_X, THC and CO, confirming that at such diluted mixtures most of the engine-out emissions come from the pre-chamber.

Discussion

The performed experimental study confirmed the potential of PC-HCCI combustion mode to achieve similar combustion characteristics and performance benefits as conventional HCCI while ensuring reliable control of combustion phasing. However, the pre-chamber geometry could strongly affect the required operating conditions and the resulting performance. Therefore, the future experimental research will be expanded to a much wider set of operating conditions including different pre-chamber geometries.

Acknowledgments

The research is funded by the Croatian Science Foundation (HRZZ).

Keywords

Pre-chamber induced homogeneous charge compression ignition, combustion analysis, emission analysis

Optimization of Seakeeping Characteristics and Superstructure Resistance of a Ship

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Introduction

This study aims to evaluate the seakeeping characteristics, precisely the ship motions and resistance, of two variants of ship forms sailing in ocean waves. Ship motions are important in terms of translations, rotations, and accelerations at particular points of interest. These accelerations affect the loads on the ship's structure, notably the equipment, as well as the comfort and safety of passengers and crew. Furthermore, the design of a superstructure also plays a significant role in the overall performance of the ship.

Methods

Seakeeping calculations were conducted for a research cruise ship designed for trips in polar regions. The sea state selected for testing corresponds to a severe condition with a significant wave height of 3 meters and a spectral peak period of 7.43 seconds. Accelerations were recorded at three specific locations on the ship, with the ship's design speed being 16 knots. However, a speed reduction to 8 knots is expected in the tested sea conditions to minimize the possibility of high wave loads and green water. The seakeeping calculations were carried out over 100 seconds, using the same approximation of the wave field in both simulations. Specifically, consistent phase shifts among individual wave components were maintained to define the wave field in both simulations, thereby ensuring better comparability. Furthermore, calculations of the air resistance have been conducted in order to validate the newly developed automated calculation method. Simulations are performed using the Naval Hydro Pack library.

Preliminary results

Two variants of the ship form are compared: one without passive fin stabilizers and the other with passive fin stabilizers. In this study, two degrees of freedom, specifically heave and pitch, are examined. Simulations are performed with a ship sailing in head waves, where the angle between the ship's longitudinal axis and the wave propagation direction is 0 degrees. Accelerations are measured at three locations on the ship considering vertical and longitudinal directions. Air resistance of the ship superstructure is also considered in the scope of this study.

Discussion

The research has shown that the passive stabilizers examined in this study do not offer improved seakeeping characteristics of the ship. This research also showcases the capability of a newly developed software environment to quickly and efficiently compare two or more forms for optimizing their seakeeping characteristics and the air resistance of a superstructure.

Acknowledgments

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Keywords

Seakeeping, Air resistance, Self-propulsion

Numerical Assessment of Ship Hydrodynamic Characteristics in Off-Design Conditions

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Introduction

One of the short-term, operational measures for the mitigation of GHG emissions is slow steaming, which is being widely implemented. However, there is a lack of research conducted regarding the impact of slow steaming on the ship hydrodynamic characteristics. Computational Fluid Dynamics (CFD) is employed as a reasonable alternative to towing tank tests to assess the ship hydrodynamic characteristics. Full-scale numerical simulations are carried out to avoid the extrapolation of the model scale results. Consequently, it is important to determine the scale effects on the ship hydrodynamic characteristics. Numerous studies deal with the ship hydrodynamic characteristics in design conditions, which can be considerably different from the ones in off-design conditions. This study aims to determine the impact of slow steaming and different loading conditions on the ship hydrodynamic characteristics using CFD.

Methods

The numerical simulations of the resistance, open water (OWT) and self-propulsion test (SPT) based on viscous flow are conducted at different scales to investigate the scale effects on the ship hydrodynamic characteristics. The mathematical model is based on the Reynolds Averaged Navier-Stokes (RANS) equations. To transform the differential equations into a system of algebraic equations the Finite Volume Method (FVM) is employed. The Volume of Fluid (VOF) method is used to locate and track the free surface. To model the ship motion, the Dynamic Fluid Body Interaction (DFBI) model is used in the Free Surface Simulations (FSS). Double Body Simulations (DBS) are applied for the determination of the form factor and nominal wake. The Moving Reference Frame (MRF) method is used for modelling the propeller rotation in the OWT simulations. To model the effects of the rotating propeller within the numerical simulations of the SPT, the body force propeller and overset mesh method are used. The uncertainty due to time step and grid size is determined with the Grid Convergence Index (GCI) method and a validation study is conducted based on the experimental results.

Preliminary results

The influence of the numerical parameters on the total resistance of a full-scale container ship is investigated. The wind and air resistance are determined for the container ship at different loading conditions, defined with the trim angle and the container configurations, and speeds. Numerical simulations of the resistance test, OWT and SPT are conducted for the case of the Japan Bulk Carrier. The obtained numerical results are verified and validated using the results obtained from the towing tank experiments. The scale effects on the resistance and propulsion characteristics are determined.

Discussion

The numerical simulations of the OWT and SPT for the container ship at the model and full scale will be carried out. The scale effects on resistance and propulsion characteristics will be investigated in detail. Also, the impact of slow steaming and different loading conditions on the ship hydrodynamic characteristics, which includes the resistance, wake fraction, circumferential averaged non-dimensional axial velocity distribution, thrust deduction fraction, as well as the propeller operating point will be assessed.

Acknowledgments

This study has been fully supported by the Croatian Science Foundation under the project Sustainable slow steaming for low carbon shipping (STARSHIP), (Project No. IP-2020-02-8568).

Keywords

CFD, RANS, Moving Reference Frame, Body Force Propeller Method, Scale effects

Development of Compliant Linear Stages for Nanopositioning

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Introduction

Piezoelectric compliant mechanisms and linear stages are complex designs that require careful consideration of multiple interdependent variables. Traditional manufacturing technologies often introduce design constraints that limit the variety of possible solutions. However, 3D printing has the potential to eliminate these constraints and enable more innovative and customizable designs.

When designing compliant mechanisms with integrated mechanical amplifiers, minimizing internal loss is a crucial factor to consider. Internal loss is caused by the reluctance of the mechanism to move due to the resistance of flexure hinges to deformation. Additive manufacturing allows for more complex geometries, which can be used to create demanding hinge applications with minimal internal loss.

Methods

The novel hinge geometry design was experimentally tested and compared with traditionally used ones to determine whether more complex hinge geometries could enhance linear stage efficiency. Displacement measurement with Mahr P2004 probe was used for acquisition of experimental results of both horizontal and vertical axes. The mounting mechanism was clamped with bolts to the same base plate as the compliant mechanism, and weights were utilized to achieve 5 N of load force for measurement of the vertical displacement of the stage. Similarly, a spring was used to achieve a force of 3N for measurement of horizontal displacement.

Preliminary results

It has been confirmed by experimental measurements that around 1,9 times the original displacement can be achieved by using the perforated geometry. Additionally, the displacement caused by the weight of the measurement equipment has been experimentally tested, which is generally considered undesirable. To determine if the geometry change significantly impacts vertical stiffness, an additional experiment was conducted. The results have shown that the vertical displacement has only been increased by 1,2 times.

Discussion

It is possible to conclude that negative effects are outweighed by the displacement improvement in the desirable direction. A significant increase in horizontal displacement was achieved with only a minor loss of loading capacity. Therefore, the linear stage efficiency was significantly improved by the overall impact of the geometry change. The potential in the 3-dimensional hinge geometry optimization is shown by the promising results of this article, which should be further researched in the future. More performance improvement could be achieved by further researching the hinge geometry with the goal of finding more optimized shapes.

Keywords

homodyne interferometer, piezoelectric stage, compliant hinge, linear stage

Vibration Sensor Placement Optimization in Structural Health Monitoring

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Introduction

For many years now, Sensor Placement Optimization (SPO) is a topic that is being actively researched and developed. It is applicable to many technical fields, the one important for this thesis being Structural Health Monitoring (SHM). While SPO is continually improving, the topic is nowhere near exhausted as it is still not feasible to encompass all the physical parameters of a structure that play a role in its behaviour, due to financial and computational limitations.

Research on SPO is usually focused on getting best results with very limited sensor inputs, and a way to contribute is using simple cost functions that group sensors in a particular way first, and then optimise the number and position of groups (clusters). Sensor selection for clustering can be arbitrary, but here it will be done so that all the possible sensors that correspond to a real location on the structure are grouped into one cluster.

Such location clusters are a requirement for this thesis as the thesis also includes a damage location detection (DLD) algorithm that is finding damage location on a structure using vibration response data of the structure, which requires data from all existing axes.

Methods

SPO algorithm takes stiffness, damping and mass matrices of a discretized model and transforms them into a state space system. State space format is utilized for finding best sensor positions with minimising observer error, while also grouping sensors into clusters. Optimised sensor locations are the input for DLD algorithm, which simulates a large number of evenly distributed damage locations, and then uses a multi-step comparison of simulated behaviour and sensor input from a real structure to find most likely damage location on the real structure.

Preliminary results

Both SPO and DLD algorithms were tested on a 2D grid of springs and masses (which behaves similarly to an FM meshed structure), and both algorithms are returning results that seem logical and promising.

Discussion

The contribution of the thesis would be laid grounds for developing SHM related algorithms that take a long time for damage simulations once (perhaps while a structure is being built), but are very efficient and fast (comparatively) for testing structural health of the structure.

Acknowledgments

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Keywords

Sensor placement optimization, Convex optimization, Mixed L0/L2 norm, L0 norm relaxation, Observer error

Capturing Relations Between the Implementation of Flexibility Options, Renewable Capacities, and Renewable Energy Capacity Factors – Novel Approach Using Automated Energyplan Simulations

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Introduction

In order to assess the potential, opportunities and difficulties in decarbonization of entire countries or regions, an approach considering all the aspects ranging from energy, mining, economy all the way to society needs to be developed. The models that encompass all these are integrated assessment models. The problems that this type of model often encounters while modelling renewable energy sources is the inability to assess the variability of renewable energy generation.

Methods

An approach that implements the detail modelling of energy systems into integrated assessment models was developed. This research presents the novel approach in performing the simulations using Python coupling EnergyPLAN. This approach modifies the initial approach developed during LOCOMOTION Horizon 2020 project. In this approach, the main difference is in the choice of EnergyPLAN input parameter values. This research proposes the implementation of random value parameter generation in the given range instead of using fixed input values. In this approach, the higher resolution of input data is implemented which reflects as well in the higher resolution of output data.

Preliminary results

Preliminary results show that the newly developed approach improved the quality of generated data.

Discussion

This approach provides the opportunity to reduce the required number of total cases that are run which results both in reduction of computational time and in increase of results detail. The results data will in further research be used as an input into regression analysis to generate simple relations between the inputs and outputs that can be used in integrated assessment models such as WILIAM.

Acknowledgments

This work has received support from the project LOCOMOTION, funded through European Union's Horizon 2020 research and innovation programme, under grant agreement No 821105

Keywords

Integrated assessment model, Energy planning, EnergyPLAN, Regression analysis, Decarbonization

Surface Hardness Uniformity of the Hardness Reference Blocks Produced by Slm Technology and Heat Treatment

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Introduction

The manufacturing quality of the reference standard blocks directly affects the measurement uncertainty when calibrating the hardness testing machines, and they are an indispensable part of the measurement traceability chain. The technologies for producing reference blocks did not change significantly until the advent of additive processes that enable the production of materials with a greater range of changes in properties compared to conventional processes, which allow the precise production of blocks with s specific hardness. Maraging steel, produced through additive manufacturing techniques like selective laser melting (SLM) which promote rapid solidification and uniform microstructure, offers superior mechanical properties compared to conventional methods. Maraging 300, a commonly used steel in SLM, undergoes heat treatments like aging after annealing which form a martensitic matrix with dispersed precipitates, yielding specific and narrow hardness values.

Methods

Test samples were produced from maraging 300 steel using SLM technology on the EOS M 290 device. The parameters of the aging heat treatment were varied, and the samples were subjected to different holding times at a specific temperature to achieve varying levels of hardness. Subsequently, the samples were polished, and a hardness test were conducted on different parts of the surface under various loads to determine the hardness uniformity.

Preliminary results

With the SLM technology using MARAGING steel, it is possible to create samples with a homogeneous structure that results in uniform surface hardness in the as-build state according to the recommended process parameters. By optimizing the parameters of the heat treatment, it is possible to vary the hardness values while maintaining the uniformity of the surface hardness in the range from 360 HV to 570 HV. The measuring results in means of surface hardness uniformity are in compliance with the standard HRN EN ISO 6507-3:2018 which is the guideline to test specific requirements for reference hardness blocks.

Discussion

Preliminary investigations show consistent hardness values, indicating potential for fabricating samples with uniform surface hardness which is one of the substantial factors for producing reference hardness blocks. That can be a crucial step in reference hardness blocks production using additive technology of the same or higher level than the standard plates produced by conventional methods. Further analysis of microstructure and physical properties can help in optimizing the production parameters of such blocks.

Keywords

hardness, reference hardness blocks, SLM, Maraging steel

Experimental Characterization of High-Pressure Biofuel Sprays

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Introduction

One of the short-term solutions in the gradual transition to sustainable transportation is the utilization of biofuels from various sources, as dictated by the Renewable Energy Directive of the European Union. Biofuel properties depend on the biomass source and production process and significantly influence the characteristics of the fuel injection spray, which has a dominant effect on the combustion in compression ignition engines. Therefore, in this research, the characteristics of the spray of biofuels from various previously uninvestigated sources, such as waste coffee grounds, and fatty acid methyl, pentyl and propyl esters (FAME, FAPE and FAPRE) will be analysed.

Methods

The characterization is performed on the experimental setup consisting of a high-pressure fuel injection system, an optical measurement system including a high-speed camera capable of up to 10 kHz recording, and a high-power diode-pumped green laser with sheet optics for planar illumination. The laser-induced fluorescence (LIF) method is used on an axial spray cut to obtain macroscopic spray characteristics using DaVis software and application developed during this project based on Deep Learning image analysis method.

Preliminary results

In the research, the effect of injection duration and – pressure on a cone spray angle and penetration length of different fuel blends is investigated and compared to standard diesel fuel. The changes in the physical properties of the fuel such as density, viscosity and surface tension correlate with the changes in spray characteristics. The experiment was performed on three injection pressures of 300, 500 and 700 bars and four injection duration of 0.6, 0.8, 1 and 3 milliseconds with various ratios of biofuel blended with conventional diesel.

Discussion

Before total migration to the electric vehicles, biofuels are a promising solution for decreasing CO_2 emissions. Experimental results will be used in numerical simulations for improving model of spray dispersion in order to accelerate adoption of various biofuels. Additional setup of pressure chamber will be developed to examine impact of atmospheric pressure and further investigation of microscopic characteristics will be provided in the pursuit of optimal source for biofuels.

Acknowledgments

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Keywords

Experimental investigation, biofuel, spray, internal combustion engine

Numerical Modelling of Vascular Flow

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Introduction

Hemodynamics has been shown to play an important role in the progression of arterial diseases such as aneurysms and dissections. Although pulsatory flows have been investigated for the past several decades, research mainly focused on high Reynolds number flows in the turbulent regime, while research regarding low Reynolds number flows in the transitional regime, like the ones encountered in vascular flows, has been fairly limited. Consequently, the question of how to properly model arterial flow regime is still an open issue in hemodynamics. Hence, numerical techniques have only had a limited effect in advancing understanding of arterial flows, primarily due to oversimplifications and ambiguity in turbulence and transition modelling. It is therefore the aim of this research to assess the applicability of current turbulence and transition modelling approaches for vascular flow modelling.

Methods

Computational fluid dynamics (CFD) simulations are carried out using the OpenFOAM software employing the Finite Volume Method (FVM). Several turbulence modelling approaches, primarily Reynolds averaged Navier-Stokes (RANS) and Large Eddy Simulation (LES), capable of capturing transition to turbulence and available within OpenFOAM are evaluated. The models considered have previously succesfully been used in transitional flow regimes, albeit not necessarily in pulsatory flows emblematic of the ones encountered in hemodynamics. A viability assesment is made based on the quality of the results, as well as numerical stability and computational cost.

Preliminary results

The results of RANS and LES simulations are compared to experimental and Direct Numerical Simulation (DNS) data available in the literature. The numerical examples include flat plate and pipe flows and cover a range of Reynolds numbers.

Discussion

The results show that LES models are generally in agreement with comparison data, although a finer than expected temporal resolution is necessary, while RANS models yield mixed results, especially at lower Reynolds numbers present at the onset of transitional flow. Further testing is needed to determine the cause of the afforementioned discrepancies.

Acknowledgments

This work was supported by grants from the Croatian Science Foundation (projects IP-2018-01-3796, DOK-2020-01-5698, D. Ozretić).

Keywords

hemodynamics, pulsatory flow, turbulence transition, OpenFOAM, Finite Volume Method

Optimal Water and Energy System Modelling Based on the Renewable Energy Sources and Energy Storage Technologies

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Introduction

The provision of secure, affordable, and clean water and energy supply is crucial for the normal functioning of modern society. In the face of challenges posed by climate change and unstable geopolitical situations, ensuring a secure supply has become even more vital. This proposed research builds upon previous studies exploring the interconnection between water and energy systems, drawing upon available commercial and open-source models, as well as data from relevant stakeholders. The primary objective of this work is to validate and improve the modelling of the complex water-energy nexus, thereby enhancing future infrastructure planning through cost reduction and better integration of renewable water and energy sources.

Methods

The study employs a two-level spatial modelling approach to comprehensively analyse the water and energy nexus. At the regional and country level, the energy system modelling incorporates hydrology from the water system's perspective, integrating it with the energy system modelling using the available models such as DipaSET. This integration enables a holistic understanding of how water availability and usage impact energy production and consumption, with a particular focus on hydropower generation, and its effect on the thermal power plant cooling. At a lower spatial level, the study investigates the connection between the water distribution system and renewable energy sources, specifically PV systems on the island basis. The water distribution system is operated using PV power, leveraging RES to power the water infrastructure. Moreover, the study considers the integration of battery storage systems on the energy side to enhance energy management and enable a more resilient water distribution system. The joint optimal operation of the water and energy sectors on the lower spatial level is written using the Python programming language while using the GUROBI as a main solver.

Preliminary results

Results are showing that holistic approach results with the overall water and energy systems savings in both the higher and lower spatial scales. On the higher spatial scales results are showing that optimal hydropower operation saves the water resources and results with the overall lower system cost. Moreover, on the water system scale, the results are showing that using RES and BES with the optimal water and energy system operation results with the energy and water system cost.

Discussion

The are many benefits of the joint water and energy system modelling and operation. Firstly, by modelling the interaction between water and energy systems, a comprehensive understanding of the interdependencies between the two sectors is achieved. This knowledge can inform policymaking and resource management strategies, facilitating the development of sustainable solutions for both water and energy sectors.

Acknowledgments

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Keywords

hybrid system operation, optimization, hydropower, renewable energy sources

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